The Western Interconnection Synchrophasor Project

Western Electricity Coordinating Council

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1. Abstract

Title: The Western Interconnection Synchrophasor Project (WISP)

Topic Area: Electric Transmission Systems

On June 25, 2009, the U.S. Department of Energy (DOE) issued Funding Opportunity Announcement (FOA) DE-FOA-0000058 to facilitate investment in “Smart Grid” technologies. In response to the FOA, the Western Electricity Coordinating Council (WECC) in conjunction with public and private partners throughout the U.S. portion of the Western Interconnection is submitting this application for Smart Grid Investment Grant Program (SGIG) funding to deploy a large-scale synchronized phasor measurement system with selected smart grid functions. This deployment involves investment in synchrophasor infrastructure and software applications and will improve situational awareness, system-wide modeling, performance analysis, and wide-area monitoring and controls for the Western Interconnection. Synchrophasor data and supporting technologies will enable operators to analyze stress on the bulk electric system through earlier indication of system vulnerabilities, evolving disturbances, and to take timely actions to avoid wide-spread system blackouts.

WISP will deliver significant reliability enhancement, economic growth, and job creation through vendor-partner involvement and increased staffing requirements, and financial benefits for WECC, WECC's partners throughout the U.S. portion of the Western Interconnection and the nation’s power industry. This interconnection-wide synchrophasor system will also enable smart grid functionality such as improved integrated system operations, enhanced energy loss reduction, more efficient asset use, knowledge-based real-time advanced warning systems, improved market efficiency, and more reliable and efficient integration of intermittent renewable resources.

WECC is submitting its proposal in collaboration with partners throughout the U.S. portion of the Western Interconnection, including: Bonneville Power Administration (BPA), California ISO(CAISO)/California Energy Commission (CEC)/Electric Power Group (EPG), Idaho Power Corporation (IPC), NV Energy, PacifiCorp, Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and the Salt River Project (SRP). Also included in the proposal is a variety of industry vendors and the academic community, working closely with each of the interconnection partners on the implementation of synchrophasor systems.

WECC believes the promise of synchrophasor technology could change the landscape of real-time system controls. There is a significant opportunity for improved system-wide reliability and the ultimate prevention of system-wide disturbances. It is time to take a significant leap forward in deploying the myriad uses of this technology. We can stand on the shoulders of utility, government, and academic visionaries whose research and development over the past 30 years will guide us in the effort to implement a better, more flexible, and more resilient grid.

2. Project Tasks and Schedule

This section describes the tasks and schedule needed to move from the existing phasor research network and set of applications to a secure, reliable, production-grade synchrophasor infrastructure that will provide the foundation for real-time system-wide analysis and controls. WISP encompasses program and project management and systems integration services to deliver:

- The large-scale deployment of phasor measurement units (PMU) (250-300) and phasor data concentrators (PDC) throughout the U.S. portion of the Western Interconnection.
- The design and implementation of a new private wide-area network backbone that meets the performance, high-availability, any-to-any communication, reliability and security requirements for real-time phasor data exchange between the entities located in the U.S. portion of the Western Interconnection and WECC.
- The planning, design, coordination, and demonstration of WECC's ability to integrate synchrophasor data exchange through North American Synchrophasor Initiative network (NASPInet).
- The expansion of existing WECC data center facilities to support new system infrastructure and technology. This enables the aggregation and integration of synchrophasor data and energy management software packages to provide visualization for system-wide situational awareness, model and performance analysis, and real-time controls.

The program estimated cost is $107.8 million, which includes a matching funding request from the U.S. Department of Energy (DOE) for 50 percent of the total cost ($53.9 million). The duration of WISP is three years, with production deployment scheduled in September 2012. The high-level program timeline is illustrated in *Figure 2-1*, with specific milestones identified in *Table 2-1*.

Figure 2-1: WISP High Level Schedule

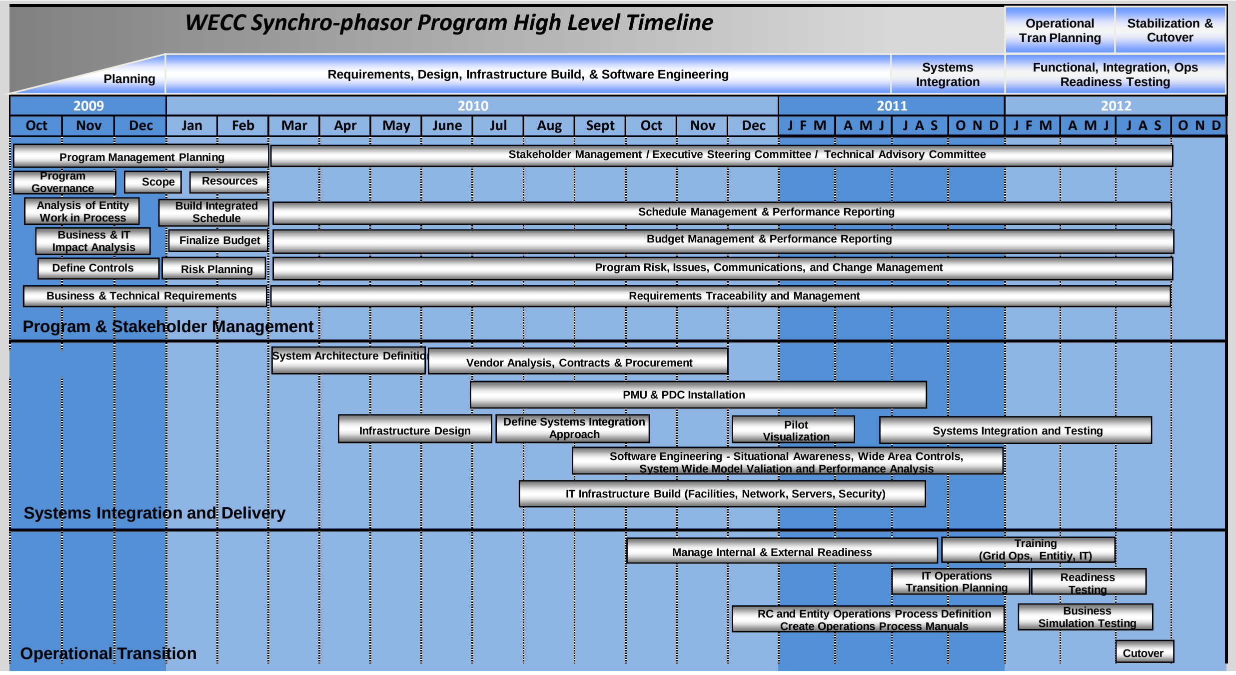


Table 2-1: WECC Synchrophasor Milestone Chart

Proposed Program Milestones	Start	Finish	Months
Program Initiation	July 1, 2009	Sept 30, 2009	2
Program Management Planning	Oct 1, 2009	Feb 26, 2010	5
Requirement Analysis	Nov 2, 2009	Feb 26, 2010	4
System and Infrastructure Design	Mar 1, 2010	Sept 3, 2010	6
Software Engineering	Sept 6, 2010	Dec 30, 2011	16
IT Infrastructure Build Out	Aug 2, 2010	Aug 26, 2011	13
Installation of PMUs and PDCs	Aug 2, 2010	Aug 12, 2011	13
Testing	July 11, 2011	Aug 31, 2012	15
Training	May 28, 2012	Aug 31, 2012	3
Transition to Production	July 9, 2012	Sept 28, 2012	3

2.1. Major Deliverables

2.1.1 Network and IT Infrastructure Design and Implementation

2.1.1.1 Wide-Area Network Implementation

A new production-grade wide-area network will be designed and implemented to support phasor data exchange between entities and the aggregation of data up to the WECC Reliability Coordination Offices (RCO). This includes upgrading and implementing a new network infrastructure at the entity level to connect an estimated 250-300 PMUs throughout the U.S. portion of the Western Interconnection. Existing PMUs that do not comply with current phasor data protocols (e.g. C37.118) will be replaced and new devices deployed to provide a system-wide view across the U.S. portion of the Western Interconnection. Cyber security protection will be put in place for synchrophasor data used for operational decision-making.

2.1.1.2 IT Infrastructure Design and Implementation

Design and implementation of WECC IT infrastructure in both redundant WECC data centers will be conducted. This includes the deployment of PDCs and all IT infrastructure (servers, software, storage area networks, security devices, integration middleware, backup solution, and network devices) to support an integrated test environment, a production environment, and a disaster recovery environment for the new synchrophasor systems and applications.

2.1.1.3 NASPInet Phasor Gateway and Wide-Area Integration Pilot

WISP will conduct field demonstrations on various aspects of the North American Synchrophasor Initiative Network (NASPInet) architecture and its functional components, such as data transport performance, quality of service, any-to-any connectivity, publish and subscribe architecture, device registration, event management, and cyber security.

2.1.2: Engineering and Implementation of Wide-Area Situational Awareness

2.1.2.1 Implement Trending Measurements

WISP will implement five high-speed trending measurements:

i. Interconnection Frequency:

   WISP proposes to conduct continuous trending of the following frequencies in the interconnections: At least two frequency-monitoring sites within each potential island, El Paso, Colorado (within Public Service of CO/Western Area Power Administration systems), Oregon/Washington, Idaho, in California (north and south of Path 15), Phoenix (East of River), Western Montana, British Columbia and Alberta.

ii. System Voltages at Key Load Center and Bulk Transmission Busses

   In this application a display frame would remain “green” as long as voltages stay within the corresponding limits. When the voltage moves outside the limits, an autoscale function would be enabled and the display frame would turn “red.” An operator would have an option to disable the autoscale function and return to the pre-set limits. Long-term voltage trend duration would be one hour. Long-term voltage trend is provided by System Control and Data Acquisition. Short-term voltage trend duration would be one minute.

iii. Path Loading

   Real and reactive power flows on the major paths currently monitored by the WECC reliability coordination function (RC) will be trended. A short-term (30 second) plot will be used with the long-term path flow trend.

iv. Phase Angles

   Phase angles between major load centers and generation sites will be trended and phase angle differences monitored. The proposed sites consist of: Malin (California–Oregon Border), Grand Coulee, Palo Verde, Four Corners, major load centers, and generation centers. Relative phase angles provide stress indication throughout the Western Interconnection.

v. Oscillation Energy

   Oscillation energy is a good indicator of damping conditions. Operators are concerned with oscillations typically experienced in the summer operating season. Oscillation energy plots will be created for the major modes of inter-area oscillations in the interconnection.

2.1.2.2 Implement Synchrophasor Based Alarming on Phase Angles

The North American Synchrophasor Initiative (NASPI) is sponsoring a study to baseline phase angles in the Western Interconnection. A two-step approach will be used. First, historic phase angle data will be used to correlate system performance to the measured angular separation. Second, power system simulations will be done to predict how system performance relates to the phase angles under large disturbance events. Phase angle alarm settings will be determined based on the studies. When phase angles exceed critical limits, operators will be presented with decision support options to increase reactive power reserves, insert series capacitors, or reduce path flows.

2.1.2.3 Implement Reactive Reserve Monitors

WISP will deploy improved measurements to assure the availability of reactive power reserves. With many paths in the Western Interconnection being voltage-stability limited, generators are required to carry a certain amount of primary reactive reserves (automatically deployed within one second) and secondary reserves (deployed over several minutes to help the system recover and settle on a new, secure operating state) to provide voltage support during a contingency. Reactive reserve monitors provide system operators with visibility of available reactive reserves needed for the voltage support of load centers as well as major transmission paths. WISP will calculate reactive power reserves at wind power plants.

2.1.2.4 Implement Voltage Instability Indicators

With wind generation displacing existing thermal generation in the West, voltage support has become a major risk factor because wind turbines are typically located far from major load centers. Wide-area measurements will be used to determine the adequacy of a transmission corridor to deliver reactive support to a load center. The methods will be applied to the following major load centers in the West: Seattle, Portland, San Francisco Bay Area, and the Los Angeles Basin.

2.1.2.5 Implement Mode Meter

Mode meters provide early detection of inter-area oscillation damping risks. A significant proportion of DOE-sponsored research resulted in several approaches being developed and prototyped. These approaches are currently being tested in the Western Interconnection. WISP will deploy production-grade mode meters at the WECC RCOs and the control centers of several major path operators affected by inter-area oscillations.

2.1.3 Implementation of Regional Control Schemes

A secure, reliable synchrophasor infrastructure will provide a foundation for wide-area voltage stability controls. The synchrophasor network infrastructure will be built to meet control quality specifications.

While several wide-area control projects are being pursued in the West, only two regional voltage control applications will be deployed during the three-year performance period. The first will use wide-area synchronized phasor measurements to make decisions about switching reactive power resources to stabilize the grid during a major disturbance. This deployment is expected to increase the voltage stability limit of California-Oregon Intertie (COI). The second application will determine the primary and total reactive power requirements for wind power plants. To facilitate this coordinated reactive control, PMUs will be installed at wind facilities to record substation voltage and substation transformer current.

2.1.4 Deployment of tools and processes for system performance base lining and event analysis

2.1.4.1 Event Analysis

Deploy processes and tools using wide-area synchronized recordings for event analysis, compliant with NERC disturbance monitoring standards.

2.1.4.2 Power System Performance Analysis

WISP will make use of increased PMU data to deploy processes and tools using wide-area synchronized recordings for power system performance analysis.

2.1.4.3 Data Mining Tools

Even with today's PMU limited coverage, WECC collects several terabytes of synchrophasor data annually. With the proposed PMU expansion, the volume of data is expected to reach tens of terabytes annually. There is a need to have automated data-mining tools that can scan the historic data and extract useful information for (a) unusual operating conditions, (b) disturbance events (such as frequency and voltage excursions), and (c) unusual oscillatory activity in the interconnection. In addition, the data mining tools will provide seasonal operational reports. WISP will build and deploy such tools at the WECC RCOs and several WECC Balancing Authorities.

2.1.5 Standardized Tools and Processes for System-Wide Model Validation

2.1.5.1 Generator Model Verification

WECC has developed methods and tools for continual generator model validation and performance monitoring. These methods have been used to find numerous control problems with generation controls and their models, as presented at NASPI. WISP will enhance the methods and tools in the Western Interconnection.

Large-scale integration of wind power plants represents a new challenge for modeling. Wind power plant performance can vary greatly depending on the type of technology used, control settings and operating mode. Accurate models are required to correctly evaluate the impacts of wind generation on power system stability. As a part WISP WECC and its project partners will install PMUs at the point of interconnection of many wind power plants. Disturbance data will be collected and used for model validation and generation performance monitoring.

2.1.5.2 High Voltage Direct Current (HVDC) Intertie Modeling

WECC has two major HVDC interties in its footprint, and several more have been proposed. The Pacific HVDC Intertie (PDCI) connects the Pacific Northwest and Los Angeles Basin area. The PDCI is rated at 3,100 MW. The Intermountain Power Project (IPP) connects central Utah and Southern California. The IPP is rated at 1,800 MW. Both HVDC lines are known to have major impact on the dynamic behavior of the Western Interconnection. The PDCI was a contributor to the negatively damped oscillations developed during the August 10, 1996 system outage.

Accurate modeling of the PDCI and IPP lines is critical for reliable operations and planning in the Western Interconnection. WISP will upgrade or replace PMUs at PDCI terminals and install new PMUs at IPP terminals. Control signals and DC quantities will be measured as well as AC quantities. Synchronized data provided by PMUs will enable a process of HVDC model validation as well as assessment of DC modulation controls for damping inter-area oscillations.

2.1.5.3 Load Modeling

WECC’s Load Modeling Task Force is in the final stages of implementing a new composite load model structure in grid simulators. WISP furthers that effort and use synchrophasor data for load model validation.

2.1.5.4 System Model Verification

Overall system verification is the ultimate step in ensuring simulation models reasonably match reality. This application addresses three issues: the need for a validation base case, the deployment of more sophisticated tools to judge model performance, and the creation of a process to reconcile differences between models and actual performance.

2.2. Tasks and Schedule

This section provides a rolled up task plan and schedule illustrated in *Table 2-2,* that demonstrates the bottom-up, work breakdown approach used to define the overall schedule, milestones, deliverables, and supporting budget items.

Table 2-2: Detailed Tasks and Schedule

ID	Task Name	Duration	Start	Finish
1	**WECC Synchro Phasor Program Plan**	**848 days**	**July 1, 2009**	**September 28, 2012**
2	*MILESTONE: Project Kickoff*	*0 days*	*July 1, 2009*	*July 1, 2009*
3	**INITIATION PHASE**	**66 days**	**July 1, 2009**	**September 30, 2009**
4	**Develop Program Business Case for BOD**	**22 days**	**July 1, 2009**	**July 30, 2009**
11	*MILESTONE: Present Business Case to Board*	*0 days*	*July 30, 2009*	*July 30, 2009*
12	**Complete the FOA Application**	**22 days**	**July 8, 2009**	**August 6, 2009**
17	*MILESTONE: Submit FOA Application*	*0 days*	*August 6, 2009*	*August 6, 2009*
18	**Implement the Program Governance Model**	**39 days**	**August 7, 2009**	**September 30, 2009**
32	*MILESTONE: Program Governance Model Complete*	*0 days*	*September 30, 2009*	*September 30, 2009*
33	**PLANNING PHASE**	**107 days**	**October 1, 2009**	**February 26, 2010**
34	**Engage the Program Team**	**43 days**	**October 1, 2009**	**November 30, 2009**
42	*MILESTONE: Program Team Ramp Up Complete*	*0 days*	*November 30, 2009*	*November 30, 2009*
43	**Develop the Program Management Plan**	**107 days**	**October 1, 2009**	**February 26, 2010**
64	*MILESTONE: Program Management Plan Complete*	*0 days*	*February 26, 2010*	*February 26, 2010*
65	**Requirements Gathering**	**83 days**	**November 2, 2009**	**February 24, 2010**
66	**Business Requirements Definition**	**83 days**	**November 2, 2009**	**February 24, 2010**
67	Conduct Wide Area Feasibility & Benefit Survey	21 days	November 2, 2009	November 30, 2009
68	Capture the "As-Is" Business Process Definition	10 days	December 1, 2009	December 14, 2009
69	Capture the "To-Be" Business Process Definition	10 days	December 15, 2009	December 28, 2009
70	Conduct Joint Application Design (JAD) Sessions	10 days	December 29, 2009	January 11, 2010
71	Define business-level requirements	22 days	January 12, 2010	February 10, 2010
72	Requirement reviews and approval - WECC amd Entities	10 days	February 11, 2010	February 24, 2010
73	*MILESTONE: Business Process Requirements Complete*	*0 days*	*February 24, 2010*	*February 24, 2010*
74	**PMU / PDC Requirements**	**35 days**	**November 2, 2009**	**December 18, 2009**
81	*MILESTONE: PMU /PDC Requirements Complete*	*0 days*	*December 18, 2009*	*December 18, 2009*
82	**Network & Infrastructure Requirements**	**35 days**	**December 21, 2009**	**February 5, 2010**
87	*MILESTONE: Infrastructure Requirements Complete*	*0 days*	*February 5, 2010*	*February 5, 2010*
88	**Software Application Requirements**	**82 days**	**November 2, 2009**	**February 23, 2010**
89	**Software Requirements - Situational Awareness**	**70 days**	**November 2, 2009**	**February 5, 2010**
90	Document Target Software Application Portfolio	5 days	November 2, 2009	November 6, 2009
91	**Document Real-Time Trending Requirements**	**25 days**	**November 9, 2009**	**December 11, 2009**
97	**Document Synchro-Phasor Display / Alarm Requirements**	**20 days**	**December 14, 2009**	**January 8, 2010**
102	**Document Advanced Metric Display / Alarm Requirements**	**20 days**	**January 11, 2010**	**February 5, 2010**
107	**Software Requirements - Wide Area Controls**	**20 days**	**January 4, 2010**	**January 29, 2010**
108	Regional Voltage Stability Controls	10 days	January 4, 2010	January 15, 2010
109	Wind Site Voltage Controls	10 days	January 18, 2010	January 29, 2010
110	**Software Requirements - Off-line Analysis Tools**	**37 days**	**January 4, 2010**	**February 23, 2010**
111	**Document Event Analysis Requirements**	**18 days**	**January 4, 2010**	**January 27, 2010**
114	**Document Power System Analysis Requirements**	**19 days**	**January 28, 2010**	**February 23, 2010**
117	**Software Requirements - System Wide Model Validation**	**37 days**	**January 4, 2010**	**February 23, 2010**
118	**Document System Model Validation Requirements**	**37 days**	**January 4, 2010**	**February 23, 2010**
124	*MILESTONE: Software Requirements Complete*	*0 days*	*February 23, 2010*	*February 23, 2010*
125	*MILESTONE: Planning Phase Complete*	*0 days*	*February 26, 2010*	*February 26, 2010*
126	**DESIGN PHASE**	**135 days**	**March 1, 2010**	**September 3, 2010**
127	**System Architecture Design**	**40 days**	**March 1, 2010**	**April 23, 2010**
131	**PMU / PDC Architecture Design**	**15 days**	**July 12, 2010**	**July 30, 2010**
134	**Network & Infrastructure Design**	**95 days**	**March 1, 2010**	**July 9, 2010**
140	**Data Center Facilities Design**	**10 days**	**July 12, 2010**	**July 23, 2010**
143	**Software Application Design**	**95 days**	**April 26, 2010**	**September 3, 2010**
150	*MILESTONE: Design Phase Complete*	*0 days*	*September 3, 2010*	*September 3, 2010*
151	**PROCUREMENT & CONSTRUCTION PHASE**	**385 days**	**July 12, 2010**	**December 30, 2011**
152	**Equipment Procurement**	**110 days**	**August 2, 2010**	**December 31, 2010**
158	**PMU / PDC Deployment**	**180 days**	**January 3, 2011**	**September 9, 2011**
161	**Network & Infrastructure Build Out**	**385 days**	**July 12, 2010**	**December 30, 2011**
168	**Software Procurement & Engineering**	**345 days**	**September 6, 2010**	**December 30, 2011**
169	Software Procurement	80 days	September 6, 2010	December 24, 2010
170	Software Engineering (Address Design Gaps)	240 days	December 27, 2010	November 25, 2011
171	Develop the Visualization PILOT	25 days	November 28, 2011	December 30, 2011
172	*MILESTONE: Construction Phase Complete*	*0 days*	*December 30, 2011*	*December 30, 2011*
173	**TEST PHASE**	**355 days**	**April 25, 2011**	**August 31, 2012**
174	**Hardware / Infrastructure Test**	**190 days**	**April 25, 2011**	**January 13, 2012**
180	**Software Application System Test**	**200 days**	**November 28, 2011**	**August 31, 2012**
181	**System Test Planning**	**80 days**	**November 28, 2011**	**March 16, 2012**
186	**Execute Software Acceptance Test**	**180 days**	**December 26, 2011**	**August 31, 2012**
187	Execute Factory Acceptance Test (FAT) - Vendor Site Test	40 days	December 26, 2011	February 17, 2012
188	Execute Site Acceptance Test (SAT) Plans - On-Site System Test	40 days	February 20, 2012	April 13, 2012
189	Execute System Integration Test (SIT) - End-to-End Integration Test	60 days	April 16, 2012	July 6, 2012
190	Execute Business Acceptance Test (BAT)	40 days	July 9, 2012	August 31, 2012
191	*MILESTONE: Test Phase Complete*	*0 days*	*August 31, 2012*	*August 31, 2012*
192	**IMPLEMENTATION PHASE**	**90 days**	**May 28, 2012**	**September 28, 2012**
193	**Training**	**70 days**	**May 28, 2012**	**August 31, 2012**
194	**Develop Training Materials**	**50 days**	**May 28, 2012**	**August 3, 2012**
198	Execute Training	20 days	August 6, 2012	August 31, 2012
199	**Transition to Production**	**60 days**	**July 9, 2012**	**September 28, 2012**
200	**Plan for Final Cutover**	**58 days**	**July 9, 2012**	**September 26, 2012**
203	Execute Final Cutover (Go-Live)	2 days	September 27, 2012	September 28, 2012
204	*MILESTONE: Implementation Phase Complete*	*0 days*	*September 28, 2012*	*September 28, 2012*

2.2.1 Initiation Phase

The initiation phase of WISP is underway and includes the development of the project business case, the completion of the FOA application and the implementation of the program governance model.

2.2.2 Planning Phase

The planning phase is scheduled to start in early October, 2009 after the announcement of DOE’s SGIG funding of awards. During the planning phase the project team will be engaged, the program management plan will be developed, business requirements will be documented, and the scope further defined.

2.2.3 Design Phase

The design phase scheduled to start in March 2010 and includes the development of the WECC-level system architecture and the detailed technical design of the PMU/PDC integration, IT Network, infrastructure, software applications, and data center facilities.

2.2.4 Procurement and Construction Phase

The procurement and construction phase of the project, scheduled to start in July 2010, includes the procurement and installation of PMUs, PDCs, network equipment and server hardware. In addition, the software selection, application engineering, and installation will be completed.

2.2.5 Test Phase

The test phase, scheduled to start in April 2011, includes testing of hardware, communications, integration, and software applications. The execution of “standard” testing of the field installations of PMUs, verification of PMU test results, status input verification, setting validation, and communication testing is completed in this phase. The test phase also includes the planning and execution of Factory Acceptance Test (FAT), Site Acceptance Test (SAT), System Integration Test (SIT) and Business Acceptance Test (BAT) of the software applications.

2.2.6 Implementation Phase

The implementation phase is scheduled to start in May 2012 and end with the completion of the system cutover in September 2012. The implementation phase includes training, business readiness verification, system cutover planning, and transition to production.

2.3. Project Reporting

The WISP program management office will provide all quarterly, annual, and final reports as described in the FOA. The reporting content will be developed collaboratively with the partners and sub-awardees of WISP. In addition, WECC will provide monthly reports on the progress of WISP to the WECC Board of Directors (Board).

2.4. Regulatory Approvals

PG&E is contributing $25 million to WISP. Shortly after WECC files this application with DOE, PG&E plans to file with the Federal Energy Regulatory Commission (FERC) a request for expedited approval of PG&E’s portion of the project under the FERC’s recently adopted Smart Grid Policy Statement, issued July 16, 2009 in FERC Docket No.

PL09-4-000. PG&E expects that FERC will act on its request prior to the DOE's decision on grant awards under the SGIG program.

PG&E is in a unique position as an entity participant in this application, being the only sub-awardee. As a sub-awardee, PG&E is proposing substantial investment in its system to install synchrophasor technology to meet its needs as a transmission owner and operator. Significant detail is available about their portion of the total WISP project and would be made available upon request.

3. Management Plan

3.1. Relevance

WISP will implement the phasor data collection equipment, network infrastructure and software applications that allow the WECC and partnering utilities, transmission operators and Balancing Authorities to utilize smart grid synchrophasor technology. Utilization of smart grid synchrophasor technology provides benefits that are directly responsive to the purpose and goals of the DOE SGIG program.

WISP Benefits:

- Large-scale outage avoidance and faster system restoration as a result of the improved situational awareness of operators in the Western Interconnection and the use of wide-area control and protection
- Increased transmission transfer capability and better congestion management
- Improved utilization of intermittent renewable generation
- Reduced capacity cost for supporting intermittent renewable generation

WISP will enhance the reliability of the electric power system by dramatically improving the wide-area view for system operators. This is not only an expanded view from a geographic perspective, but will provide much higher quality and granularity of data, allowing for detection and evaluation of higher frequency power system phenomenon, that is not currently available in most control centers in the Western Interconnection. Today, operators are not able to view the damping status of the grid and no recommendations are available in real-time for improving system damping or resiliency. For those control rooms currently equipped with synchrophasor data, WISP will vastly improve the coverage of the interconnection with high-fidelity data and will provide much more sophisticated analysis, awareness, and control applications than are available today. The expanded tools will provide a common wide-area view for Western operators to enhance their awareness of developing situations involving systems beyond their own footprints – allowing them to see the same views and talk with each other using the same information to solve the problem. This capability extends to wide-area oscillations experienced in the summer operating season of each year that threaten the overall reliability of large areas of the Western Interconnection.

WISP will dramatically increase functionality of operational control centers through enhanced tools such as intelligent alarming, decision support for operators, load encroachment, island detection, system restoration, and enhanced state estimation. WISP will improve system flexibility by enabling applications such as adaptive islanding and load shedding as well as wide-area control schemes that provide automatic safety nets for the interconnection. This will allow the interconnected systems to be more resilient and fault tolerant; a self-healing grid concept.

WISP will improve operational efficiency of the Western grid by providing additional information to the system operator and more accurately determining the limits of safe operation. This will facilitate the deployment of additional renewable energy resources. Operational efficiency will be improved as operators that jointly manage the Western Interconnection in real-time will be able to provide additional levels of security not currently possible with existing Energy Management System (EMS) tools.

The deployment of PMUs is a necessary pre-condition for expanding wide-area monitoring, control and protection. Delivery of WISP will enable the achievement of the following goals enumerated within the DOE's overall SGIG program:

- Improve interconnection reliability and power quality delivery by detection and response to both transient and steady-state disturbance phenomena.
- Accommodate all types of central and distributed electric generation and storage options as the deployment of PMUs is a necessary pre-condition for expanding wide-area control schemes to ensure reliable power delivery.
- Enable new products, services, and markets to deliver a bundled renewable energy and imbalance product to energy markets.
- Optimize asset utilization and operating efficiency of the Western Interconnection by allowing the system to reliably operate at higher transfer levels.
- Anticipate and respond both manually and automatically to system disturbances by providing early warning detection of oscillations and transient phenomena.
- Facilitate resiliency to attacks and natural disasters by enabling wide-area control and protection technology.

The following metrics will be positively impacted by WISP:

- Improved system performance and societal cost benefit due to large-scale outage avoidance and faster restoration.
- Reduced costs due to more efficient use of the transmission system resulting in less high-voltage transmission investment.
- Earlier utilization of larger amounts of renewable energy resources with the corresponding environmental benefits such as reduced GHG emissions.
- Reduced capacity cost for supporting intermittent renewable generation
- Jobs created for deployment and jobs sustained for managing and monitoring the synchrophasor infrastructure and keeping the applications up to date.

The successful implementation of WISP will provide the platform from which additional smart grid technologies will be deployed.

Transmission-level metrics identified in the FOA that will be positively impacted are:

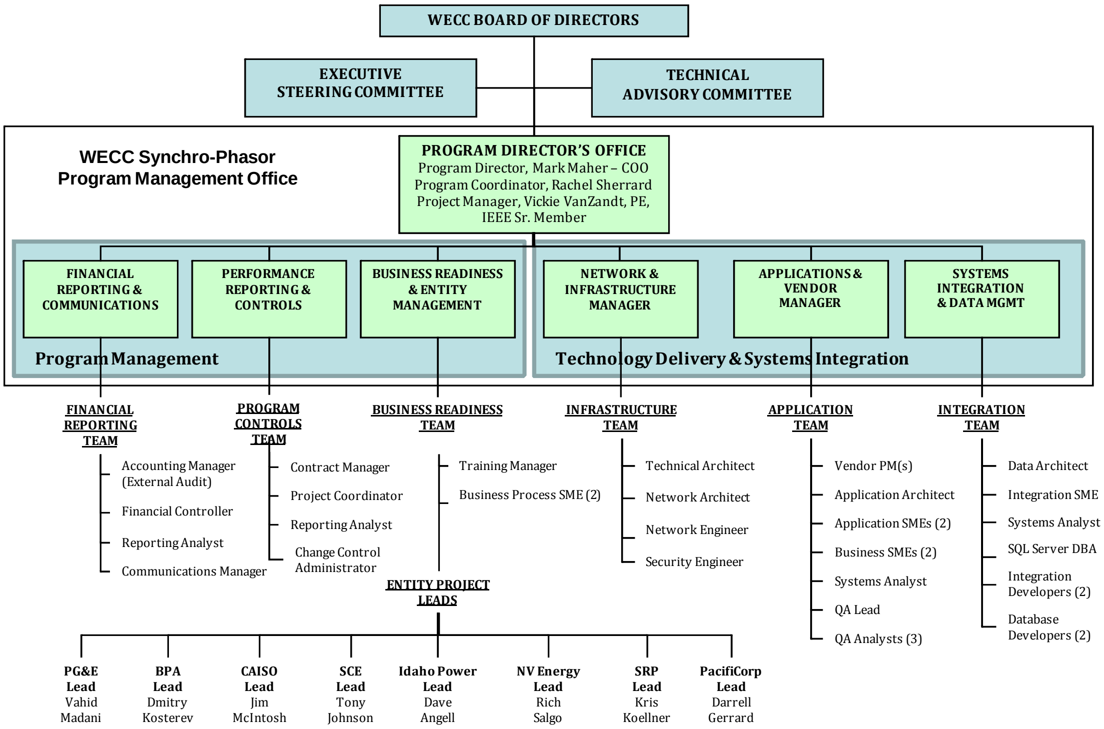
- The number of installation points and percentage and magnitude of the total load in the interconnection covered by PMUs.
- The number of installation points and percentage and magnitude of the total load in the interconnection served by PDCs receiving data from PMUs that share all relevant data with external parties in support of reliability management.

- The number of installation points and percentage and magnitude of the total load in the interconnection served by real-time data management and visualization systems receiving data from PDCs and PMUs.
- The number of installation points and percentage magnitude of the load in the interconnection covered by automated electric transmission systems or possessing advanced measurement.

3.2. Project Team

To accomplish the objectives of WISP, several projects need to be delivered by WECC and its partner entities (Balancing Authorities, Transmission Operators, etc.) in a coordinated manner. In order to effectively coordinate the planning, execution, and delivery of these projects WECC will implement the program governance model illustrated in *Figure 3-1*.

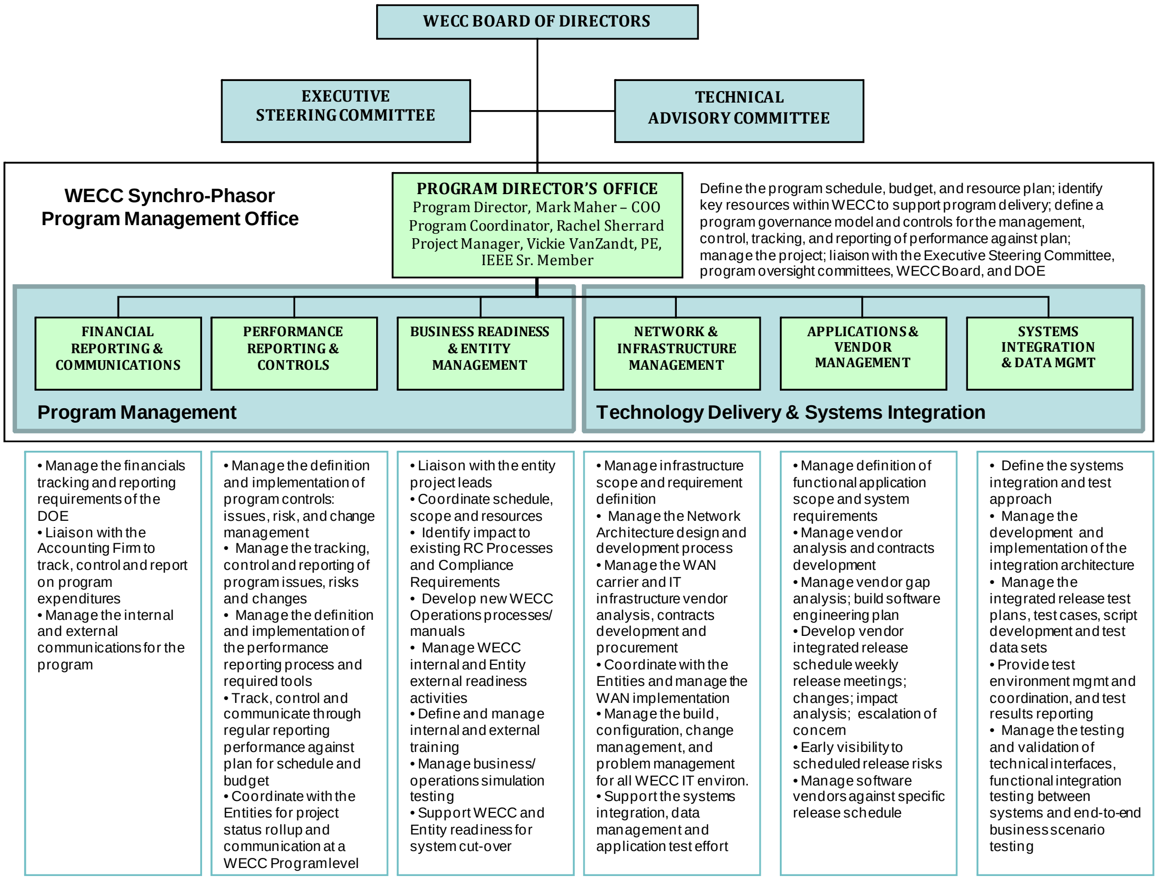
Figure 3.1: WISP Program Organization Chart



WECC Chief Operating Officer, Mark Maher will be the Program Director with executive responsibility for delivering WISP. The Program Director will be accountable to the WECC Board, and guided by an Executive Steering Committee made up of WECC Board members and executives from partnering entities.

The Program Director's Office will deploy the Program Coordinator, Rachel Sherrard, and the Project Manager, Vickie VanZandt. Outreach to stakeholders and partnering entities, communications activities, and financial and reporting requirements will be undertaken by the Program Coordinator. The Project Manager will oversee the scope management, task execution, and schedule compliance of the Project.

Figure 3-2: WISP Management Roles



Define the program schedule, budget, and resource plan; identify key resources within WECC to support program delivery; define a program governance model and controls for the management, control, tracking, and reporting of performance against plan; manage the project; liaison with the Executive Steering Committee, program oversight committees, WECC Board, and DOE

FINANCIAL REPORTING & COMMUNICATIONS	PERFORMANCE REPORTING & CONTROLS	BUSINESS READINESS & ENTITY MANAGEMENT	NETWORK & INFRASTRUCTURE MANAGEMENT	APPLICATIONS & VENDOR MANAGEMENT	SYSTEMS INTEGRATION & DATA MGMT
• Manage the financials tracking and reporting requirements of the DOE • Liaison with the Accounting Firm to track, control and report on program expenditures • Manage the internal and external communications for the program	• Manage the definition and implementation of program controls: issues, risk, and change management • Manage the tracking, control and reporting of program issues, risks and changes • Manage the definition and implementation of the performance reporting process and required tools • Track, control and communicate through regular reporting performance against plan for schedule and budget • Coordinate with the Entities for project status rollup and communication at a WECC Program level	• Liaison with the entity project leads • Coordinate schedule, scope and resources • Identify impact to existing RC Processes and Compliance Requirements • Develop new WECC Operations processes/ manuals • Manage WECC internal and Entity external readiness activities • Define and manage internal and external training • Manage business/ operations simulation testing • Support WECC and Entity readiness for system cut-over	• Manage infrastructure scope and requirement definition • Manage the Network Architecture design and development process • Manage the WAN carrier and IT infrastructure vendor analysis, contracts development and procurement • Coordinate with the Entities and manage the WAN implementation • Manage the build, configuration, change management, and problem management for all WECC IT environ. • Support the systems integration, data management and application test effort	• Manage definition of functional application scope and system requirements • Manage vendor analysis and contracts development • Manage vendor gap analysis; build software engineering plan • Develop vendor integrated release schedule weekly release meetings; changes; impact analysis; escalation of concern • Early visibility to scheduled release risks • Manage software vendors against specific release schedule	• Define the systems integration and test approach • Manage the development and implementation of the integration architecture • Manage the integrated release test plans, test cases, script development and test data sets • Provide test environment mgmt and coordination, and test results reporting • Manage the testing and validation of technical interfaces, functional integration testing between systems and end-to-end business scenario testing

As illustrated in *Figure 3-2*, the Program Management Team reports to the Program Director and has responsibility for financial reporting and communications, performance reporting and controls, business readiness and coordination of program, and entity project schedules through the entity management leadership.

The Technology Delivery and Systems Integration Team also reports to the Program Director and has responsibility for the delivery of the WECC-level infrastructure required by WISP. This team will be directly responsible for the delivery of the network infrastructure, data consolidation, systems integration, and software applications in the portfolio of the overall program that comprises the common inter-utility communication architecture (PDC-to-PDC communication), collection of the synchrophasor data into super PDCs at the RCOs, deployment of the historical data archival system, data mining tools, and West-wide tools for real-time and off-line applications.

The Executive Steering Committee shown in *Table 3-1*, will be responsible for making executive-level decisions on issues that impact the overall program scope, schedule, budget, or performance. Mark Maher will chair the Executive Steering Committee.

Table 3-1: Membership of the Executive Steering Committee:

Name	Title	Organization
Mark Maher (Chair)	Chief Operating Officer and WISP Program Director	WECC
TBD	WECC Board Member x 2. To be appointed by the WECC Chair	WECC
Larry Bekkedahl	VP of Transmission Engineering and Technical Services	BPA
Jim Detmers	VP of Grid Operations	CAISO
Lisa Grow	VP of Transmission	IPC
Mario Villar	VP of Transmission	NV Energy
John Cupparo	VP of Transmission	PacifiCorp
Kevin Dasso	Senior Director of Transmission Asset Strategy and Planning	PG&E
Paul De Martini	VP of Advanced Technology	SCE
Joe Nowaczyk	Manager of Electronic Systems	SRP

WISP will also establish a Technical Advisory Committee (TAC) to leverage the world-class knowledge and experience with synchrophasor technology that exists within the Western Interconnection. The TAC will be consulted by the project team in developing application requirements, establishing specifications for PMUs, answering technology and integration questions, and establishing standards and common protocols for sharing phasor data. They will also assist in the resolution of technology, integration, and deployment issues through the development of options, alternatives, and recommendations to present for decision by the Program Director and Executive Steering Committee. The TAC will be made up of WECC's Joint Operating and Planning Coordination Committee Synchrophasor Work Group members, technical leads of the partnering entities, and other relevant technical individuals and groups such as NASPI.

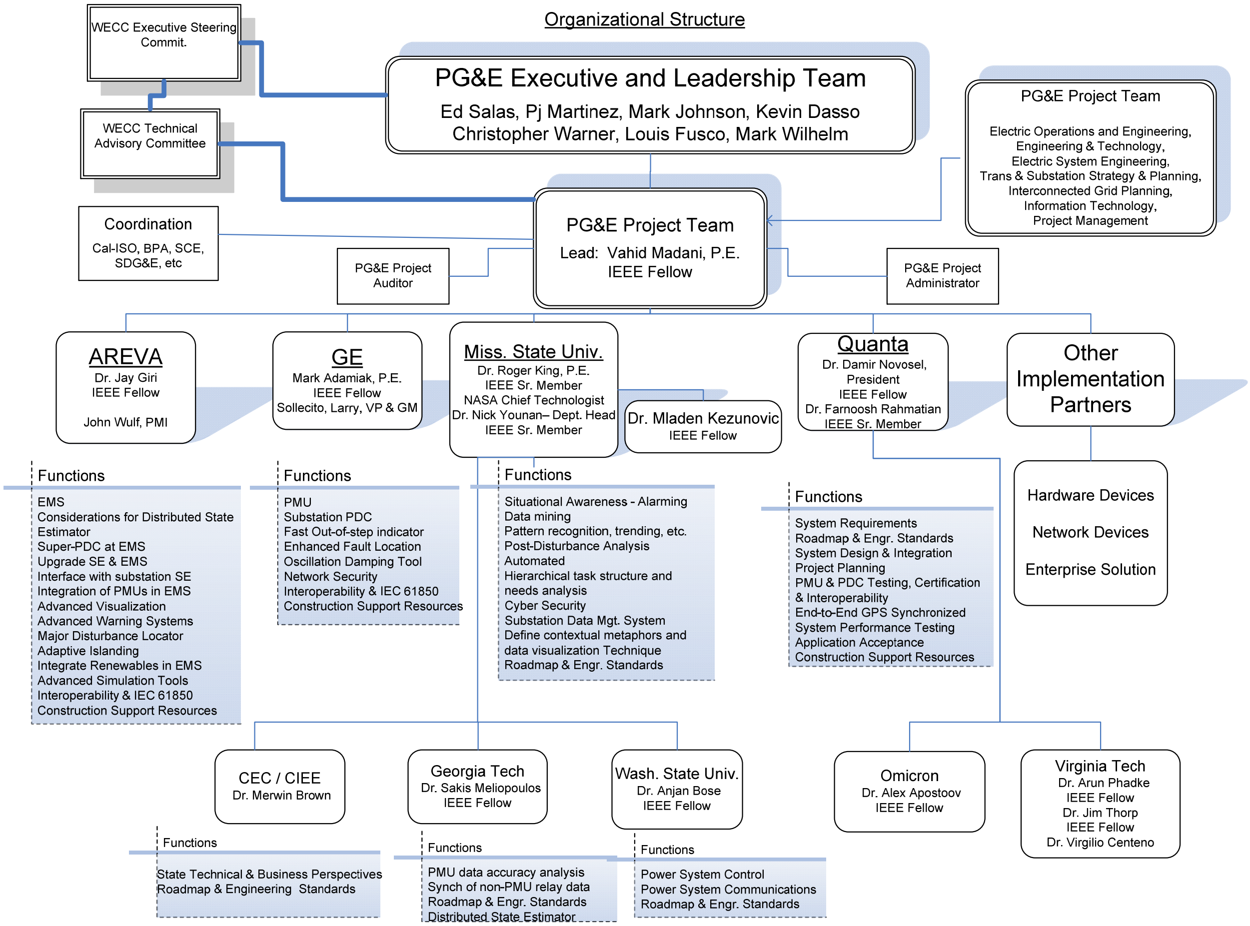
Membership of TAC includes the project leads from each entity named in the organization chart above and includes expertise required in each of the following disciplines: power system analysis and visualization, power system control and protection, systems engineering and integration, and IT network and infrastructure design and deployment.

The Entity Manager will be responsible for the coordinating with entity leadership teams on the delivery of their projects. Each partnering entity will also use a robust management approach with roles and responsibilities for deployment of WISP components within their service territories and/or control centers. They will deploy PMU, PDC, and intra-utility infrastructure within their systems to meet their entity's requirements as well as those of the synchrophasor wide-area network. They will deploy the common interconnection-wide tools within their control centers as well as those of entity-specific applications. The integration of the vast scope of WISP will be assured through the close coordination of the WECC program office and the entity partners.

The WISP team represents a large group of experienced industry organizations including electric utilities, independent system operators, the WECC's two RCOs, product suppliers, the academic community, and consulting organizations. The Team includes those in the forefront of every aspect of smart grid technology research and development, and relevant standard setting. In addition, team members are a part of every level of the NASPI organization — from the technical through to the leadership and the executive steering committees.

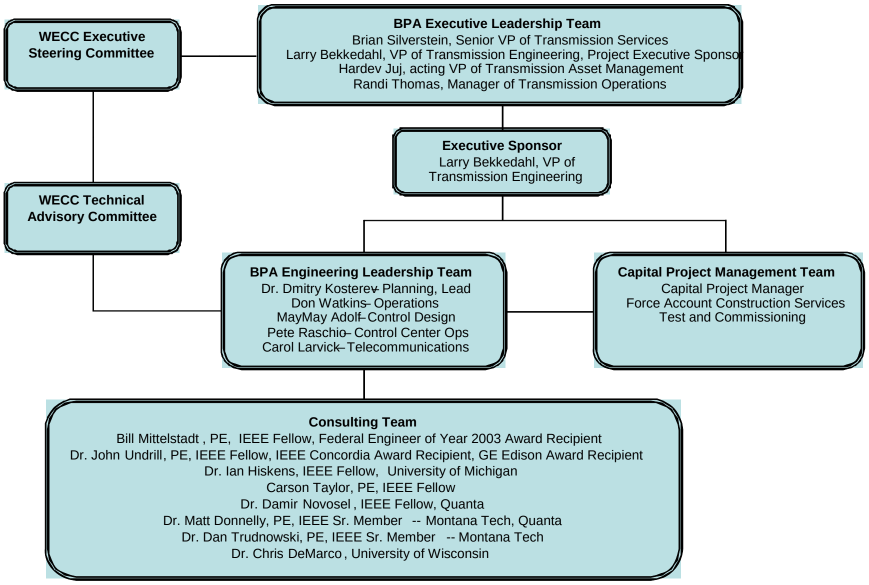
The PG&E team shown in *Figure 3-3*, will use Mississippi State University (MSU) as the lead academic institution to provide expertise and facilitate bridging to other prestigious universities — Virginia Tech (VTU), Georgia Tech (GTU), and Washington State University (WSU) — to focus on to tools and concepts related to adaptive protection, real-time tracking and trending algorithms, and modeling. For example, the SuperCalibrator applications (or equivalent) will be implemented at one or two sites using expertise from GTU, and new control methods utilizing protective relays and flexible AC transmission system devices will utilize WSU's expertise.

Figure 3-3: PG&E Organizational Structure



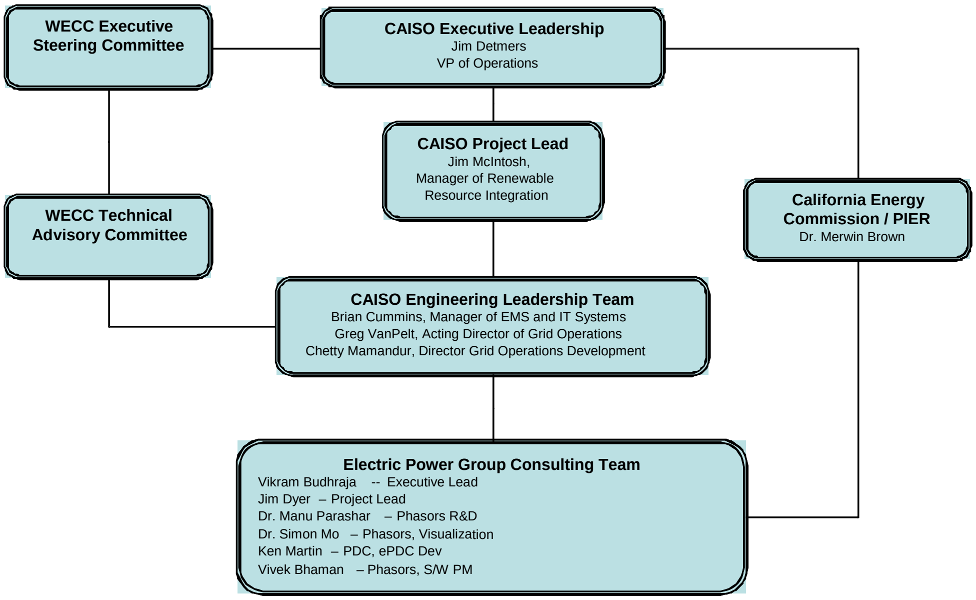
The BPA team illustrated in *Figure 3-4*, is comprised of a number of industry leaders in synchrophasor technology and applications — including Montana Tech and consultants with pioneering wide-area measurement and control backgrounds — and will focus on the deployment of oscillation detection, mode meters, intelligent alarming, decision support tools for operators, and wide-area controls.

Figure 3-4: BPA Project Organization Chart



CAISO/CEC/EPG team illustrated in *Figure 3-5,* will be led by the operations staff of the CAISO, funded by the CEC, and supported by EPG's expertise in phasor applications, visualization, and data concentrators.

Figure 3-5: CAISO Organization Chart



3.3. Risk Management Matrix

Program risks are identified in *Table 3-2*. The risks shown below will be further refined during the program planning phase and the probability impact of each risk will be quantified. A risk management plan will then be created to define risk mitigation management and ownership.

Table 3-2: Risk Management Matrix

Risk		Likelihood	Impact	Risk Management/Mitigation
Business Risks				
1	Change in capital investment decisions in annual budget review cycles of funding partners	L	H	– Senior executives at funding partners are convinced of the smart grid investment strategy. Letters of commitment are submitted as part of the WECC application. – The project management team will have regular and proactive communications to partner senior executives and key stakeholders regarding project progress, costs and benefits as well as potential risks to keep their continued buy-in and commitment to the project
2	User acceptance and benefit realization	M	H	– The project will include user-friendly software for end-users to access the data and applications. – The project plan includes extensive user training, and continuous user involvement and validation. – The project plan includes data analysis to continually assess and validate benefits.
Project Risks				
3	Vendor resource availability	L	H	– All vendor-partners will be contractually obligated to this project's success. – All partners in the integrated project team will need to demonstrate that they are companies with proven resources. In addition, they will need to demonstrate the availability of backup resources as needed. – The project plan includes small subprojects, that allow continued monitoring and mitigation of potential resource limitations.

Risk		Likelihood	Impact	Risk Management/Mitigation
4	Scope increase – additional requests from organizations and users during the project (e.g., after they see what can be done with the synchrophasor data)	M	M	– Project management will create a scope change control process. Funding for approved scope changes will be borne by the applicants, not DOE.
5	Schedule delay	M	M	– Delay due to resource availability: see resource availability risk above. – Material supply risk: suppliers of key technologies are included as partners in the integrated team to minimize this risk.
Technical Risks				
6	Immature technologies – PMU/PDC and synchrophasor applications are relatively new NASPInet architecture and specifications have not been field proven	H	H	– To minimize this risk, WECC will employ the technology maturity model described in *Table 4-1*. WECC will engage advanced and proven product and service providers, as well as academics and synchrophasor experts at partner utilities.
7	System scalability and performance	L	H	– Same mitigation strategy as Risk #6, immature technologies – The project plan includes small subprojects, that allow incremental validation of system scalability and performance, and system tuning as needed.
8	Technology integration and interoperability	M	M	– Please see Section 5, Interoperability and cyber security
9	Cyber security	M	M	– Please see Section 5, Interoperability and cyber security
10	Technology obsolescence	L	M	– The engaged partners are all leading users of synchrophasor products and services, have been actively involved in organizations such as NASPI and IEEE/IEC to advance smart grid and synchrophasor technologies, and corporately committed to the smart grid and synchrophasor industry.

4. Technical Approach to Enabling Smart Grid Functions:

4.1. How the Project involves smart grid technologies, tools, or techniques that meet the conditions of “qualifying investments”:

WISP will enable smart grid functions on the of the U.S. portion of the Western Interconnection. It will upgrade existing PMUs and deploy new PMUs, PDCs, Super PDCs, and historical data archival systems. The network architecture to connect these measurement devices is included, as is the deployment of both real-time and off-line tools to provide visualization for operators, event and system performance analysis for operational and planning engineers, model validation, the implementation of real-time control and protection, and system restoration.

4.2. How the Project installs the qualified smart grid technologies, tools, or techniques and connects them to the electric system, building, or piece of equipment:

WISP will deploy PMUs, PDCs, and Super PDCs in a general interconnection infrastructure as depicted *Figure 4-1*. All PMUs and PDCs will be networked to multiple PDCs. Although infrastructure for the Canadian provinces British Columbia and Alberta are shown, they are not part of this application for matching funds.

Figure 4-1: PMU and PDC Deployment in the Western Interconnection

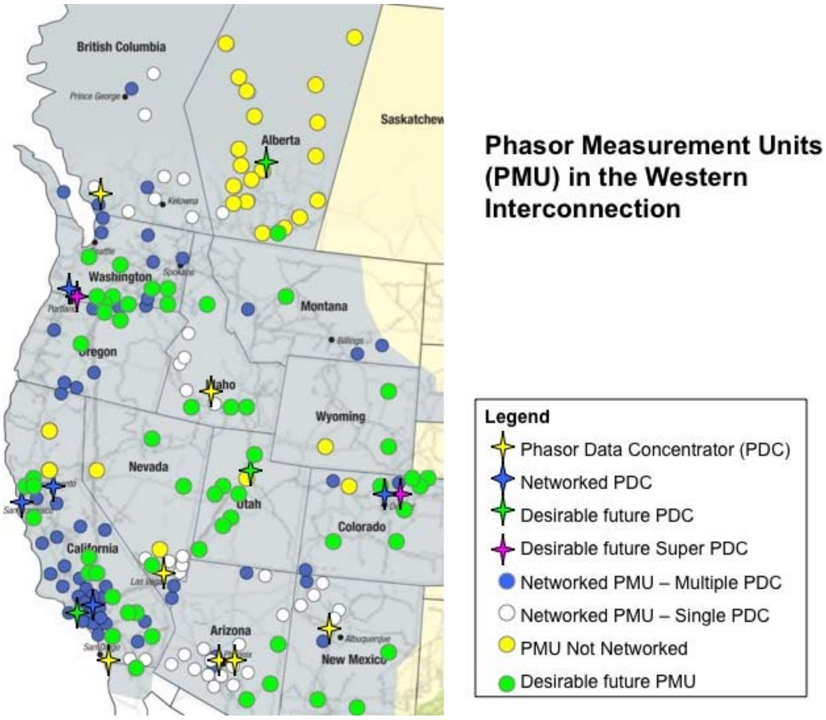
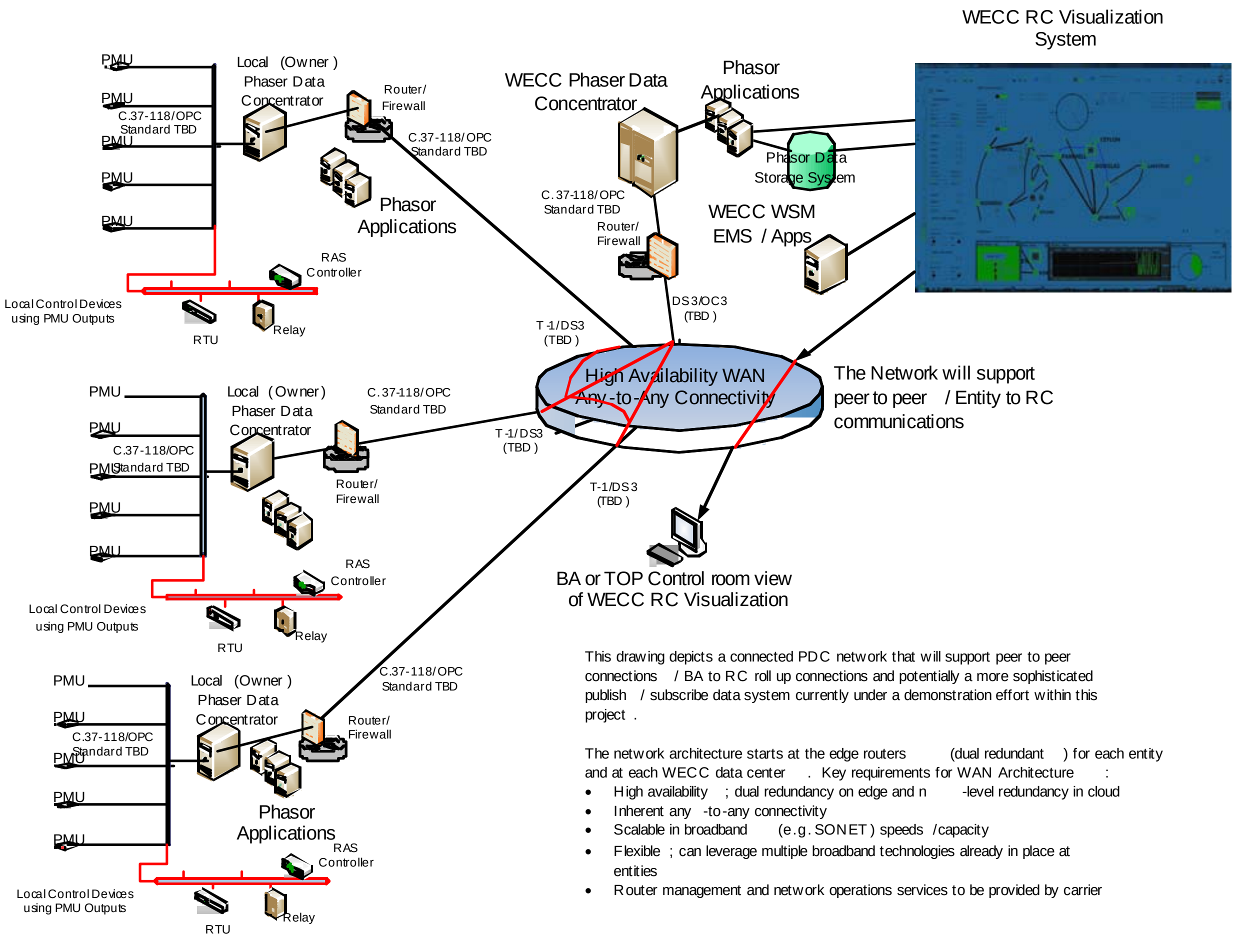


Figure 4-2 shows a connected PDC network that will support peer-to-peer connections, and Balancing Authority or Transmission Owner/Operator roll-up connections and anticipates NASPInet — the more sophisticated ‘publish and subscribe’ system currently in draft specification status for its data bus and phasor gateway. The WECC inter-utility network architecture starts at the edge router of each entity.

Figure 4-2: Phasor Communications Architecture



This drawing depicts a connected PDC network that will support peer to peer connections / BA to RC roll up connections and potentially a more sophisticated publish / subscribe data system currently under a demonstration effort within this project.

The network architecture starts at the edge routers (dual redundant) for each entity and at each WECC data center. Key requirements for WAN Architecture:

- High availability; dual redundancy on edge and n-level redundancy in cloud
- Inherent any-to-any connectivity
- Scalable in broadband (e.g. SONET) speeds /capacity
- Flexible; can leverage multiple broadband technologies already in place at entities
- Router management and network operations services to be provided by carrier

4.3. How the Project plans to operate the smart grid technologies, tools, or techniques in a manner that causes smart grid functions to actually occur:

The existing synchrophasor system is not comprehensive in coverage, and is viewed as a research-grade system that is primarily for off-line applications such as system performance analysis, model validation, and prototyping research ideas. The network does not currently meet reliability and cyber-security requirements for real-time applications such as wide-area control and operator situational awareness.

Reliability of the existing synchrophasor network has been the primary reason for the slow pace of synchrophasor adoption for real-time applications. Data drop-outs are frequent from key locations, particularly from inter-utility data exchanges. The failures are mostly attributed to the radio communications used with original PMUs installed decades ago. Most entities have moved, or are moving to, a digital communications infrastructure that can better support PMU networking. Digital communications, mainly fiber-optics, will be used for this Project’s production-grade synchrophasor network.

Currently WECC member utilities archive data that is locally collected through their own intra-utility synchrophasor network. The most common mechanism for this is the use of contiguous five-minute binary files in the PhasorFile format. The process for sharing inter-utility data files during a major disturbance is a manual process and is done through a secure File Transfer Protocol site. Commercial technologies have matured sufficiently to allow WISP to implement an automated West-wide data archival and access management system that will greatly streamline the archival and data mining process in support of off-line applications.

Utilities, independent system operators, and reliability coordinators jointly operate the interconnection and need to exchange real-time synchrophasor data with their interconnected partners. WISP will improve the infrastructure and expand the network for broad coverage and data management (collection, archiving, and inter-utility exchange). Synchrophasor data is not currently available at the WECC RCOs. WISP will provide data from the Western Interconnection to the WECC RCOs, deploy the archival systems there, and provide a full suite of applications at these sites as well.

The use and purpose of synchrophasor data, the applications, will be deployed in four areas: 1) off-line tools for power system element model validation, and system performance and event analysis, 2) real-time situational awareness tools, and 3) real-time wide-area control and protection, and 4) system restoration. Common visualization tools would be deployed in the Western Interconnection for Transmission Owner/Operator, Balancing Authority, Independent System Operator, and RCOs. Off-line tools would be deployed in the Western Interconnection for operational and planning engineers. Wide-area controls will be deployed as a reliability defense measure and a safety net for evolving interconnection vulnerabilities.

WISP will deploy infrastructure and applications according to the maturity model shown in *Table 4-1*. Level 1 represents the lowest level of maturity and readiness, and Level 4 the highest. WISP application deployments are highlighted in red. Future applications are shown in blue.

Table 4-1: WISP Maturity Model

	Infrastructure	Situational Awareness NASPI Class B & C Service Level	Wide-area Control & Protection NASPI Class A Service Level	Model Validation NASPI Class D Service Level	System Performance and Event Analysis NASPI Class D Service Level
Level 4		Intelligent alarms and grid optimizers	*Inter-area continuous feedback and discrete control and protection		
Level 3	* NASPInet Phasor Gateway & Data Bus proof-of-concept demonstrations	*Alarms that use wide-area measurements to calculate system stability margins and pre-determined operator actions (voltage instability predictor, mode meter, etc.)	*Regional "defense in depth" control systems that take proportionate actions based on wide-area measurements *Regional continuous feedback controls	* Model parameter identification from real-time data	
Level 2	*Build out the existing network *Develop architecture for integrating Synchrophasor Network in the control centers *Implement historical archive for synchrophasor data	*Phase Angle Alarms *Reactive Reserve Alarms *Wind Generation State Awareness	*Regional controls that take pre- determined discrete actions based on wide-area measurements *Arming existing RAS based on wide-area measurements *Reactive power management controls	*Processes and tools for system-wide model validation in time and frequency domain	*Tools for data mining and data management *Processes and tools for using synchronized phasor measurements for system performance analysis (e.g., oscillation damping, mode shapes, participation factors)
Level 1	*Upgrade the existing Synchrophasor Network to interoperability and cyber-security standards	*Trending high-speed wide-area measurements - frequency, voltages, path flows, phase angles, and oscillation energy	*Research benefits and feasibility of wide-area control applications	*Processes and tools for equipment model verification (power plants, including wind, HVDC systems, Static Var Compensators, etc)	*Processes and tools for using synchronized wide-area data for disturbance event analysis *Compliance with NERC Disturbance Monitoring Standard PRC-002
	INFRASTRUCTURE	REAL-TIME		OFF-LINE	

WISP, when complete, will result in a system of PMUs, PDCs, the network to connect them and the applications to better manage the operation of the interconnection. This system will provide the ability to see and manage the intermittent nature of renewable resources and to deploy the ancillary services needed to solidify the changing nature of the West’s generation fleet. It would provide for better understanding and modeling of the power system’s dynamic nature, leading to more accurate transmission path limits and better planning of significant future infrastructure investments. Additionally, wide-area control and protection to automatically take corrective actions will significantly increase the reliability of the interconnection and should release latent transmission capacity at very low cost.

4.4. How the Project plans to extend installation and operation of the qualified smart grid technologies, tools, or techniques to a broader set of locations and applications after the Project is complete (e.g., company-wide, city-wide, state-wide, system-wide, interconnection-wide, or nation-wide):

WISP has a very large geographic scope (the U.S. portion of the Western Interconnection) and involves the participation of public, private, vendor, academic, and regulatory entities. When WISP is complete — and some period of operational and engineering experience is achieved with the set of common tools, models and controls — next steps may be taken to further the applications and reach of the synchrophasor system.

Extending the networking and data collection from the Canadian entities may take place in parallel, but will remain separate from WISP funding. This will allow for greater visibility of this critical part of the interconnection. Summer oscillatory power system behavior includes a significant north-south mode, and reliability of the power system must be considered an interconnection-wide concern.

Infrastructure and applications associated with WISP will be deployed so that they are scalable. As additional generation is added, particularly renewable resources, PMU coverage of those generation sites will be added for continued comprehensive visibility to ensure no degradation of the situational awareness and reliability management gained from WISP will occur.

The next phases of application development can be built upon the suite of applications deployed in WISP. Referring again to *Table 4-1*, the higher levels of applications in the maturity model would be undertaken for the greater benefit of the SGIG goals. While much has been done to research the feasibility and potential algorithms to accomplish the wide-area control objectives, they are not yet ready for deployment and need to be tested and demonstrated to ensure appropriate integration into the operation of the stability-limited Western Interconnection to ensure reliable (operates every time desired) as well as secure (never operates when not desired) performance. WECC may consider a Smart Grid Demonstration Grant request under DE-FOA-000036 to further this work. These applications, shown in blue in *Table 4-1* may be developed when the project is complete.

Because the scope of WISP is so large geographically, interoperability of the infrastructure and applications is a key success factor. Utilities (both public and private, large and small), Independent System Operators, Independent Power Producers, Transmission Owners/Operators, and Balancing Authorities have invested heavily in infrastructure and systems of different vintages and by different manufacturers. The PMUs and PDCs of different types must operate together not only to meet functional requirements, but performance requirements as well. WISP will follow applicable IEEE standards (i.e., C37.118) and NASPI guidelines to assure interoperability. The applications deployed will have different speed requirements for effectiveness. These must be able to be integrated into a variety of EMS systems as well. Successful performance in this area of the Project would mean not only interconnection-wide integration, but could also translate to nation-wide deployment.

4.5. How the Project plans to assess operational performance of the smart grid technologies, tools, and techniques and use the results of that assessment to optimize the way electricity is generated, delivered, or used and enable or enhance smart grid functions and help achieve the purpose and goals of the SGIG:

WISP will deploy infrastructure and applications according to the maturity model shown in *Table 4-1*. Level 1 represents the lowest level of maturity and readiness, and Level 4 the highest. WISP application deployments are highlighted in red. Future applications are shown in blue. WISP will assess the performance of the project elements in a disciplined manner using a maturity model. This method will be used to manage risks and realize benefits as quickly as practical. The maturity model greatly minimizes project risks, as maturity levels become stage gates for expanding project complexity. The model provides visibility of the readiness of the interconnection for infrastructure and application deployment and is expected to lead to an efficient allocation of resources and capital and appropriate timing of project steps.

With each stage gate deployment, project elements will be compared with their functional and performance objectives and mitigation steps taken if either timing, functional, or performance results are less than expected. Each project element will be assessed individually and for its impact on the whole suite of project elements.

For infrastructure, critical points within the interconnection with low visibility will be deployed early — as will networking PMUs to PDCs and linking the PDCs together — to provide entity-to-entity information exchange or to roll up to a broad interconnection view at the WECC RCOs. Testing and tracking of the performance of the synchrophasor network is a long term objective of WISP. Assessment of the data exchange accuracy and drop-out rate will be continuously monitored. As real-time applications are deployed, operators and the automatic control systems must be assured of synchrophasor information that is accurate, timely, and synchronized.

As greater expansion of the synchrophasor network is achieved, disturbance data will be comprehensively reviewed and the actual power system behavior compared against simulated performance using the same initiating event(s) and models of generators, transmission, and loads. These models will either be validated or their discrepancies will be researched and better, more accurate models will result. Grid planning and operating decisions rely on simulations of the dynamic behavior of the power system. Both the technical and commercial segments of the industry must be confident that the dynamic simulation models and databases are accurate and current. Optimistic models can result in unsafe operating conditions (risking cascading electrical outages) while pessimistic models can result in overly conservative grid operation and underutilization of transmission capacity leading to adverse economic results (limiting the free flow of electricity on the grid). Having accurate models is essential to reliable and economic power system operation. It is expected that latent transmission capacity can be released with better models at very low cost. This direct result helps optimize the way electricity is delivered.

Additionally, developing real-time controls to automatically take corrective actions will significantly increase the reliability of the interconnection. It will result in more accurate assessment of the interaction between transmission paths with flows that occur simultaneously. Some western nomograms reflecting the simultaneous path limits are expected to allow more combinations of path flows that meet safe operating criteria. This, too, is expected to release latent transmission capacity at very low cost and help optimize the way electricity is delivered.

Large-scale integration of renewable resources will present an additional challenge to the system operators. Initial experience indicates that large and fast power ramps can be expected in both directions, dramatically shifting the generation patterns. PMU technology will provide the ability to see and manage the intermittent nature of renewable resources, including the ability to deal with high-speed ramps and to deploy the ancillary services and reactive support needed to solidify the changing nature of the Western Interconnection's generation fleet. This helps optimize the way in which electricity is generated to meet the variety of economic and environmental objectives that are goals of the SGIG.

4.6. Justification for Earning a High Technical Merit for Criterion 1

WECC believes the proposal merits a high score for this criterion because WISP aims to improve operational performance. It will increase asset utilization – by more precisely determining the safe operating limits of the variety of paths needed for reliability and markets in the Western Interconnection, leading to increased transmission capacity and utilization of the existing infrastructure. Reliability will be improved through more accurate and validated models, more visibility of the behavior of the power system in real-time, intelligent alarming and operator decision support, and the safety nets afforded by the wide-area controls.

WISP proposes to deploy approximately 250 to 300 PMUs across the U.S. portion of the Western Interconnection:

- Upgrading or replacing many of the old units that do not conform to current or emerging standards for both steady-state and dynamic performance.
- Creating or enhancing the communications system needed to collect the data into a new system of data concentrators needed to deliver interconnection-wide networking.
- Installing historical archival systems at the WECC RCOs.
- Deploying common visualization applications to see the synchrophasor data – both steady state and dynamic results.
- Deploying alarming and operational decision support tools.

Together, this will allow the operators from the control rooms of the Balancing Authorities, Transmission Owners/Operators, ISOs, and Reliability Coordinators.

WISP anticipates NASPInet's publish and subscribe protocols and stays connected with NASPI through technical, leadership and executive sponsorship committees. In one connection from a PDC to one of the RCOs, the NASPInet's data bus and phasor gateway specifications will be deployed and field tested.

5. Technical Approach to Interoperability and Cyber Security

The WECC Program Team and its entity partners are committed to ensuring and promoting interoperability and cyber security compliance for WISP. Current industry-standard data formats, transport protocols, and software integration standards will be relied upon to achieve interoperability between systems and applications throughout the Western Interconnection. Requiring the use of industry standards means less reliance on proprietary technology, opens up the opportunities for increased vendor participation, and enables the use of off-the-shelf products and applications. Furthermore, WECC will ensure that new synchrophasor infrastructure, systems, and software are engineered and operated to comply with NERC Critical Infrastructure Protection (CIP) Standards for reliable operation of the bulk electric system.

5.1. Interoperability

WISP will leverage standards defined, or in the process of being defined, by the U.S. Commerce Department’s National Institute of Standards and Technology (NIST). NIST was selected by the U.S. Congress in the Energy Independence and Security Act (EISA) of 2007 to coordinate the development of a framework of protocols and model standards to achieve interoperability of the smart grid. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology. NIST recently identified 16 standards or sets of standards that encompass the smart grid vision. Of the 16 standards identified by NIST, six are relevant to this program and will be leveraged in the engineering and deployment of the U.S. portion of the Western Interconnection’s synchrophasor systems and infrastructure. These six, along with other pertinent standards, are identified and categorized by their associated area of the technology stack. Interoperability proof-of-concept methodology will be used during the detailed engineering phase to minimize project risk for the resolution of standards and interfaces issues that may appear.

5.1.1 Data Transport Standards

Phasor data is read in real-time by PMU and sent to PDC for data aggregation, synchronization, and historical trend analysis. The synchronized sampling process (synchronized via GPS timestamp) of different waveforms at multiple plant locations provides a common reference for phasor calculations. PDCs at different utilities throughout the U.S. portion of the Western Interconnection will then be connected to a common set of central PDCs at WECC to aggregate data across the utilities and provide an interconnection-wide snapshot. It is the data transport standards that make it possible to build an interconnection-wide integration architecture, leveraging different PMU and PDC vendor products throughout the U.S. portion of the Western Interconnection. The following data transport standards are under consideration for this program. Selection of specific standards will occur during the infrastructure requirement and design process. Note: the specific standards chosen will be used in conjunction with the Internet Protocol (IP) for the transmission of synchrophasor data of today’s commonly used local-area and wide-area network technologies.

IEC 60870-6 defines the Inter-control Center Communications Protocol (ICCP) standard that enables the exchange of real-time and historical power system information including status and control data, measured values, scheduling data, energy accounting data, and operator messages. It is currently the transport protocol of choice for power systems data collection by energy management systems. However, ICCP does not yet support high volumes of data continuously transmitted between control centers and therefore is not under immediate consideration for synchrophasor data exchange. The Program Team is aware that this standard may evolve to cover synchrophasor data and intends to contribute to and monitor the effort over the next 12-24 months.

IEEE C37.118 defines all aspects of synchrophasors including a standard data transport method to communicate from PMU to PDC and between PDCs. In 2005, C37.118

became the IEEE standard for synchrophasor implementations, replacing the IEEE 1344 synchrophasor standard that had been the standard since 1995. C37.118 is also the identified NIST Smart Grid standard for the communication of synchrophasors. However, this standard will need to be integrated with cyber security standards to meet data integrity and security requirements.

IEC 61850 is a collection of profiles that define different aspects of substation communications, including models and service, quality assurance, and a substation configuration language for support of different engineering tasks. These protocols can run over TCP/IP or directly on an Ethernet dataframe (GOOSE) through local and wide-area networks to support sub-second data requirements, and are currently being tested throughout the country to support synchrophasor data exchange. In addition, NIST has developed a Priority Action Plan around the harmonization of IEEE C37.118 and IEC 61850. IEC 61850 and C 37-118 harmonization is one of NIST top priorities identified at the NIST meeting on August 3–4, 2009. Even now, products exist that transport synchrophasors over IEC 61850 and testing of these products is very active. There is a possibility that it could parallel the IEEE C37.118 standard in the communication of synchrophasors as well as relevant inter-utility communications protocols, and thus will be closely considered for this program.

The proposed IEEE standard - PC 37.238 - is a utility profile for application of the IEEE 1588 Precision Time Protocol over Ethernet, and is being developed by the IEEE Power & Energy Society’s Power System Relaying Committee. This profile, when implemented in products, will enable the microsecond time synchronization required by the synchrophasor computation process and is an alternative to the present method of time synchronization of IRIG-B over copper or fiber. This standard is still under development and will be closely monitored for production readiness the next 12-24 months.

Object Linking and Embedding (OLE) for Process Control (OPC Data Access) is a real-time data access protocol. Interoperability is assured through the creation and maintenance of open standards specifications that were initiated in 1996 and have continued to evolve. Based on Microsoft's OLE component object model (COM) and distributed component object model (DCOM) technologies, the specification defines a standard set of objects, interfaces, and methods for use in process control and automation applications to facilitate interoperability. Multiple power systems software product vendors have incorporated OPC Data Access interfaces into current products and therefore it and the newer version — OPC Unified Architecture — are considerations for interoperability for this program. In addition, products using structured query language (SQL) access requests to databases exist and will also be considered.

5.1.2 Wide-Area and Systems Integration Standards

The NASPI architecture infrastructure will allow phasor data exchange between utilities and the WECC RCOs to enable real-time situational awareness, wide-area measurement and control, system-wide model validation and system-wide performance analysis. NASPI has submitted multiple architecture design specifications for industry community review and is on a three-to-five-year plan to build out the NASPInet infrastructure. It is the intent of this program team to work with vendors, utility partners, and the academic community to actively contribute to the NASPInet specifications and ultimately to demonstrate the ability to integrate the WISP infrastructure with NASPInet to support wide-area communications and systems integration.

Systems Integration Standards comprise a combination of integration framework, technologies, and services that form a middleware to enable the integration of disparate systems and applications. Systems integration middleware is being considered for this program to enable the integration of multiple, top tier vendor applications. The benefits of utilizing integration middleware include:

- Phasor data integration – ensuring that data in multiple systems is kept consistent.
- Vendor independence – extracting commonly leveraged business policies, rules, and services from applications and implementing them in middleware.
- Common façade – providing a common front-end for a cluster of synchrophasor applications, delivering a single consistent visualization interface and preventing users from having to learn to interact with multiple vendor software packages.

The following systems integration standards are under review and will be further considered during the systems analysis and integration architecture design process.

- IEC61970 and IEC61968 Common Information – a series of standards under development that will define application interfaces for information exchange between electrical distribution systems; and provides a set of standards to facilitate: (1) the integration of applications developed by different suppliers in the control center environment, (2) the exchange of information to systems external to the control center environment, and (3) the provision of suitable interfaces for data exchange between legacy and new systems.
- Common Information Model (CIM) including CIM XML Full - standard developed by the electric power industry that enables application software to exchange information about the configuration and status of an electrical network. The CIM is currently maintained as a Unified Modeling Language and defines a common vocabulary and basic ontology for aspects of the electric power industry. The CIM can be used to derive 'design artifacts' (e.g. XML Schema, Resource Description Framework Schema) as needed for the integration of related application software.
- Enterprise Service Bus (ESB) provides fundamental services for complex architectures via an event-driven and standards-based messaging-engine. ESB integration architecture is under consideration to support a synchrophasor application portfolio that could be based on multiple, best of breed software vendors. As such, integration interfaces will be required to support data exchange between vendor software packages.
- Extensible Markup Language (XML) - XML is widely used as a technology to facilitate the exchange and simultaneous translation of data between disparate systems. Simple Object Access Protocol (SOAP) is a protocol specification for exchanging structured information based on Web services. It relies on XML as its message format. SOAP can form the foundation layer of a Web services protocol stack, providing a basic messaging framework upon which Web services can be built for the integration of real-time data systems.

5.2. Cyber Security

This section describes how WISP will address industry requirements and compliance standards for cyber security. Existing WECC cyber security policies, processes, and controls will be extended where applicable to support compliance to industry standards and regulations, namely NERC CIP-002-1 through CIP-009-1. Key design principles for WECC cyber security include defense in depth, minimizing the attack surface, separation of duties, least privileges, establishing secure defaults, using a positive model, and assuming external systems and services are insecure. These design principles work together to satisfy current NERC CIP requirements and result in a set of policies, processes, tools and organizational definition that will form the starting point for risk assessment of new synchrophasor systems, infrastructure, and applications.

In order to provide a comprehensive assessment, the WECC cyber security approach will take multiple perspectives into account. It will assess the risk to each system based on system role, sub-system, network, or actor basis. The synchrophasor systems will also be designed and implemented in a way that provides clear boundary definitions and interface handoff so that the security risks can be continually reviewed in the context of its system definition. This also enables a risk-based prioritization and focus on the handoffs between discrete system components where vulnerabilities are inherently introduced.

Cyber security risk analysis and compliance will also be covered through the WECC systems engineering and deployment lifecycle. Cyber security risk assessment, identification and mitigation, specifically in the context of satisfying NERC CIP-002-1 through CIP-009-1, will be vertically aligned and interspersed throughout each stage of the lifecycle, including: business and system requirements analysis, architecture, system and infrastructure design, software/system engineering, testing, and deployment.

PMUs, PDCs, associated protocol conversion servers, middleware servers, and the synchrophasor application systems are expected to be defined as critical cyber assets (CCA). The following sections identify how WISP will address cyber security, with a focus on compliance to NERC CIP for CCAs.

Cyber security architecture, an integral part of the system architecture, facilitates systems design to adequately mitigate cyber security risks from both typical usage and from malicious cyber attacks. The security architecture focuses on building layered security defenses at each level of the technology stack (i.e. network, system, middleware, application) provide common security controls (e.g., authentication, authorization, auditing, administration) across all levels. Cyber security focuses on three core pillars: 1) Availability – ensures systems and data are available to authorized users when they need it, 2) Integrity – ensures data is not tampered with or altered by unauthorized users, and 3) Confidentiality – controls access to data by specific user and system permissions. The key objective of the security architecture is to provide a security framework that supports all of the business requirements and business processes in an integrated systems environment, where availability, integrity, and confidentiality are designed into the environment on the front-end. Having NERC CIP compliance built into the WECC systems engineering and deployment lifecycle will assure that this happens.

Critical Cyber Asset Identification (CIP-002) - All network and system assets must be audited to identify CCAs. As previously mentioned, all synchrophasor data collection, analysis, and application systems are expected to be considered CCAs. As such, they will be engineered and implemented to ensure compliance to NERC CIP standards. In addition, WECC will leverage a risk-based methodology, aligned with CIP requirements, to implement regular audits of all IT Systems (including the new synchrophasor infrastructure) to identify and ensure cyber security compliance as the IT environment continues to grow and change over time.

Security Management Controls (CIP-003) – System monitoring and change control policies must be documented and adhered to. This includes definitions and documentation on access control levels for critical assets such as the newly planned synchrophasor systems and any associated front-end (e.g., visualization portal) and backend solutions. To ensure system integrity and to maintain the security posture and continuous compliance, WECC will deploy Automatic Change Auditing (ACA). ACA provides automatic discovery that detects unauthorized changes to system configuration, identifies new devices and/or new applications in the infrastructure, and alerts system and security administrators. Misconfigured devices and/or cyber security attacks can be identified and contained quickly, thereby mitigating impact to system reliability and availability. ACA tools and supporting processes will be implemented and integrated with the existing WECC Enterprise Change Management process to effectively satisfy CIP-003 standards and requirements.

Personnel and Training (CIP-004) – These requirements direct that personnel having authorized access (either cyber or physical) have an appropriate level of personnel risk assessment, training, and security awareness. WECC currently satisfies CIP-004 standards and requirements through a combination of policies and processes for the management, control and auditing of WECC staff and contractor background checks, visitor check-in and escorting, physical access to the Control Room and Data Center floor space, and security awareness and training programs. New WECC staff and contractors required to support WISP and ongoing operations and maintenance of the synchrophasor systems will be required to comply with the aforementioned existing control policies and processes.

Electronic Security Protection (CIP-005) – This group of requirements mandate the implementation of an electronic security perimeter (ESP) to control network and system access to CCA systems. All perimeter access points must be identified and controlled. Clearly defined network boundaries allow the design and the deployment of a solid network perimeter defense at multiple levels. Specific security policies and firewall rules can be defined and enforced for each security zone for access control, communication protocols, malware protection, and intrusion detection. Firewalls and intrusion detection systems are installed on every network perimeter. Communication protocols can be restricted between two zones and firewalls shall be used to further detect and filter out unsolicited payloads.

Electric Grid Intrusion Detection – Electric grid control systems are susceptible to intrusion. As such, WECC proposes to work with partners in the Western Interconnection to develop an anomaly detection based intrusion detection architecture which monitors C37.118 network traffic at PMU interfaces for intrusions and creates a stochastic probability of intrusion for each interface. Local intrusion detection devices placed at the PMU edge, and at specific access points throughout synchrophasor data architecture, will aggregate intrusion probabilities across the Western Interconnection and proactively adjust the process control system to identify and contain possible intrusions.

Physical Security Program (CIP-006) – Physical Security controls that provide perimeter monitoring and logging along with robust access controls should be documented and implemented. Current WECC physical security monitoring and controls will be extended where necessary to include any new data center or staffing facilities required to support new synchrophasor systems and staffing.

Systems Security Management (CIP-007) – WECC plans to expand existing system and network monitoring and alerting to include the synchrophasor systems. This includes leveraging existing tools for intrusion and change monitoring, logging and alerting at all layers of the IT technology stack – network, desktops, servers, operating systems, middleware, and applications. WECC also plans to conduct annual vulnerability assessments and identify risks in security controls, tools, processes, and procedures. To effectively incorporate new synchrophasor CCAs, WECC will also augment current logging and auditing methodology in the areas of policy violations and management, intrusion detection and prevention, system change management, incident reporting and response, and forensic analysis.

Leveraging a restricted list of communication protocols makes network communication protection much easier to achieve. Standard protocols, such as SSL/TLS, SSH, SFTP and IEC 62531 shall be supported and used for providing access control, data confidentiality, data integrity and non-repudiation where are applicable. Unused system and application communication ports shall be closed at network perimeters using firewalls. In addition, best practices for the hardening of selected operating systems will be implemented and, at the application level, unused services will be disabled.

The planned WECC synchrophasor security architecture will also provide an Access Control Framework (ACF). The ACF is composed of three framework services: Login, Authentication, and Authorization. The three services work together to acquire and verify user credentials and grant authorization to application content for each synchrophasor system. Multi-factor authentication, single-sign-on, centralized identity management, and role-based access control are all supported by the ACF and are under consideration for WISP.

Incident Response and Reporting (CIP-008) – This mandates the requirement for a cyber security incident response plan and team that addresses the classification, response, and reporting of cyber security incidents related to CCAs. WECC will expand its existing incident response plan and procedures to incorporate the new synchrophasor systems.

Disaster Recovery (CIP-009) – This requirement calls for having a disaster recovery plan in place for the CCAs. The synchrophasor systems will be implemented in both the primary (production) and secondary (disaster recovery) WECC data centers. The existing WECC Disaster Recovery Plan will be revised to include the new synchrophasor systems. System fall-back (failover to the secondary data center) and fall-forward (bringing the systems back on-line in the production facility) procedures will be documented and tested on a regular basis (e.g., quarterly). These procedures will include a step-by-step procedure to run the synchrophasor systems, for an extended period of time, out of the secondary data center in the event of a disaster to the production facility.

6. Costs and Benefits

6.1. Costs

The total estimated WISP costs are $107.8 million. The recurring costs on completion of WISP are estimated to be $2.89 million per annum. Details are contained in Form SF424A and Budget Justification files included with this application.

6.2. Benefits

WISP has the potential to provide numerous economic benefits by improving reliability, operating efficiency, asset utilization, system planning, and environmental impact. According to an analysis done by Energy and Environmental Economics, Inc. (E3), these benefits include:

1. Large-scale outage avoidance
2. Increased transmission utilization
3. Increased utilization of intermittent renewable generation
4. Reduced capacity cost for supporting intermittent renewable generation

A summary of E3's calculations of these four potentially large benefits is found in *Table 6-1*, which shows the minimum expected value from each benefit stream.

Table 6-1: Minimum Benefits from WISP, Present Value over 40 Years ($2008)

Benefit	Minimum Value
Large-Scale Outage Avoidance	$1,220,540,494
Increased Transmission Utilization on a Major Transmission Path	$34,748,816
Increased Utilization of Intermittent Renewable Generation	$323,755,442
Reduced Capacity Costs for Intermittent Generation	$307,735,069

Details of each of these calculations are found in the following section. Assumptions that are common to all benefit streams are found below in *Table 6-2*.

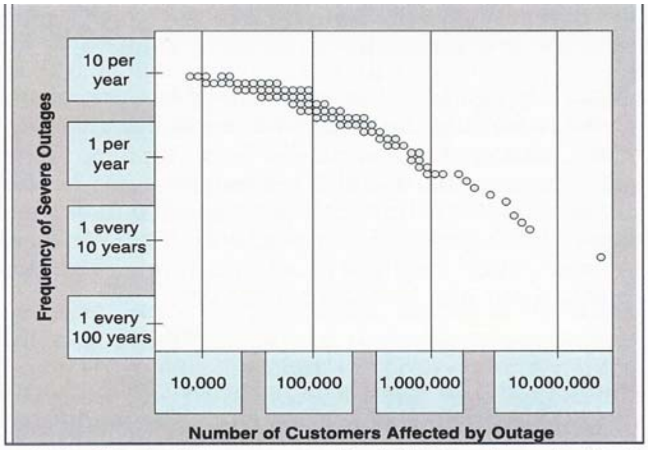
Table 6-2: General Assumptions for all Benefit Streams

Assumptions	
Inflation Rate	3%
Utility Discount Rate	8.8%
Lifetime (years)	40

6.3. Large-scale Outage Avoidance

Improvements in wide-area situational awareness and wide-area controls due to the WISP have the potential to significantly reduce the frequency of large-scale, long-duration outages originating in the bulk power grid. Each outage that does not occur represents substantial savings to customers in terms of lost production and lost amenities avoided. For large cities, a major outage typically has customer costs valued in the hundreds of millions of dollars and above.

Figure 6-1: North American Power System Outages, 1984-1997[1]



Note: The bubbles represent individual outages in North America between 1984 and 1997.

Source: Adapted from John Doyle, California Institute of Technology, "Complexity and Robustness," 1999. Data from NERC.

Figure 6-1 above illustrates the scale and frequency of power system outages in North America, showing that an outage affecting 1,000,000 customers can be expected to occur about once a year. The benefits calculation here conservatively assumes that an outage affecting 500,000 customers occurs every other year in the Western Intereconnection, and that the deployment of WISP would reduce the frequency of such major outages by 10 percent. Thus, over 40 years, WISP would be conservatively expected to prevent two major outages. E3 estimates the benefit of avoiding two outages affecting 500,000 customers each to range from $1.2 billion to $3.5 billion over 40 years, depending on what time within the 40-year period the avoided outages occur. *Table 6-3* provides further detail on the results. The steps followed were:

1) Assume a customer class breakdown as shown in *Table 6-4*.
2) Assume outage cost by customer class as shown in *Table 6-4*.
3) Assume outage duration of eight hours.
4) Assume that WISP would avoid an outage in years 1 and 20 in one case, and years 20 and 40 in the second case.
5) Assume an inflation rate and discount rate as shown in *Table 6-2*.
6) Calculate net present value of avoided outage costs for each case.

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[1] Figure taken from "US-Canada Power System Outage Task Force Report: Causes of the August 14, 2003 Blackout in the United States and Canada", https://reports.energy.gov/BlackoutFinal-Web.pdf

Table 6-3: Results of Avoided Outage Calculation

Number of Customers	Outage Duration (hours)	Year of First Outage	Present Value of Outages over 40 years (2008$)
500,000	8	20	$1,220,540,494
500,000	8	1	$3,510,982,465

Table 6-4: Assumptions Regarding Outage Cost by Customer Class

Customer Class Assumptions	
% Large C&I Customers	5%
% Small C&I Customers	10%
% Residential Customers	85%
Large C&I Cost of 8 hr Outage	$94,000
Small C&I Cost of 8 hr Outage	$4,800
Residential Cost of 8 hr Outage	$11.00

6.4. Increased Transmission Utilization

Currently, transmission facilities are not used to their full capacity in the Western Interconnection because grid operators lack sufficiently granular, time-synchronized measurements of the flows of electricity throughout the transmission system. WISP will allow available transmission capacity to be based on these precise real-time measurements rather than existing slower, coarser measurements or simulation methods such as transmission path nomograms. This will increase the effective capacity of congested lines, increase transmission asset utilization and lower energy costs to consumers.

As an example of the benefit of increased transmission utilization for one major transmission path, E3 looked at transmission between California and the Pacific Northwest using the COI. E3 assumed that WISP would enable an increase in COI transfer capability of 100 MW during high-load hours (HLH). This was done for a summer period of June through September and an extended summer period of April through October.

E3 estimates the benefits of a 100 MW increase in transfer capability on COI to be $35 million to $75 million over 40 years. The results for this COI example are shown in *Table 6-5* and the assumptions are found in *Table 6-6*. It should be noted that COI is not the only path that could benefit from WISP, although it is the largest. There are 39 other paths in WECC that would experience benefits if WISP were adopted.

The steps followed in this analysis were:

1) Obtain hourly electricity price data for the trading hubs Mid-C and NP15. The data used was from 2007.
2) Obtain BPA Southern Intertie rate for hourly non-firm transactions (*Table 6-6*).
3) Assume 3 percent losses (*Table 6-6*).
4) Calculate the direction of electricity flow based on price difference: MidC-NP15<0, flow is from north-to-south, MidC-NP15>0, flow is from south-to-north.

5) Multiply the lower electricity price from above by 103 MW (generation including losses) and subtract the higher electricity price multiplied by 100 MW and a 100 MW multiplied by the BPA Southern Intertie charge.
6) Sum results for all hours of the year.
7) Assume value in Step 5 is realized annually for 40 years.
8) Calculate net present value of annual benefit stream from increased transfers.

Table 6-5: Results

Present Value of 100 MW Increase in COI Transfer Capability (2008$)	
June through September	$34,748,816
April through October	$75,585,256

Table 6-6: Transmission Assumptions

Transmission Assumptions	
BPA Southern Intertie Charge	$3.72
Losses	3%
High Load Hours (hours ending)	7-21

6.5. Increased utilization of intermittent renewable generation

As the use of intermittent renewable resources, such as wind and solar, expands, there is growing concern that transmission systems will be unable to absorb all of the generation. This would lead to “spilling” of wind and other intermittent generation in order to maintain reliability, making Renewable Portfolio Standards (RPS) and Greenhouse Gas (GHG) policy fulfillment more difficult and costly. By improving visibility of transmission, generation and load conditions with WISP, wind resources will be better utilized, increasing their capacity factors (CF). As shown in *Table 6-10*, the levelized cost of electricity from wind decreases as capacity factor increases.

E3 estimates the value of increased wind utilization to range from $323 million to $3.6 billion over 40 years. To estimate this benefit, E3 calculated the savings from using wind at higher CFs. The steps for this calculation were as follows:

1) Calculate the low and high RPS energy requirements of WECC in 2020 and assume that 50 percent of these targets are supplied by wind (*Tables 6-8 and 6-9*).
2) Calculate the levelized busbar cost of electricity of wind at different capacity factors (34 percent, 33 percent, and 29 percent) using E3’s Western Electric Industry Leaders model (*Table 6-10*).[2]
3) Multiply the RPS energy requirements by the levelized cost of electricity for wind at each CF to get the total cost of wind meeting the RPS target for each year between 2009 and 2040.
4) Net present value the costs in Step 3.

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[2] E3’s WEIL model is a transparent spreadsheet model that examines the cost-benefit ratios of fixed capacity lines between zones in WECC. Results from this model can be found at: http://www.ethree.com/documents/e3_weil_complete_study.pdf.

5) Calculate the difference between the present value costs of wind at 34 percent CF and 33 percent CF (savings of 1 percent increase in CF) and the difference in present value cost between 34 percent CF and 29 percent CF wind (savings of 5 percent increase in CF) (*Table 6-7*).

Table 6-7: Results of Increased Wind Utilization

Present Value Savings from Using Higher CF Wind to Meet RPS Targets (2008$)		
	Low RPS	*High RPS*
1% Increase in CF	$323,755,442	$637,533,711
5% Increase in CF	$1,844,599,510	$3,632,353,988

Table 6-8: RPS Requirements

High and Low 2020 RPS Requirements		
	Low RPS	*High RPS*
Total RPS Energy Requirement (MWh)	167,082,301	305,121,174
Wind Portion of RPS Energy Requirement (MWh)	83,541,151	152,560,587

Table 6-9: Percentage of Load Met by Wind

RPS Assumptions		
	Low RPS	***High RPS***
2009-2020	7.5%	13.7%
2021-2049	15%	30%

Table 6-10: Levelized Cost of Electricity from Wind

Levelized Cost of Electricity from Wind at Different Capacity Factors ($/MWh)	
Cost of Electricity at 34% CF	$82.60
Cost of Electricity at 33% CF	$85.41
Cost of Electricity at 29% CF	$98.61

6.6. Reduced capacity firming costs for intermittent generation

Intermittent renewable resources typically have low firm capacity values, and as the penetration of these resources increases the system must be augmented by firm capacity resources to maintain grid reliability. WISP will increase the diversity of resources on the transmission grid, enabling a reduction in peak capacity and operational reserves for Western Interconnection. For this benefit, E3 assumed that WISP would reduce the peak capacity of the Western Interconnection by either 1 percent or 2 percent, and reduce its annual ancillary service operating costs by either 1 percent or 2 percent.

With these reductions in peak capacity and operating reserves due to WISP, E3 estimates the savings delivered by WISP to range from $307 million to $631 million over 40 years

(*Table 6-11*). To estimate this benefit, E3 calculated the reduction in peak capacity and operational reserves costs as follows:

1) Calculate the 2020 peak load for the Western Interconnection using E3's WEIL model (*Table 6-12*).
2) Assume WISP will cause a 1 percent reduction in the need for peak capacity.
3) Assume peak capacity would be met by combustion turbines (CT) and multiply 1 percent of peak capacity by the CT cost to get the savings from reduced capacity in the first year (*Table 6-13*). Repeat for the 2 percent case.
4) Assume WISP will reduce the need for peak capacity by 1 percent of the growth each year thereafter and calculate CT savings the same as in Step 4. Repeat for 2 percent case.
5) Net present value the savings of avoided peak capacity.
6) Calculate the need for regulation, spin, and non-spin reserves according to *Table 6-13*.
7) Calculate the cost for ancillary services in the Western Interconnection by multiplying each service by its corresponding price and percentage of peak load (*Table 6-14*).
8) Assume WISP will reduce total WECC ancillary services costs by 1 percent. Repeat for 2 percent case.
9) Net present value the savings of avoided operational reserves.

Table 6-11: Results for Capacity and Operating Savings

Capacity and Operating Savings due to WISP (2008$)		
	1% Savings	*2% Savings*
Peak Capacity Savings	$171,752,926	$343,505,852
Operating Savings	$135,982,143	$288,480,116
Total Savings	$307,735,069	$631,985,968

Table 6-12: Load Assumptions

WECC Load Assumptions (2020)	
Peak Load (MW)	199,770
Load Factor	65%
Low Growth Rate (post-2020)	1%
High Growth Rate (post-2020)	2%

Table 6-13: CT Costs

Ancillary Service Assumptions for WECC		
	Requirement as a Percentage of Peak Load	*Price ($/MWh)*
Regulation	2%	$30
Spin	2.50%	$8
Non-Spin	2.50%	$4

Table 6-14: Ancillary Service Assumptions

Cost of a CT ($/kW-yr)	
Capital Cost	$162
Energy Margin	($50)
Resource Adequacy Payment	($28)
Net CT Capacity Value	$84

6.7. Major Data Collection Targets

WISP has identified four major benefits. To quantify these benefits over time, WISP will collect the following data:

- Total load in the WECC footprint covered by the synchrophasor system
- Number of disturbances and large-scale outages
- Level of total load in the service territories covered by the enhanced EMS System
- Congestion costs in the WECC footprint
- Level of penetration of renewable resources in the WECC footprint
- Equipment failure rate in the service territories covered by the PMU system
- Reported protection system operations in the WECC footprint
- Transmission system losses
- Congestion costs in the WECC footprint
- Number of staff-hours to find faults

Appendix 1: NERC LETTER OF SUPPORT

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Robert W. Cummings
Director of Event Analysis &
Information Exchange

August 5, 2009

Ms. Vickie VanZandt
WECC Synchro-Phasor Project Manager
One Park Place
7600 NE 41st Street, Suite 201
Vancouver, WA 98662

RE: NERC Support for the WECC Synchro-Phasor Project

Dear Ms. VanZandt,

I am writing this afternoon to affirm NERC's full support of the Synchro-Phasor Project proposed by the Western Electric Coordinating Council (WECC). The proposal to install phasor measurement units (PMUs), phasor data concentrators (PDCs), and super data concentrators (Super PDCs) to provide real-time, high-speed power system data to system operators will represent a significant step forward in real-time grid visualization and control across the Western United States and Canada.

NERC has committed to the furtherance of synchro-phasor technology throughout North America, partnering with the U.S. Department of Energy and the electric industry in the North American Synchro-Phasor Initiative (NASPI). The WECC proposal is in concert with that initiative and is fully within the North American countries' national interests.

WECC has long led North America in the application of synchro-phasor technologies, using them for analysis of system disturbances and validation of generation models for dynamic analysis. As a result of that extensive work, the inherent oscillatory behavior of the Western Interconnection is well understood. This project will substantially enhance reliability by setting the stage for extension of that knowledge to operational situational awareness and real-time controls on a wide-area basis. The project will also further enhance the region's ability to analyze system disturbances, validate system dynamic models, and ultimately lead to a better understanding of the dynamic behavior of the electric system.

This interconnection-wide project will significantly further the goal of providing reliable power in the Western United States and enhance the capability to intelligently integrate renewable resources and meet the challenges of understanding system behavior as smart grid technologies are adopted. NERC urges the funding of this project to ensure the reliability of the bulk power system in North America.

Sincerely,

Robert W. Cummings
Director of Event Analysis
and Information Exchange

CC: Mr. Rick Sergel, President and CEO, NERC
Mr. John Q. Anderson, Chairman, NERC
Ms. Louise McCarren, CEO, WECC
Mr. David G. Areghini, Chairman, WECC

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Appendix 2: RESUMES REDACTED IN PUBLIC POSTING