PROJECT MANAGEMENT PLAN

Energy and Water in the Western and Texas Interconnects

October 15, 2010

WORK PERFORMED UNDER AGREEMENT

RC-BM-2010

SUBMITTED BY

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1. Executive Summary

This project is in response to the Research Call to DOE/Federal Laboratories for "Technical Support for Interconnection-Level Electric Infrastructure Planning, RC-BM-2010" Area of Interest 3: Water/Energy Nexus. According to the stated needs of the Research Call, three overarching objects are identified:

1. Develop an integrated Energy-Water Decision Support System (EWDSS) that will enable planners in the Western and Texas Interconnections to analyze the potential implications of water stress for transmission and resource planning.
2. Pursue the formulation and development of the Energy-Water DSS through a strongly collaborative process between members of this proposal team and the Western Electricity Coordinating Council (WECC), Western Governors' Association (WGA), the Electric Reliability Council of Texas (ERCOT) and their associated stakeholder teams.
3. Exercise the Energy-Water DSS to investigate water stress implications of the transmission planning scenarios put forward by WECC, WGA, and ERCOT.

The lead laboratory for this project is Sandia National Laboratories (Sandia) supported by other national laboratories, a university, and an industrial research institute. Specific participants include Argonne National Laboratory (Argonne), Idaho National Laboratory (INL), the National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory (PNNL), the University of Texas (UT), and the Electric Power Research Institute (EPRI). Each institution brings a rich portfolio of experience with respect to water, energy, and the environment.

Beyond efforts toward project management and reporting, the project is organized according to eight project tasks focused on the development of the EWDSS. The initial foundation for this tool is Sandia National Laboratories (Sandia) Energy-Power-Water Simulation (EPWSim) model. This existing framework provides an interactive environment for exploring trade-offs, and "best" alternatives among a broad list of energy/water options and objectives. The framework currently supports prototype modules for calculating thermoelectric power demand and related water use; water demand from competing use sectors; surface and groundwater availability, and; an energy for water calculator. Each of these modules will be updated and expanded, while additional process modules will be added.

Development of the DSS will be conducted in close cooperation with WECC, WGA, ERCOT and their stakeholder teams. To enhance transparency and consensus a Collaborative Modeling Team (CMT) will be assembled to oversee development of the EWDSS. Team membership will include a subgroup of our interconnection partners. The CMT will meet on a periodic basis with our project modelers to define: 1) key metrics and decision variable for inclusion in the EWDSS; 2) vet process models; 3) vet data, water use factors, etc; 4) jointly review the models and conduct calibration analyses; and 5) conduct desired scenario analyses.

The first module of the EWDSS calculates water withdrawals and consumption for current and projected thermoelectric power generation. Input to the model are WECC and ERCOT's transmission planning results. Water demands are calculated according to power plant capacity, production, type of plant, type of cooling, and type of emissions control. Accompanying parasitic energy loads imposed by emission controls and water-conserving cooling technologies are also calculated. Using information on population growth, Gross State Product and historical water use trends, future water demands are calculated for competing water use sectors (municipal, industrial, agriculture, mining and livestock). The source of the withdrawal (surface water, groundwater, or non-potable water) is tracked as well as the return flows.

The DSS is also fitted with a water availability model that provides a regional measure of water supply for surface water, groundwater, and non-potable resources. The model has two principle components, “wet” and “paper” water. Wet water provides a measure of the physical water available in a basin for use, while paper water addresses the institutional controls (policies) that define access to the water. The model combines historical gauge data and other information to project surface and groundwater availability.

The water demand and availability modules are accompanied by additional process models to further resolve water availability. The first of these is an environmental controls model for identification and assessment of potential environmental risks associated with growing water use. A climate change calculator is included for estimating potential changes in water availability. This will include two components – a climate downscaling model to provide future climate forcing data for the watershed model and a dynamic large-scale watershed model to project related changes to water availability. Beyond the scarcity of water, information concerning the potential cost of water for a new withdrawal is calculated including water rights purchase, value of goods and their water intensity, and cost of treating non-potable water. Finally, an energy for water calculator is included to calculate electricity demand to pump, convey, treat (both primary and waste water), and distribute water.

The EWDSS is fitted with an interface that serves as the “dashboard” controlling scenario makeup, simulation operations, and the rendering of results. This dashboard provides an interactive, real-time environment comprised of slider bars, buttons and switches for changing key input variables, and real-time output graphs, tables, and geospatial maps for displaying results. The EWDSS operates on a laptop computer taking only few seconds to accomplish a simulation. The EWDSS can be distributed to users on CD or via download from the internet.

A key deliverable from this project is an integrated Energy-Water DSS that will enable planners in the Western and Texas Interconnections to analyze the potential implications of water stress for transmission and resource planning. Working with WECC, WGA, and ERCOT and utilizing this Energy-Water DSS a wide range of transmission planning scenarios will be simulated and evaluated.

While timely accomplishment of these tasks is important and necessary, we are striving for broader impact. Currently there are no long-range, interconnection-wide transmission plans for the Western and Texas Interconnections. Consequently, the ability to assess how various infrastructure options balance reliability, cost, and the environment from an interconnection-wide perspective does not exist. This project coordinated with the efforts of WECC, WGA, ERCOT and their partners will create a comprehensive package of stakeholder-vetted, regional planning models, data, and conclusions that are coordinated at the interconnection-wide level. Cumulatively, this information will substantially improve the quality and quantity of information available to industry planners, state and federal policymakers and regulators. Specifically, this project will supplement interconnection-wide transmission planning studies with information on water availability, which is critical in shaping electricity generation options.

This proposed project represents the first comprehensive, regional analysis of the energy-water nexus. This is also the first coordinated analysis undertaken by federal and state agencies, the power industry, NGOs and other interested stakeholders. In this way, the data, models, scenario analyses, and insights derived from this effort will provide a significantly improved body of evidence for policy making at local, state and federal levels.

2. Risk Management

Risk is inherent to all projects, which if realized has the potential to impact the success of the project. In efforts to mitigate such risk a set of procedures and processes has been adopted to control all aspects pertaining to the development and application of the EWDSS. These processes and procedures follow commonly accepted approaches, such as those given in The Project Management Institute's A Guide to the Project Management Book of Knowledge. Processes and procedures specific to the EWDSS project are specified in Quality Assurance Program Description (QAPD) appended to this document (Appendix A). Accompanying the QAPD is an Intellectual Property Management Plan that addresses potential issues concerning treatment of intellectual property brought to this project as well as intellectual property developed as part of this project (Appendix B).

3. Milestone Log

The following are key project milestones. The milestones are organized according to their planned completion date. A full description of each activity is given in the appended Scope of Work (SOW). Note that the current list only includes the first phase of activities (5 of 11 tasks). This list will be expanded to include the other tasks once the SOWs have been vetted and approved by all project participants.

Title: ARRA Reporting
Planned Date: Beginning July 2010 with monthly reports through duration of project
Verification Method: Submitted financial and status reports

Title: Complete Project Scope of Work (SOW): Phase I
Planned Date: September 3, 2010
Verification Method: Submitted SOW

Title: Complete Project Management Plan (PMP)
Planned Date: October 15, 2010
Verification Method: Submitted PMP

Title: Establish project website
Planned Date: November 1, 2010
Verification Method: Operable website

Title: Establish CMT
Planned Date: November 1, 2010
Verification Method: First CMT meeting

Title: Develop initial water withdrawal/consumption factors and parasitic energy use factors.
Planned Date: December 1, 2010
Verification Method: Publish data table

Title: Complete Project Scope of Work (SOW): Phase II
Planned Date: December 15, 2010
Verification Method: Submitted SOW

Title: Develop initial water withdrawal/consumption factors and parasitic energy use factors in Texas
Planned Date: December 23, 2010
Verification Method: Publish data table

Title: Integrate CCS module into the EPWSim model.
Planned Date: January 7, 2011
Verification Method: Functional model module operating in decision support system

Title: Water institutions tool: Phase I
Planned Date: April 1, 2011
Verification Method: Draft water institutions module operating within decision support system

Title: Plant level estimates of water withdrawal/consumption in Texas
Planned Date: April 1, 2011
Verification Method: Publish data table

Title: Develop water use needs for CCS for plants in Texas
Planned Date: April 1, 2011
Verification Method: Publish data table

Title: Biofuel-EPWSim model integration.
Planned Date: May 2, 2011
Verification Method: Functional model module operating in decision support system

Title: Plant level estimates of water withdrawal/consumption
Planned Date: June 1, 2011
Verification Method: Publish data table

Title: Link saline sinks to the CCS module
Planned Date: June 1, 2011
Verification Method: Functional model module operating in decision support system

Title: Integrate groundwater data available from Federal sources into EPWSim
Planned Date: June 1, 2011
Verification Method: New groundwater metrics integrated in decision support system

Title: Integrate non-potable source data beyond that collected by EPRI into EPWSIM
Planned Date: June 1, 2011

Verification Method: Publish data table

Title: Collect non-potable source data for Texas (wastewater, produced water and saline groundwater)
Planned Date: June 1, 2011
Verification Method: Publish data table

Title: Integrate water use/consumption data for energy extraction into EPWSim
Planned Date: September 1, 2011
Verification Method: Functional model module operating in decision support system

Title: Update surface water supply metrics for Texas
Planned Date: September 30, 2011
Verification Method: Publish data table

Title: Complete pilot water supply metrics study with 3-4 western states
Planned Date: September 30, 2011
Verification Method: Publish data table

Title: Hourly water use calculator
Planned Date: November 30, 2011
Verification Method: Functional model module

Title: Integrate the non-potable source data into EPWSim
Planned Date: March 1, 2012
Verification Method: Functional non-potable water supply module

Title: Water institutions tool: Phase II
Planned Date: April 2, 2012
Verification Method: 2nd draft water institutions module operating within decision support system

Title: Climate change and policy implications in the West
Planned Date: March 1, 2012
Verification Method: Publish data table

Title: Water institutions tool in Texas
Planned Date: April 3, 2012
Verification Method: Publish data table

Title: Hourly water use calculator
Planned Date: April 2, 2012
Verification Method: Functional model module

Title: Parasitic energy requirements for cooling systems

Planned Date: May 1, 2012
Verification Method: Publish data table

Title: Update EPWSim water demand model with data from Texas
Planned Date: May 1, 2012
Verification Method: Publish data table

Title: ERCOT Training
Planned Date: May 11, 2012
Verification Method: Training accomplished

Title: Geographic and climate specific water requirements for energy crops
Planned Date: June 1, 2012
Verification Method: Publish data table

Title: Geographic locations for energy crops
Planned Date: June 1, 2012
Verification Method: Publish data table

Title: Estimate water use for energy crops in Texas
Planned Date: June 1, 2012
Verification Method: Publish data table

Title: Integrate water use/consumption data for gas shale extraction into EPWSim
Planned Date: June 1, 2012
Verification Method: Publish data table

Title: Integrate groundwater data available from state sources into EPWSim
Planned Date: July 17, 2012
Verification Method: Publish data table

Title: ERCOT Scenario analysis
Planned Date: Delivery dates to be defined by partners through August 1, 2012
Verification Method: Deliver scenario results to interconnection partners

Title: Update EPWSim water demand model with state provided data and additional data from the USGS surveys
Planned Date: November 30, 2012
Verification Method: Functional water demand module

Title: Update surface water supply metrics
Planned Date: November 30, 2012
Verification Method: Functional water supply module

Title: Water institutions tool: Final
Planned Date: April 1, 2013
Verification Method: Final water institutions module operating within decision support system

Title: WECC Training
Planned Date: May 13, 2013
Verification Method: Training accomplished

Title: Update CCS and carbon sink model with state specific data
Planned Date: July 31, 2013
Verification Method: Publish data table

Title: Integrate the VHP into EPWSim
Planned Date: July 31, 2013
Verification Method: VHP operating within the decision support system

Title: Maintain project website
Planned Date: Beginning in October 2010 and running to end of project
Verification Method: Up to date website

Title: WECC Scenario analysis
Planned Date: Delivery dates to be defined by partners through December 24, 2013
Verification Method: Deliver scenario results to interconnection partners

4. Funding and Costing Profile

Given below is the funding and cost profile for the project. Table 1 gives the project funding profile by participant. Table 2 gives the monthly project spending plan. Budget projections by task are given in the appended Scope of Work (SOW). Note that the current list only includes the first phase of activities (5 of 11 tasks). These profiles will be expanded to include the other tasks once the SOWs have been vetted and approved by all project participants.

5. Project Timeline

Given below is the project timeline broken down by each task and subtask. Figure 1 provides this information as a Gantt chart. Note that the current list only includes the first phase of activities (5 of 11 tasks). The timeline will be expanded to include the other tasks once the SOWs have been vetted and approved by all project participants.

Table 1 - Project Funding Profile

	Budget Period 1		Budget Period 2		Budget Period 3		Total	
	Government Funding	Cost Share	Government Funding	Cost Share	Government Funding	Cost Share	Government Funding	Cost Share
Prime Applicant - Sandia National Laboratories (SNL)	$ 523	$ -	$ 469	$ -	$ 280	$ -	$ 1,272	$ -
Team Member 1 - Argonne National Laboratory (ANL)	$ 30	$ -	$ 15	$ -	$ 15	$ -	$ 60	$ -
Team Member 2 - Idaho National Laboratory (IDL)	$ 105	$ -	$ 120	$ -	$ 85	$ -	$ 310	$ -
Team Member 3 - National Renewable Energy Laboratory (NREL)	$ 145	$ -	$ 120	$ -	$ 15	$ -	$ 280	$ -
Team Member 4 - Pacific Northwest National Laboratory (PNNL)	$ 15	$ -	$ 15	$ -	$ 15	$ -	$ 45	$ -
Team Member 5 - Electric Power Research Institute (EPRI)	$ 35	$ -	$ 69	$ -	$ 15	$ -	$ 119	$ -
Team Member 6 - University of Texas at Austin (UT)	$ 110	$ -	$ 106	$ -	$ 8	$ -	$ 225	$ -
TOTAL ($s in thousands)	**$ 963**	**$ -**	**$ 914**	**$ -**	**$ 433**	**$ -**	**$ 2,311**	**$ -**
Cost Share %		**0.00%**		**0.00%**		**0.00%**		**0.00%**

Table 2 - Project Spending Plans

Table 2.1 - Project Spending Plan BP1

BP1 - October 2010 - September 2011	
October	$ 80
November	$ 80
December	$ 80
January	$ 80
February	$ 80
March	$ 80
April	$ 80
May	$ 80
June	$ 80
July	$ 80
August	$ 80
September	$ 80
Total ($k in thousands)	**$ 963**

Table 2.2 - Project Spending Plan BP2

BP2 - October 2011 - September 2012	
October	$ 76
November	$ 76
December	$ 76
January	$ 76
February	$ 76
March	$ 76
April	$ 76
May	$ 76
June	$ 76
July	$ 76
August	$ 76
September	$ 76
Total ($k in thousands)	**$ 914**

Table 2.3 - Project Spending Plan BP3

BP3 - October 2012 - September 2013	
October	$ 36
November	$ 36
December	$ 36
January	$ 36
February	$ 36
March	$ 36
April	$ 36
May	$ 36
June	$ 36
July	$ 36
August	$ 36
September	$ 36
Total ($k in thousands)	**$ 433**

Figure 1. Project Timeline

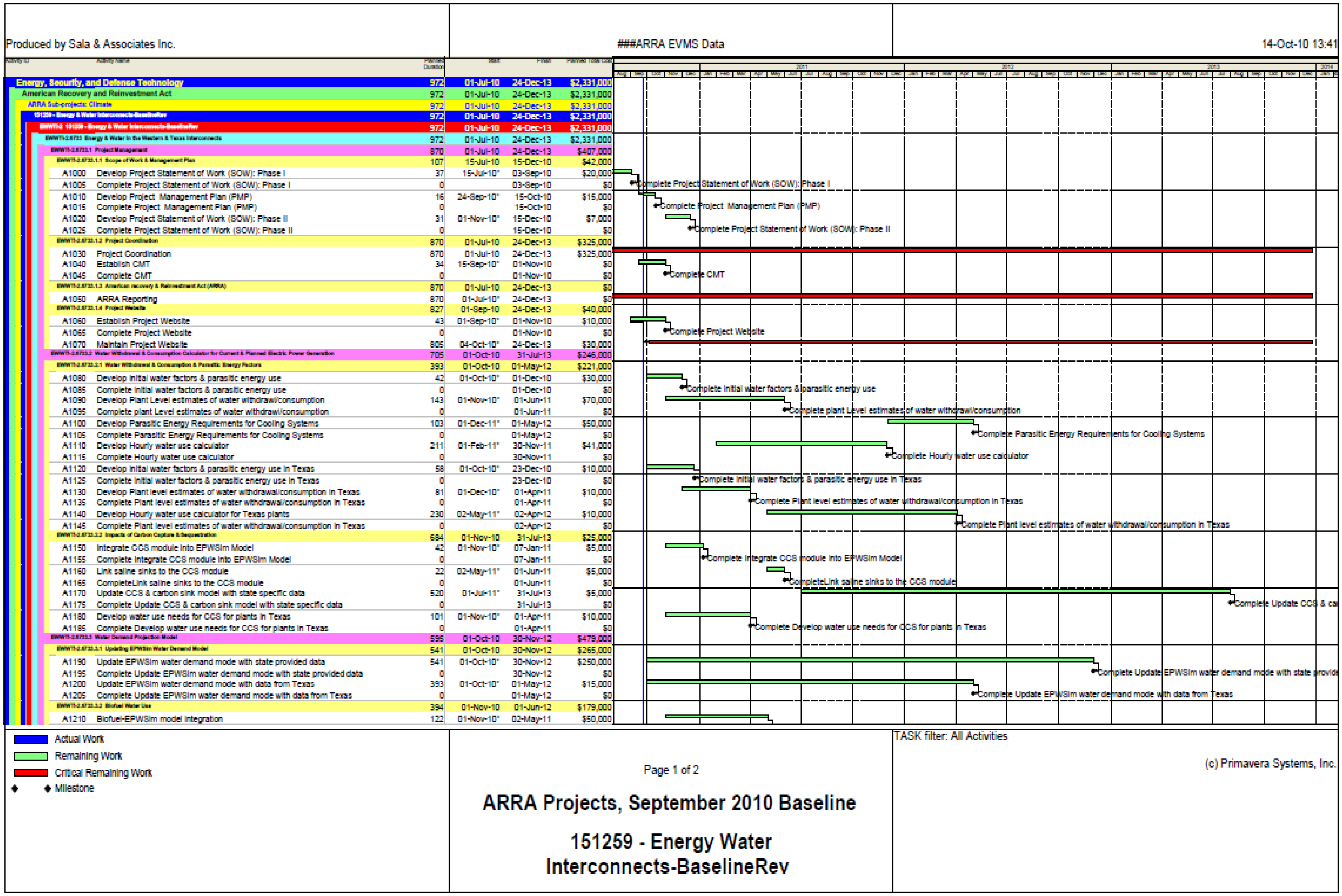
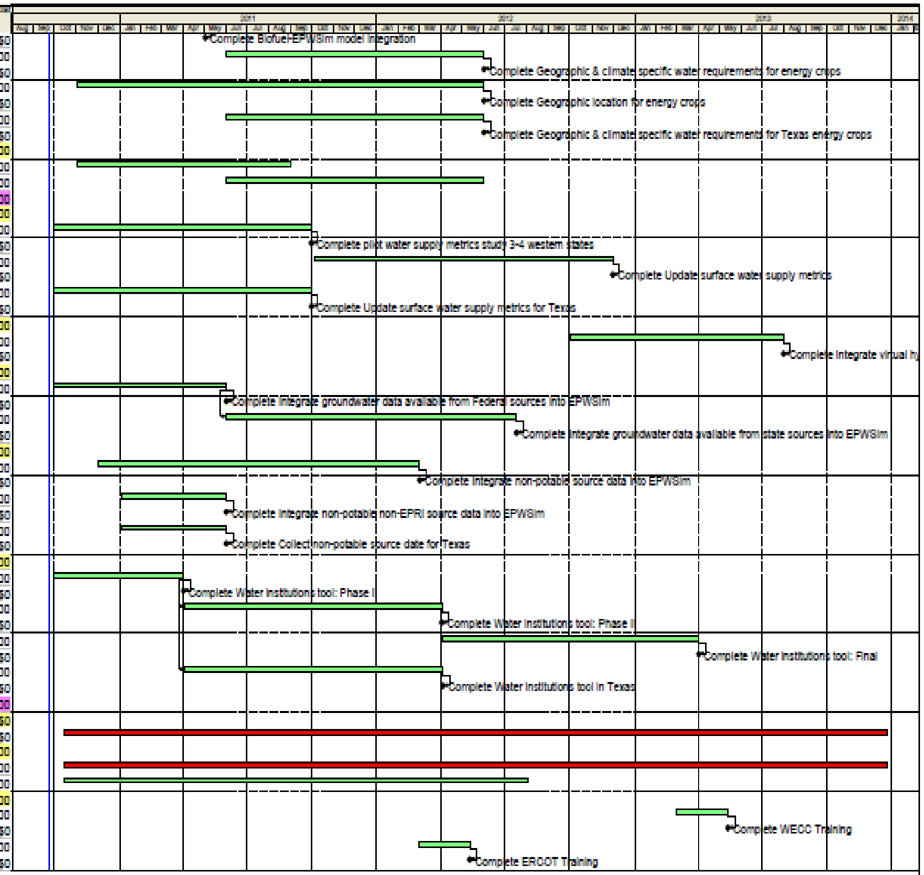


Figure 1. Project Timeline

Activity ID	Activity Name	Planned Duration	Start	Finish	Planned Total Cost
A1215	Complete Biofuel-EPWSim model integration	0		02-May-11	$0
A1220	Geographic & climate specific water requirements for energy crops	252	01-Jun-11*	01-Jun-12	$44,000
A1225	Complete Geographic & climate specific water requirements for energy crops	0		01-Jun-12	$0
A1230	Geographic location for energy crops	394	01-Nov-10*	01-Jun-12	$65,000
A1235	Complete Geographic location for energy crops	0		01-Jun-12	$0
A1240	Geographic & climate specific water requirements for Texas energy crops	252	01-Jun-11*	01-Jun-12	$20,000
A1245	Complete Geographic & climate specific water requirements for Texas energy crops	0		01-Jun-12	$0
EWWTI-2.8733.3.3 Water Usage for Energy Extraction		428	01-Nov-10	01-Jun-12	$35,000
A1246	Integrate water use/consumption data for energy extraction into EPWSim-Argonne	214	01-Nov-10*	01-Sep-11	$15,000
A1248	Integrate water use/consumption data for gas shale extraction into EPWSim-Texas	281	01-Jun-11*	01-Jun-12	$20,000
EWWTI-2.8733.4 Water Availability Model		705	01-Oct-10	31-Jul-13	$1,044,000
EWWTI-2.8733.4.1 Update EPWSim Water Availability Model		541	01-Oct-10	30-Nov-12	$415,000
A1250	Perform pilot water supply metrics study 3-4 western states	249	01-Oct-10*	30-Sep-11	$250,000
A1252	Complete pilot water supply metrics study 3-4 western states	0		30-Sep-11	$0
A1254	Update surface water supply metrics	291	04-Oct-11*	30-Nov-12	$150,000
A1255	Complete Update surface water supply metrics	0		30-Nov-12	$0
A1260	Update surface water supply metrics for Texas	249	01-Oct-10*	30-Sep-11	$15,000
A1265	Complete Update surface water supply metrics for Texas	0		30-Sep-11	$0
EWWTI-2.8733.4.2 Expand Water Availability Model		207	01-Oct-12	31-Jul-13	$70,000
A1270	Integrate virtual hydropower prospector into EPWSim	207	01-Oct-12*	31-Jul-13	$70,000
A1275	Complete Integrate virtual hydropower prospector into EPWSim	0		31-Jul-13	$0
EWWTI-2.8733.4.3 Expand Groundwater Availability Model		446	01-Oct-10	17-Jul-12	$80,000
A1280	Integrate groundwater data available from Federal sources into EPWSim	164	01-Oct-10*	01-Jun-11	$35,000
A1285	Complete Integrate groundwater data available from Federal sources into EPWSim	0		01-Jun-11	$0
A1290	Integrate groundwater data available from state sources into EPWSim	282	02-Jun-11	17-Jul-12	$45,000
A1295	Complete Integrate groundwater data available from state sources into EPWSim	0		17-Jul-12	$0
EWWTI-2.8733.4.4 Non-Potable Resources		309	01-Dec-10	01-Mar-12	$114,000
A1300	Integrate non-potable source data into EPWSim	309	01-Dec-10*	01-Mar-12	$74,000
A1305	Complete Integrate non-potable source data into EPWSim	0		01-Mar-12	$0
A1310	Integrate non-potable non-EPRI source data into EPWSim	105	04-Jan-11*	01-Jun-11	$20,000
A1315	Complete Integrate non-potable non-EPRI source data into EPWSim	0		01-Jun-11	$0
A1320	Collect non-potable source date for Texas	105	04-Jan-11*	01-Jun-11	$20,000
A1325	Complete Collect non-potable source date for Texas	0		01-Jun-11	$0
EWWTI-2.8733.4.5 Water Institutions Tool		620	01-Oct-10	01-Apr-13	$365,000
A1330	Water Institutions tool: Phase I	122	01-Oct-10*	01-Apr-11	$125,000
A1335	Complete Water Institutions tool: Phase I	0		01-Apr-11	$0
A1340	Water Institutions tool: Phase II	250	04-Apr-11*	02-Apr-12	$125,000
A1345	Complete Water Institutions tool: Phase II	0		02-Apr-12	$0
A1360	Water Institutions tool: Final	248	03-Apr-12*	01-Apr-13	$100,000
A1365	Complete Water Institutions tool: Final	0		01-Apr-13	$0
A1370	Water Institutions tool in Texas	251	04-Apr-11	03-Apr-12	$15,000
A1375	Complete Water Institutions tool in Texas	0		03-Apr-12	$0
EWWTI-2.8733.10 Scenario Analysis		796	15-Oct-10	24-Dec-13	$155,000
EWWTI-2.8733.10.1 Scenario Development		796	15-Oct-10	24-Dec-13	$0
A1380	Provide Scenario development	796	15-Oct-10*	24-Dec-13	$0
EWWTI-2.8733.10.2 Scenario Analysis		796	15-Oct-10	24-Dec-13	$135,000
A1390	Provide WECC Scenario Analysis	796	15-Oct-10*	24-Dec-13	$90,000
A1400	Provide ERCOT Scenario Analysis	447	15-Oct-10*	01-Aug-12	$45,000
EWWTI-2.8733.10.3 Training		301	01-Mar-12	13-May-13	$20,000
A1410	WECC Training	52	01-Mar-13*	13-May-13	$10,000
A1415	Complete WECC Training	0		13-May-13	$0
A1420	ERCOT Training	52	01-Mar-12*	11-May-12	$10,000
A1440	Complete ERCOT Training	0		11-May-12	$0



6. Success Criteria and Decision Points

Two overarching success criteria are established for this project: first, development of an integrated Energy-Water Decision Support System (EWDSS); second, utilization of the EWDSS by WECC and ERCOT planners in interconnection wide transmission planning. Below are described specific and measurable metrics which we will use to evaluate project performance against these success criteria. Additionally, a discussion of the probable advantages and possible disadvantages of these work products is provided.

The first success criteria involves the development of an integrated Energy-Water DSS that will enable planners in the Western and Texas Interconnections to analyze the potential implications of water stress for transmission and resource planning. To achieve this goal the EWDSS must meet several specific criteria. First, the EWDSS must easily interface with the transmission planning models utilized by WECC and ERCOT. Specifically, output from the transmission models, representing various planning scenarios, must form the primary input to the EWDSS. Second, EWDSS results must be sensitive to the configuration and composition of the future electrical power plant fleet. That is, the EWDSS must be able to accurately reflect differences in water withdrawals and consumption across different planning scenarios at the regional and interconnection level. Third, the EWDSS must provide insight into the potential for water stress stemming from new water demands in the thermoelectric sector. Consistent with the specifications in Interest Area 3 of the Research Call, the EWDSS must address such issues as growing water demands in sectors beyond thermoelectric generation; regional water supply for surface water, groundwater, and non-potable sources; institutional controls on new water appropriations; potential environmental controls; climate change impacts; water costs; and, energy for water. Fourth, the EWDSS needs to be accessible to the stakeholders. The EWDSS needs to run as a web server application or operate on a PC, providing an interactive, real-time environment comprised of slider bars, buttons and switches for changing key input variables, and real-time output graphs, tables, and geospatial maps for displaying results.

There are currently no similar tools available for which we can draw technical or economic comparison. For this reason, an advantage of this effort is to develop the first regional model for assessing the nexus between energy and water. Beyond potential impacts of growth in the thermoelectric power sector the EWDSS will also assess potential water demands in other energy sectors including extraction of energy fuels (e.g., coal, gas from gas shales, oil from oil sands) and biofuel production. As the model addresses multiple water demand sectors it has the potential for broad use by other western wide planning projects conducted by WGA, WSWC and others. However, it should be realized that this model will not fully address all energy-water nexus issues. For example, engineering design of the water supply for specific future power plants will require more detailed modeling than will be possible with this tool.

The second success criterion is based on the utilization of the EWDSS in WECC and ERCOT planning efforts. Accomplishment of this goal can be evaluated in a couple of concrete ways. First, scenario evaluation by WECC and ERCOT include water criteria along with other transmission specific criteria in scoring the various options. It is also likely that water stress criteria will enter into scenario evaluation in other qualitative means as well. Second, the EWDSS will generate parasitic energy losses due to cooling technology choices, carbon capture and sequestration regulation, as well as energy demands due to the extraction/treatment/distribution of water. Feedback of this information to WECC and ERCOT transmission planning is an indication of their use of the EWDSS in their scenario planning process.

Currently there are no long-range, interconnection-wide transmission plans for the Western and Texas Interconnections. Consequently, the ability to assess how various infrastructure options balance reliability, cost, and the environment from an interconnection-wide perspective does not exist. This project coordinated with the efforts of WECC, WGA, ERCOT and their partners will create a comprehensive package of stakeholder-vetted, regional planning models, data, and conclusions that are coordinated at the interconnection-wide level. Cumulatively, this information will substantially improve the quality and quantity of information available to industry planners, state and federal policymakers and regulators. Specifically, this project will supplement interconnection-wide transmission planning studies with information on water availability, which is critical in shaping electricity generation options. This is also the first coordinated analysis undertaken by federal and state agencies, the power industry, NGOs and other interested stakeholders. In this way, the data, models, scenario analyses, and insights derived from this effort will provide a significantly improved body of information for policy making on issues pertaining to the energy-water nexus. Ultimately, this coordinated planning effort should result in reduced time and tensions associated with the siting of future power plants. The potential disadvantage of this effort is that transmission planning has not traditionally considered water in a significant manner. As such planners will be challenged in ways they are not accustomed and the consideration of water is likely to complicate the planning process.

7. Agreement Statement of Project Objectives

Attached in Appendix C is the Phase I SOW for the project. Task 1 addresses work necessary to manage the project, prepare project management documents (Phase II SOWs, Project Management Plan), status and budget reporting, and maintaining the project website. The remaining 4 tasks address technical aspects of the project. Note that the current list only includes the first phase of activities (5 of 11 tasks). This list will be expanded to include the other tasks once the SOWs have been vetted and approved by all project participants.

Appendix A: Quality Assurance Plan

1.0 Purpose

This is the Quality Assurance Program Description (QAPD) document for the development and application of the Energy Water Decision Support System (EWDSS) project. The purpose of the QAPD is to describe those Quality Assurance practices to be applied to this effort in order to achieve a sound, systematic approach to Management Assurance and Risk Management.

Key to the successful implementation of this project is the consideration of such items as configuration management, and acceptance of work products. Treatment of intellectual property is described in Attachment B. Specifically, this QAP describes how the EWDSS Project Manager addresses and manages these concerns. Since standard SNL practices will apply to all other activities, detailed elaboration of these topics is not provided in this document.

In addition to the activities described in section 11 of this document DOE Quality Assurance requirements will be met topically, as applicable to the EWDSS effort, through implementation of the matrix of corporate procedures described in Attachment 1 of the corporate QAP. (WFS1043674).

Specifically, this QAPD describes how the EWDSS project team ensures that the outcomes of this project fully meet performance requirements and expectations relative to DOE Order 414.1C, *Quality Assurance*. It is not intended to impose additional procedural or compliance requirements beyond the respective institutional processes of the National Laboratories, EPRI and University of Texas, providing support to the EWDSS project team. The Quality Assurance approach will ensure the development and application of the EWDSS project as follows:

Traceable: Understanding the source and justification of data and other inputs that generate conclusions by means of recorded identification.

Transparent: Documented in sufficient detail as to purpose, method, assumptions, inputs, conclusions, references, and units, such that a person technically qualified in the subject can understand the documents and be able to follow the decision points, logic, calculations, and operations that produced results without recourse to the originator.

Reviewed: Ensuring that technical, quality, and managerial reviews are performed and comments are resolved.

Reproducible: Documenting the development of an analysis or model in sufficient detail such that an individual technically qualified in the subject can produce a comparable analysis without recourse to the originator.

Retrievable: Assuring that all data, models, papers (including informal documents such as white papers and position papers) or other documentary materials, regardless of physical form or characteristics, created by the EWDSS project Team is available through the SNL SharePoint site and external website.

2.0 Statement of Applicability

The document applies to all Members of Workforce participating in the performance, directly or indirectly, of the Research Call to DOE/Federal Laboratories for “Technical Support for Interconnection-Level Electric Infrastructure Planning, RC-BM-2010” Area of Interest 3: Water/Energy Nexus. Requirements of the QAP are also applicable to Sandia's subcontractors and project partners, to the extent that they flow down in the contract(s) or project Statement(s) of Work. The Manager (or a delegated representative) of Department 06926, must approve requests for exceptions to, or exemptions from, any of the requirements of this QAP.

3.0 Graded Approach

All aspects of lifecycle project performance have been considered by the Manager of Department 06926. With the additional controls described in section 11 of this document, the application of standard SNL procedures and practices results in adequate mitigation of inherent project risks. The grading approach used in arriving at this conclusion is described in CG100.6.1, *Manage Risks*, and is documented in section 12 of this QAP.

4.0 Organization

Role	Project Responsibility
Program Area Director	ME100.4.1, *Engage the Customer during "Perform Work" activities*
06350 Senior Manager	Risk Management and customer relations; Baseline Change Proposal review and approval
06926 Manager	Work Planning and Controls; Project Manager selection and performance management; identification and provision of job, function, organization and required contractor training; monthly Management Assurance review and determine grading approach.
Project Manager	Project managers have responsibility and accountability for managing projects, including processes to: • Initiate new projects. • Ensure proper funding of projects. • Structure projects to provide useful reporting information. • Ensure that projects have accurate and current information. • Close a project when the project is completed • Implement and maintain configuration control of project performance documents • Sandia Delegated Representative role
Procurement (Sandia Contracting Representative)	Also called the Buyer, the SCR is the procurement professional who acts to fulfill the Requester's requirement. Often working in consultation with the Requester, the SCR obtains quotations, negotiates and awards contracts, and administers contracts after awards have been made. Contractor requests for changes to approved contract performance schedules and milestones must be approved by the SCR.
Center Office Business Support	Cost estimating, Baseline Change Control, fulfillment of prime contract reporting requirements, FIN100.2.PLAN.6 *Manage Project Resources*
SNL Tech Staff	Requirements Definition, Sandia Delegated Representative for contractor interface, receipt and acceptance of goods and services on behalf of SNL.

5.0 Training

SBS701, *Preparing for Contract Placement for Requestors,* is required for requesters and Sandia delegated representatives. The Department 06926 Manager will determine whether the course should be added to the training matrix of additional personnel. Training assignments and status monitoring are accomplished in accordance with corporate training processes. Sandia's partners are highly qualified staff, with substantial expertise and institutional training requirements. The following courses will be assigned initially to the training folder of the Project Manager. Upon completion of the training, the Project Manager and Department Manager will consider the benefits of assigning such training to other team members.

- SQE120, *Self-Assessment Instrument for Software Quality Project Team Training*, provides an overview of the Self-assessment Instrument for Sandia's Provide Quality Software corporate procedure (IM100.3.5).
- SQE301, *Software Quality Practice Workshop – Project Management*, is designed to introduce DOE Order 414.1C and Sandia Software Quality Assurance Plan (SSQAP) principles to software development project team members.

6.0 Quality Improvement

Quality improvement is an ongoing, continuous process. Formal and/or informal assessments and feedback are used to prevent quality problems and verify conformance.

7.0 Documents and Records

Procedures specific to the EWDSS project are not required. Consistent with IM100.2.2, *Control of Records*, project documents and records, including email, will be stored in the designated SharePoint site according to the file structure established by the Project Manager. Project personnel have Add/Edit privileges, and do not have Delete privileges. Non-project personnel have View privileges only. Project documents and records are stored under version control to assure that a change log (when a change was made, who made it, what was changed) exists. Immediate email notification is provided to the Project Manager and Department Manager when a configuration item (QAP, Project Plan, Project Baseline, or Derived Project Requirements) is revised. If the change was incorrect, the Project Manager or Department Manager will authorize the Site Administrator (Full Control privileges) to revert to the prior document version.

8.0 Work Processes

Scientific and technical analyses and reviews, and modeling/simulation activities, are conducted in accordance with the established practices of each respective participant's institution. The scope and documentation detail is commensurate with the complexity and importance of the work, the skills required to perform the work, the consequences of quality problems in the product, or process.

Line management and workers cooperate to identify processes that can be improved based on feedback prior to and following implementation of the work process.

Management solicits input from workers in the development of work processes and communicates an expectation of worker accountability for quality in the performance of work.

9.0 Design

There are no specific design processes applicable to this effort.

10.0 Procurement

There are no specific Procurement or Logistics processes applicable to this effort.

11.0 Inspection and Acceptance Testing

Each National Laboratory, the University of Texas and EPRI, in support of this effort utilizes highly skilled and experienced scientific and technical personnel for the conduct of its efforts.

- Internal institutional processes are used to identify qualified personnel.
- Commensurate with risk, internal institutional peer review processes are utilized to verify the accuracy, completeness and reliability of the data/results and will be documented in project SharePoint site including objective evidence of the peer review.
- The SOWs fix the requirements for each phase of the project and participant.
- Data deliverables shall include data sources and limitations with associated documentation.
- Model development shall follow best practices guidelines to ensure model transparency considering the level of confidence appropriate for the models intended use. Software configuration management is required, fixing each version of the model and documenting the changes and date made to each subsequent version.
- Sandia National Laboratories is explicitly responsible for managing task assignments and deliverable acceptance.
- Deliverables to Sandia shall include a transmittal letter or email attesting to having followed institutional work process in the execution of the deliverable.
- Derive defined requirements with partners. Negotiate acceptance criteria with partners based upon the defined requirements.

12.0 Management Assessment

Relative to CG100.6.1 *Manage Risks*, the following determination applies to the EWDSS project.

Risk Category	Mission Execution, Loss of Customer, public confidence

Likelihood	Medium
Consequence	High o Adverse impact on Sandia's programmatic performance or the achievement of corporate strategic or operational objectives o Adverse public opinion – moderate interest, limited PR problems of short duration (days)
Inherent Risk Level	High (Likelihood * Consequence)
Residual Risk Level	Low: Adverse public opinion with short-term local negative publicity or embarrassment
Risk Control	Project Performance Baseline Change Control.
Performance Measures	Performance milestones will be individually identified and tracked in the corporate project management system.

Periodic project performance reviews (ME100.3.2 *Manage Projects Throughout Their Lifecycle*, Monitor/Control activity) occur as part of Sandia's normal Management Assurance processes. Project performance reviews are tentatively scheduled monthly at the Department Manager and Center Director levels, and quarterly at the SMU program level. Such reviews serve as partial input to the Management Assurance Review process documented in CG100.6.16 *Conduct Management Reviews*.

13.0 Independent Assessment

Independent assessments of ARRA activities are conducted by both internal and external organizations and agencies. The extent and frequency of these assessments are based upon risk, results of previous assessments, and contractual requirements. The Manager of Department 06926 is responsible for insuring that corrective actions are taken on all observations and findings and for keeping the Senior Manager (06350) and Center Director (06900) informed of the results of all assessment

Appendix B: Intellectual Property Management Plan

September 20, 2010

Introduction

The principal goals of this intellectual property (IP) management plan for the Technical Support for Interconnection-Level Electric Infrastructure Planning: Water/Energy Nexus include:

- Develop an integrated Energy-Water Decision Support System (EWDSS) that will enable planners in the Western and Texas Interconnections to analyze the potential implications of water stress for transmission and resource planning;
- Pursue the formulation and development of the EWDSS through a strongly collaborative process between members of this proposal team and the Western Electricity Coordinating Council (WECC), Western Governors' Association (WGA), the Electric Reliability Council of Texas (ERCOT) and their associated stakeholder teams, and
- Exercise the EWDSS to investigate water stress implications of the transmission planning scenarios put forward by WECC, WGA, and ERCOT.

EWDSS members include national laboratories, a university, and an industrial research institute.

Definitions

1. "EWDSS" means the funding for EWDSS awarded by DOE to SNL under Contract No. DE-ACO4-94AL85000.
2. "EWDSS Invention" means an invention conceived or first actually reduced to practice under EWDSS Funding.
3. "EWDSS IP" means EWDSS Inventions, mask works, trademarks and copyrighted works that arise under EWDSS Funding.
4. "Government" means the Federal Government of the United States.
5. "Integrated EWDSS IP" means the bundle of EWDSS IP developed under the EWDSS Program. Each contributor's IP piece is solely owned and the integrated IP bundle will be jointly owned but maintained and controlled by SNL.
6. "Discloser" means a EWDSS member who discloses Proprietary Information.
7. "Recipient" refers to the party or parties receiving Proprietary Information.
8. "Non-commercial license" refers to any license that does not in some sense involve commerce or does not have a commercial objective or emphasis.

Information Sharing

It is the intention of the EWDSS that the fruits of its research be widely and promptly disseminated, with a goal of maximizing the impact of the research and its long-term benefit to the U.S. and to society. Even in those situations in which protection of EWDSS IP is desirable, e.g., to induce further commercial development, or is required under specific funding obligations, such IP is also expected to be widely and promptly disseminated for the public good.

Conflict of Interest

EWDSS team members will have safeguards in place to manage personal and organizational conflicts of interest that may arise from the licensing of EWDSS IP.

Ownership of Inventions

The following statutes governing disposition of title to new inventions under agreements of the U.S. Department of Energy ("DOE") and its contractors will apply to inventions made under DOE Funding:

a) The Bayh-Dole Act, 35 U.S.C. 200 et seq., requires that universities, non-profits and small businesses who are participating under a funding agreement (as defined in the Bayh-Dole Act) will have the option to retain title to their own employees' inventions.

b) The Federal Non Nuclear Energy Research and Development Act of 1974, 42 U.S.C. 5908, will govern disposition of title for all other parties, regardless of whether they receive Government funding, and it requires that the Government obtains title to new inventions unless a waiver is granted.

c) Inventions made by employees of ANL, INL, NREL, PNNL and Sandia will be subject to the Management and Operating (M&O) contract terms and conditions with respect to ownership of inventions made by laboratory employees. The M&O contract generally provides that the laboratory has the right to elect to retain title to inventions made by their laboratory employees.

d) The Copyright Act (17 USC 200 et. Seq.) vests ownership of works to the author of those works. Ownership to works authored or co-authored by employees, contractors, faculty, and/or students of the parties to this MOU vests in the authoring entity.

Protection of EWDSS IP

Each EWDSS member will protect its EWDSS IP according to its standard practices and is responsible for the costs of any domestic and foreign protection that it chooses to pursue at its sole discretion. DOE will have the right to protect EWDSS IP if the owner institution does not wish to do so and may to allow other EWDSS members to protect the EWDSS IP in appropriate situations.

Each EWDSS member shall abide by the export control laws and regulations of the United States Department of Commerce and other United States' governmental agencies relating to the export of technology. Failure to obtain an export control license or other authority from the government may result in criminal liability under U.S. laws.

When a EWDSS member discloses Proprietary Information, that Proprietary Information shall be protected in accordance with the terms of this Agreement by the Recipient of that Proprietary Information. Recipient shall not disclose Proprietary Information to any third party without the prior written approval of the Discloser. Recipient shall limit access to Proprietary Information to such of its employees and contractors who are obligated to treat the same as proprietary and in the same manner and equivalent extent as provided herein with regard to confidentiality and nondisclosure. Recipient shall not remove the proprietary marking from any of the Discloser's Proprietary Information.

IP Management

SNL Tech Transfer will provide a simplified means for industry to negotiate licenses to the Integrated EWDSS IP and other agreements that may be required in support of the EWDSS Program (e.g., CRADA, WFO, bailment, option) by centralizing these activities with SNL.

Other activities with third parties relating to access to EWDSS IP (e.g., NDAs, Material Transfer Agreements, etc.) will be coordinated through SNL Tech Transfer.

Licensing of DOE IP

EWDSS (through SNL) will have the sole authority to license the integrated EWDSS IP. Each EWDSS member is granted a non-exclusive license for its own use, without the right to sublicense, in the integrated EWDSS IP.

Each EWDSS member has the authority to license the EWDSS IP that it creates in accordance with that EWDSS member's own policies and is granted a non-exclusive license for its own use, without the right to sublicense, in all EWDSS IP created by the other EWDSS members. Each EWDSS member also grants to EWDSS (SNL) a nonexclusive license, with the right to sublicense, in each EWDSS member's EWDSS IP.

If a EWDSS member contributes pre-existing IP for the benefit of EWDSS, such IP remains owned by the contributing member and the contributing member has no obligation to license such IP to EWDSS or any of the EWDSS members. Non-commercial licenses can be distributed to Federal, State, local, or regional government or not-for-profit entities at no cost.

Credible business plans shall be required for all commercial licensing of EWDSS IP, which will be on a non-exclusive basis. Before executing any license agreement for a field of use, the licensing member institution will evaluate the capabilities of the potential commercial licensee, and the company must demonstrate that it has the expertise and capital needed to further the development of the technology and successfully bring the technology to market in the field(s) of use in which a license would be granted. EWDSS IP will be licensed to companies only in the fields of use (FOU) in which the company is capable and committed to bringing the technology to market, saving other FOUs for additional licensees.

Licensing Revenue Allocations

Each EWDSS member institution that is an owner of EWDSS IP included in the integrated EWDSS IP licensed by SNL is entitled to a percentage of any royalties or other income from such licenses. Licensing income from each such license will be distributed annually as follows ("EWDSS Distribution"):

a) A standard 15% administrative fee will go to SNL to offset the cost of license administration;

b) Next, licensing income is used to reimburse EWDSS IP owners for patent expenses if their patent expenses exceed any patent reimbursement fees negotiated into the license, and received from licensee by SNL. All of license income after the above expenses will be distributed to each EWDSS IP owner in accordance with a formula agreed to by a majority of the EWDSS Commercialization Council.

For the licenses to the integrated EWDSS IP, licensing income includes fees (such as license issue fees, license maintenance or milestone fees), and royalties, but does not include reimbursement of negotiated patent fees.

Reporting to DOE

Each member institution shall report its inventions to DOE in accordance with the prime contract. In addition, each member institution shall disclose promptly to DOE, through SNL Tech Transfer, all EWDSS inventions, software, and tangible research products resulting from EWDSS Funding.

Acceptance:

Member Institution: ___________________________________

By: _________________________________

Name: _______________________________

Title: _________________________________

Date: _________________________________

SANDIA CORPORATION:

____

Harold S. Morgan

Senior Manager, Industrial Partnerships and Strategy

Date: ______________________________

Appendix C: Phase I Scopes of Work

Task 1: Project Management

PURPOSE: Appropriate attention to project management is paramount to project success. This task addresses necessary efforts toward project coordination, communication, contracting, and resource tracking.

BENEFIT TO INTERCONNECTION PLANNING: This task is necessary to maintain strong communication and coordination between members of the project team, DOE, and our interconnection partners. Significant efforts are planned in working with our interconnection partners to direct construction of the decision support system, propose the data that populates the system, and to participate and direct the accompanying analysis.

TASK BUDGET: $407K
Note that indirect costs charged by each institution cover basic overhead elements such as office space, utilities, security, upper management, taxes and a variety of other general operational expenses that support the institution as a whole. Cost elements reported here support project management including, planning, communication, and coordination activities that pertain directly to this project; that is, the labor expended by our project participants on tasks that generally benefit the entire project (i.e., conference calls, meetings, preparing planning documents).

Subtask 1.1: Scope of Work and Management Plan.
PROPOSED WORK: The first activity will include the preparation of a project Scope of Work and Project Management Plan according to the instructions in Attachments A and B, respectively of the RFP. The approach to project management will follow the basic principles set forth in the Project Managements Institute's "A Guide to the Project Management Book of Knowledge." In assembling the Project Management Plan we will work with our project partners to address issues of intellectual property, quality assurance, configuration management, etc. to facilitate communication and coordination of efforts throughout the duration of the project. Another key element on the PMP will be a clear process of review and acceptance for the products developed through this project.

Deliverable 1.1.1: Complete Project Scope of Work (SOW): Phase I
Responsible Partner: Sandia National Laboratories
Start Date July 12, 2010
End Date: September 3, 2010
Budget: $20K

Deliverable 1.1.2: Complete Project Management Plan (PMP)
Responsible Partner: Sandia National Laboratories
Start Date: September 1, 2010
End Date: October 15, 2010
Budget: $15K

Deliverable 1.1.3: Complete Project Scope of Work (SOW): Phase II
Responsible Partner: Sandia National Laboratories
Start Date: November 1, 2010
End Date: December 15, 2010
Budget: $7K

BENEFIT TO INTERCONNECTION PLANNING: Documents developed under this subtask will clearly define the work to be accomplished, deliverables, tasks, budget and the manner in which the work will be done. These documents will also provide a basis for scheduling work activities and coordinating deliverables with the needs of the Interconnection planning process.

Subtask 1.2: Project Coordination.
PROPOSED WORK: Vincent Tidwell of Sandia will serve as overall Contact Principal Investigator/Project Coordinator for research under this proposal; however, multiple principal investigators (PIs) will collaborate to plan and conduct the proposed research. This collaboration will include Argonne PI John Gasper, EPRI PI Robert Goldstein, NREL PI Jordan Macknick, INL PI Gerald Sehlke, PNNL PI Mark Wigmosta and UT PI Michael Webber. Project Coordinator and PI responsibilities include directing, coordinating and conducting research for specific projects under this proposal, jointly reporting to the DOE program manager (frequency and manner of reporting to be set by DOE), and assuring administrative requirements are met. Project coordination across this team will be pursued through periodic (at a minimum monthly) web conferences among all project participants augmented by periodic face-to-face meetings. The WGA, WECC, and ERCOT will be apprised of project team coordination and engaged as appropriate in project team meetings. In addition, the project team will ensure communication with project partners through active representation at pertinent DOE, WECC, WGA, ERCOT, and stakeholder meetings. Coordination between this project team and DOE project management will be handled through periodic face-to-face meetings and conference calls as required by DOE.

To enhance project coordination a Collaborative Modeling Team (CMT) will be assembled to oversee development of the Energy Water DSS. Team membership will involve a self-selection process of participants from the WECC, WGA, and ERCOT planning teams. The CMT may also include willing experts from other organizations as appropriate. The CMT will meet on a periodic basis with our project modelers to define: 1) key metrics and decision variables for inclusion in the DSS; 2) vet process models; 3) vet data, water use factors, etc; 4) jointly review the models and conduct calibration analyses; and 5) conduct desired scenario analyses. Meetings will largely be handled through web conferencing with occasional face-to-face meetings coordinated with other project events. Sandia has significant experience in developing models within the context of a CMT, which improves model transparency and consensus in the model and the results rendered.[1-5]

Sandia and the project team will also coordinate with WGA, WECC, and ERCOT in any public outreach, stakeholder engagement, or board review and approval as necessary for those organizations. For instance, WGA must ensure that work products and reports are approved by its 'Staff Council', the representatives of 19 member governors who serve as the board for WGA. WGA is planning broader stakeholder engagement, including from the electricity industry, water management community, and non-governmental organizations in this project. Sandia and the project team will participate in these efforts as appropriate.

Assumptions concerning the level of effort toward project coordination are as follows. Each project participant is expected to attend two 2-hour conference calls a month (on average) and attend one 2-day face-to-face meeting each year. University of Texas expenses are lower because of their lower overhead rate. In addition the Sandia Principal Investigator will attend two additional 2-day meetings a year.

Deliverable 1.2.1: Project Coordination
Responsible Partner: All partners will participate in project meetings, planning exercises, etc. This activity will proceed throughout the full duration of the project.
Start Date: July 1, 2010
End Date: December 24, 2013
Budget:

Partner	Sandia	Argonne	EPRI	NREL	INL	PNNL	UT
$/yr	25K	15K	15K	15K	15K	15K	8.3K

Deliverable 1.2.2: Establish CMT
Responsible Partner: Sandia National Laboratories
Start Date: September 15, 2010
End Date: November 1, 2010
Budget: Captured in Project Coordination budget

BENEFIT TO INTERCONNECTION PLANNING: This subtask supports efforts toward broad communication and technical project coordination across all participants. The CMT provides an opportunity for WECC, WGA, WSWC, and ERCOT staff to participate in model development and scenario testing with the purpose of enhancing transparency and dialogue.

Subtask 1.3: American Recovery and Reinvestment Act (ARRA) *Reporting*

PROPOSED WORK: Sandia acknowledges the modification of its prime contract to incorporate ARRA-specific requirements, specifically:

- DOE Clause H-999, *Special Provisions Relating to Work Funded under the American Recovery and Reinvestment Act of 2009* (APR 2009)
- DOE Clause B-9999, *American Recovery and Reinvestment Act Work Values*
- FAR 52.203-15, *Whistleblower Protections under the American Recovery and Reinvestment Act of 2009* (MAR 2009)
- FAR 52.204-11, *American Recovery and Reinvestment Act – Reporting Requirements* (MAR 2009)
- FAR 52.215-2, *Audit and Records – Negotiation* (Alt I) (MAR 2009)
- FAR 52.225-21, *Required Use of American Iron, Steel, and Manufactured Goods – Buy American Act – Construction Materials* (MAR 2009).

In addition to the foregoing requirements, Sandia receives periodic ARRA reporting guidance updates from the DOE, posted at http://www.energy.gov/recovery/ARRA_Reporting_Requirements.htm. Monthly reporting is filed by Sandia using Recipient DUNS Number 007113228. Sandia will be responsible for ARRA reporting except in terms of financials, which will be the responsibility of each project participant under separate contract to DOE.

Deliverable 1.3.1:	ARRA Reporting
Responsible Partner:	All laboratory partners and EPRI will be responsible for reporting financials directly to DOE. UT will be reported through Sandia. As the Lead Laboratory, SNL will report overall project status. This activity will proceed throughout the full duration of the project.
Start Date:	Monthly reporting beginning July 2010.
End Date:	December 24, 2013
Budget:	Budget for activity is captured in laboratory overhead.

BENEFIT TO INTERCONNECTION PLANNING: This reporting is a Federal requirement.

Subtask 1.4: Project Website.

PROPOSED WORK: A project website will be developed and maintained throughout the duration of the project. The website will serve as an internal file share and configuration management for project partners as well as a port for external communication. The internal file share will be password protected providing a place where participants can share documents and models subject to configuration managed protocols. The external public website will include a description of the effort, contact personnel, approved scopes of work, project status, presentations, and documents completed under the project. This external site will be linked to

DOE Office of Electricity's interconnection –wide planning website as well as our interconnection partner's websites.

Deliverable 1.4.1: Establish project website
Responsible Partner: Sandia National Laboratories
Start Date: September 1, 2010
End Date: Operable on November 1, 2010
Budget: $10K

Deliverable 1.4.1: Maintain project website
Responsible Partner: Sandia National Laboratories
Start Date: October 4, 2010
End Date: December 24, 2013
Budget: $30K

BENEFIT TO INTERCONNECTION PLANNING: The website will provide a convenient medium for exchanging data and information across all project partners. The external website will communicate project efforts and results to those outside the planning team.

References

1. Tidwell, V.C. and Cors van den Brink, 2008, *Cooperative modeling: Linking science, communication and ground water planning, Ground Water*, 46(2), 174-182.
2. Cockerill, K.C., V.C. Tidwell, H. Passell, and L. Malczynski, 2007, Collaborative Modeling Lessons for Environmental Management, *Environmental Practice*, 9(1), 28-41.
3. Cockerill, K.C., H. Passell, and V.C. Tidwell, V.C., April 2006, *Cooperative modeling: Building bridges between science and the public*, *Journal of American Water Resources Association*, 457-471.
4. Tidwell, V.C., H.D. Passell, S.H. Conrad, and R.P. Thomas, System dynamics modeling for community-based water planning: An application to the Middle Rio Grande, *Journal of Aquatic Sciences*, 66,357-372, 2004.
5. Cockerill, Kristan, Vincent Tidwell, and Howard Passell. Assessing Public Perceptions of Computer-Based Models. *Environmental Management*, 34(5): 609-619, 2004.

Task 2: Water Withdrawal and Consumption Calculator for Current and Planned Electric Power Generation

PURPOSE: The purpose of this model is to calculate water withdrawal and consumption at the power plant level across the Western and Texas Interconnections. Input to the water use calculator will be the output of WECC's and ERCOT's transmission planning models; specifically, the transmission planning models will define the full operational characteristics of both existing and future power plants, including capacity, production, type of plant, type of cooling, and type of emissions controls. The hourly level data from the transmission planning models along with local climate information will be used by this calculator to determine the hourly water withdrawal and consumption as well as parasitic energy demands imposed by emission controls and water-conserving cooling technologies. While the hourly power plant-level data will be available for use, calculator output will also be aggregated to an appropriate spatial and temporal resolution for use in the Energy Water Decision Support System (EWDSS). Calculated parasitic energy loads will be passed back to WECC and ERCOT for use in their transmission modeling as necessary.

Ultimately, each of the deliverables developed under this task will be integrated with deliverables from all other project tasks into a EWDSS. The DSS will be fitted with an interface that allows one to combine information from the various models to explore the wide range of dimensions important to the Energy-Water nexus. Output from the EWDSS will form the basis for the interconnection wide planning.

BENEFIT TO INTERCONNECTION PLANNING: This calculator will simulate hourly water withdrawal and consumption for current and planned electric power generation (according to individual plants) based on the scenarios developed by WECC and ERCOT. These analyses will consider both potential impacts of carbon capture and sequestration and use of alternative power plant cooling strategies. In particular, parasitic energy loss due to CCS and implementation of hybrid or dry cooling technologies will be estimated and use of this data coordinated through WECC and ERCOT. Ultimately, future thermoelectric water use scenarios can be compared in terms of total water withdrawal and consumption. Additionally, these estimates can be compared against other water use demands and water availability metrics to assess suitability of different locations for siting of new power plants.

TASK BUDGET: $246K

Subtask 2.1: Water Withdrawal and Consumption and Parasitic Energy Factors.
CURRENT STATE OF KNOWLEDGE: To date there have been a number of efforts to estimate and consolidate water withdrawal and water consumption factors based on boiler type and cooling technology for both renewable and conventional technologies.[1,2,3] Some efforts base reported numbers on estimated national averages, others use data from specific utilities, and others use a combination of both. None of these reports, however, provide data comprehensive enough to account for all the potential technologies to be deployed in the study region. Still, various studies have utilized these existing factors to estimate water withdrawals and consumption at a regional level across the US assuming various future power generation scenarios.[4-6] These modeling frameworks, however, are highly aggregated (10-13 regions on a

national scale), and are not directly applicable to specific planning processes and analyses. Planning activities require technology- and climate-specific water use factors, which as of yet have not been developed for the study region. Power plant-specific data are required to adequately assess regional water impacts, which are very localized by nature. To date, no comprehensive power-plant specific data are available for the study region. The National Energy Technology Laboratory (NETL) has developed a database of coal facilities in the U.S. that reports water usage in the year 2005.[7] This previous work on coal facilities will be leveraged in the current project, yet further research is required to incorporate other technologies.

NEED: Currently there are no comprehensive water usage estimates for the electricity sector on a power plant-specific scale, nor are there hourly estimates of these facilities' water use. Hourly power plant-specific data, however, is required to accurately project water demands as well as grid functioning in a transmission planning process.

PROPOSED WORK: This subtask supports the development of a model to calculate water withdrawal and consumption at the *power plant level*. Estimates will leverage work identifying the water use requirements of power plants for a variety of fuel types, generation technologies, and cooling types, which is more comprehensive and process-detailed than existing research.[6,8-10] Both emerging and mature technologies will be considered. The primary focus of this effort will be to develop water use factors associated with individual power plant specifications that are projected to be built.[11] Further refinement of water use factors will be needed to address the variation in power plant efficiencies associated with differences in microclimates (e.g., elevation, temperature, humidity). Once plant-specific factors have been developed, hourly estimates of water consumption and withdrawal can be calculated through integration with the appropriate parameters of the transmission planning models.

Working through the CMT, efforts will be made to vet the calculated water demands for existing power plants with data available from state water managers and utility operators. Such analysis at a power plant level has not been accomplished to date.

Another factor affecting power plant efficiencies relates to the cooling system employed. Dry cooling and hybrid cooling systems can be used to mitigate water requirements, but can impose additional energy requirements.[12-13] The focus of this particular activity will be to identify and evaluate these parasitic energy requirements and associated reduced efficiencies related to choice of cooling technology. This effort will leverage existing work on renewables being conducted by NREL and will also require collaboration with the National Energy Technology Laboratory (NETL) and other institutions to develop parasitic requirements for conventional technologies.[14]

Ultimately the water withdrawal/consumption factors along with parasitic energy losses will be consolidated according to fuel type, power plant technology (e.g. Rankine cycle, Brayton cycle or combined cycle, etc.), and cooling technology, then integrated into the decision support system to estimate water demands for the electric sector with spatial and temporal resolution. NREL will lead the effort to collect and integrate data from the Western Interconnection region while the University of Texas will lead efforts within the ERCOT region. Efforts between NREL and the University of Texas will be coordinated and data shared as appropriate.

Deliverable 2.1.1:	Develop initial water withdrawal/consumption factors and parasitic energy use factors.
Responsible Partner:	NREL
Start date:	October 1, 2010
End date:	December 1, 2010
Budget:	$30K

Deliverable 2.1.2:	Plant level estimates of water withdrawal/consumption
Responsible Partner:	NREL
Start date:	November 1, 2010
End date:	June 1, 2011
Budget:	$70K
Deliverable 2.1.3:	Hourly water use calculator
Responsible Partner:	NREL
Start date:	February 1, 2011
End date:	November 30, 2011
Budget:	$41K

Deliverable 2.1.4:	Parasitic energy requirements for cooling systems
Responsible Partner:	NREL (with NETL)
Start date:	December 1, 2011
End date:	May 1, 2012
Budget:	$50K

Deliverable 2.1.5:	Develop initial water withdrawal/consumption factors and parasitic energy use factors in Texas
Responsible Partner:	UT
Start Date:	October 1, 2010
End Date:	December 23, 2010
Budget:	$10K

Deliverable 2.1.6:	Plant level estimates of water withdrawal/consumption in Texas
Responsible Partner:	UT
Start Date:	December 1, 2010
End Date:	April 1, 2011
Budget:	$10K

Deliverable 2.1.7:	Hourly water use calculator
Responsible Partner:	UT
Start Date:	May 2, 2011
Schedule:	April 2, 2012
Budget:	$10K

BENEFIT TO INTERCONNECTION PLANNING: Accurate electric sector water withdrawal and consumption factors, on a plant-specific basis and available in hourly intervals, are an integral component of energy-water planning. These water use factors, and associated plant efficiencies, can vary significantly according to climatic conditions and cooling technologies employed. This effort will provide the most comprehensive assessment to date of plant-specific water use factors to the interconnection planners.

Subtask 2.2: Impacts of Carbon Capture and Sequestration.
CURRENT STATE OF KNOWLEDGE: The most detailed analysis of Carbon Capture and Sequestration (CCS) and its effects on water withdrawal and consumption was performed by the National Energy Technology Laboratory (NETL).[14-15] These analyses use a 1st order approach derived from a prior NETL study of the cost and performance impacts associated with CCS technologies on power plants.[16] Water consumption and withdrawal factors, gallons used per energy generated on a net generation basis, from the detailed study were developed for subcritical, supercritical and Integrated Gasification Combined Cycle (IGCC) plants. Carbon capture technologies require auxiliary power also termed "parasitic" load, which lowers the net exported power. This analysis assumed that all new additions include carbon capture technologies and that these new builds will meet the required capacity by accounting for their own parasitic load. Additionally, the existing plants that will be retrofitted with carbon capture technologies are de-rated due to the parasitic load. These studies looked at three possible scenarios to account for this capacity loss. These analyses were performed on a 13-NERC regional basis (including 3 WECC subregions) spanning the entire US. Analyses were based on spreadsheet calculations on 5-year increments out to 2030.

Currently there is a joint effort between Sandia, NETL and DOE Office of Policy and International Affairs (OPIA) to build upon and expand these previous efforts. A key aspect of this collaborative project is estimation of CCS impacts at the power plant level (rather than regional), thus providing a much more accurate depiction of potential increased water demands. Specifically, efforts are being made to identify which plants are likely to be retrofitted for CCS under different carbon capture policies, which plants are likely to close, and which might operate without capture (subject to different potential emissions policies). Water withdrawal and consumption factors as well as parasitic energy loss factors will be updated with the best and most up-to-date data available.

Sandia working with NETL have investigated the potential of deep saline formations as sinks for captured carbon.[17-18] This analysis is working to link specific plants likely to employ CCS with deep saline aquifers. This effort also estimates the volume of saline water to be produced and potential costs of treating the water for various potable uses. The UT team has also created a model to estimate grid-wide carbon emissions, parasitic losses, and dispatch effects of CCS in ERCOT,[19] and will build on that model to include water use as well.

NEED: The need here is simply to integrate this existing work into the EPWSim model (see Task 3 for a description of this model). We also expect that new data and or state-specific information are likely to arise during the course of this work, in which case we will make the necessary improvements to the model.

PROPOSED WORK: There are three basic tasks associated with this effort. First, the joint Sandia, NETL, OPIA model will be integrated into EPWSim. Second, the Sandia-NETL saline sinks model will be integrated. Finally, updates to the CCS and saline sinks model will be made as new data or state-specific data become available. Sandia will lead the effort to collect and integrate data from the western Interconnection region while the University of Texas will lead efforts within the ERCOT region.

Deliverable 2.2.1:	Integrate CCS module into the EPWSim model.
Responsible Partner:	Sandia National Laboratories
Start Date:	November 1, 2010
End Date:	January 7, 2011
Budget:	$5K

Deliverable 2.2.2:	Link saline sinks to the CCS module
Responsible Partner:	Sandia National Laboratories
Start Date:	May 2, 2011
End Date:	June 1, 2011
Budget:	$5K

Deliverable 2.2.3:	Update CCS and carbon sink model with state specific data
Responsible Partner:	Sandia National Laboratories
Start Date:	July 1, 2011
End Date:	July 31, 2013
Budget:	$5K

Deliverable 2.2.4:	Develop water use needs for CCS for plants in Texas
Responsible Partner:	UT
Start Date:	November 1, 2010
End Date:	April 1, 2011
Budget:	$10K

BENEFIT TO INTERCONNECTION PLANNING: Carbon capture and sequestration has the potential to impose significant increases in water withdrawal and consumption in the thermoelectric industry. Both direct and indirect (through parasitic energy losses) impacts must be considered for meaningful energy-water planning. This set of activities will provide the best available estimates of CCS water use to the interconnection planners.

References

1. DOE (U.S. Department of Energy). 2008. *Report to Congress: concentrating solar power commercial application study: reducing water consumption of concentrating solar power electricity generation.* Provides a summary of water use estimates for CSP technology configurations.
2. DOE (U.S. Department of Energy). 2006. *Report to Congress: Energy demands on water resources.* Provides generic water use estimates fossil and renewable generation technologies.

3. Fthenakis V. and Kim H. C. 2006. *Life Cycle uses of water in U.S. electricity generation*,. Renewable and Sustainable Energy Reviews, 14(7),2039-2048. Provides estimates from previous studies of water use in fossil and renewable generation technologies.
4. Feeley, T.J., T.J. Skone, G.J. Stiegel, A McNemar, M. Nemeth, B. Schimmoller, J.T. Murphy, L. Manfredo, 2007, *Water: A critical resource in the thermoelectric power industry*. Energy, doi: 10.1016/j.energy.2007.08.007. Provides estimates of water use/consumption for fossil based electricity generation.
5. Ongoing project: Jordan Macknick at NREL is managing a project in conjunction with Brookhaven National Laboratory, funded through the DOE Office of Policy and International Affairs, to incorporate water consumption and withdrawal values into the MARKAL model. The MARKAL model has a geographic scope of ten regions and a limited number of electricity generating technologies. Data developed under the scope of this existing work will be leveraged and expanded upon for this project.
6. C. W. King, M. E. Webber and I. J. Duncan, “Water Demand Projections for Power Generation in Texas,” prepared for the Texas Water Development Board, September 2008. http://www.twdb.state.tx.us/wrpi/data/socio/est/Final_pwr.pdf
7. NETL 2007a. 2007 Coal Plant Database. Accessed online: http://www.netl.doe.gov/energy-analyses/hold/technology.html
8. Ongoing project: Jordan Macknick at NREL is managing a project in conjunction with Argonne National Laboratory, funded through the DOE Office of Policy and International Affairs, to understand the regional climatic differences in concentrating solar power (CSP) plant efficiencies and water use requirements. Geographic specific data developed under the scope of this work will be leveraged for this project.
9. Ongoing project: Craig Turchi at NREL is managing a project to identify the parasitic energy requirements of CSP technologies under various climatic conditions. This work will be leveraged and expanded to include other technologies, in conjunction with NETL, for the purposes of this project.
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11. M.E. Webber, D.T. Allen, K. Ferland, C.W. King, G.T. McGaughey, S.J. Goldman, Y. Kimura, “A Clean Energy Plan for Texas,” prepared for the Texas Commission on Environmental Quality, August 2008.
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18. Ciferno, J., 2009, Use *of Non-Traditional Water for Power Plant Applications: An Overview of DOE/NETL R&D Efforts*. DOE/NETL-311/040609, November.
19. S.M. Cohen, G.T. Rochelle and M.E. Webber, "Turning CO2 Capture On & Off In Response To Electric Grid Demand in Texas: A Baseline Analysis Of Emissions And Economics," *ASME Journal of Energy Resources Technology*, Vol.132, Iss.2, May 17, 2010. DOI: 10.1115/1.4001573, URL: http://link.aip.org/link/?JRG/132/021003

Task 3: Water Demand Projection Model

PURPOSE: The water demand projection model provides a basis for estimating future water demand for sectors competing with electric power generation. These estimates are calculated at the interconnection, state, county and watershed levels.

Ultimately, each of the deliverables developed under this task will be integrated with deliverables from all other project tasks into an Energy-Water Decision Support System (EWDSS). The DSS will be fitted with an interface that allows one to combine information from the various models to explore the multiple dimensions of the Energy-Water nexus. Output from the EWDSS will inform interconnection wide planning.

BENEFIT TO INTERCONNECTION PLANNING: Future expansion of the electric power industry will have to compete with other use sectors for limited water resources. Siting of future power plants requires a clear understanding of available water resources. Future availability of such resources will depend on many factors. One of these factors is the growing demand for water in other use sectors. This task will develop interconnection wide coverages of current and projected future water demands for the municipal, industrial, agricultural, livestock, and mining sectors. We will consider in detail potential expanded water demands by fuel extraction (e.g., oil shales, gas shales) and biofuels. Estimates will be made at the interconnection, state, county and watershed levels. Through the EWDSS this data can be combined with other data coverages (e.g., water supply) to evaluate the suitability of various locations for power plant siting.

TASK BUDGET: $479K

Subtask 3.1: Updating the EPWSim Water Demand Model.
CURRENT STATE OF KNOWLEDGE: Water demand modeling is typically included as an integral part of water resource or water operations modeling; specifically, tools that assist in scheduling water demands based on water availability and institutional rules (as we will do in this project, see Task 4). These water resource models vary greatly by source (surface water, groundwater, watershed), physical fidelity, spatial scale, and time step. Some of the more common tools include MODFLOW[1] (groundwater modeling), Riverware[2] (river routing and reservoir operations), HEC platform of tools[3] (the Corps of Engineers toolset for river and watershed management), WEAP[4] (systems based water planning tool) and GAMs[5] (surface water planning and optimization). These and similar modeling systems have been used by local, state and federal entities to model various water supply/demand issues for many of the major river systems in the West. For example, the State of Texas has developed GAMs models for each river basin and MODFLOW models for each aquifer system in the state to assist with regional water planning.[6]

The objective of this project is to assist with interconnection wide planning, which encompasses the entire western US. It is not feasible over these scales to integrate the existing water resource models with differing assumptions, spatial/temporal scales, and software architectures. Additionally there are basins in the West that currently lack any detailed management models.

Fortunately there are several studies that have been conducted to date in which water demand projections have been developed over broad spatial scales, namely the entire United States. [7-16] The studies by Sovacool[14-16] were the only to place particular emphasis on implications of water use by the thermoelectric power sector. These efforts have the advantage that water demand projections are estimated in a consistent manner and for all regions within the US. In these studies water demands are estimated from the national level down to the county level and are divided across several different water use sectors. Each demand projection is underpinned by the water use data collected by the USGS.[17-19] These water demand projections are based largely on historical trends; for example, future municipal use is projected as a combination of current per capita water use and the projected future population.

EPWSim is a model that was developed to explore the nexus between water supply, water demand, and thermoelectric power generation across the entire US. [20] The water demand model within EPWSim follows a very similar approach and utilizes the same set of data as do the studies noted above. Specifically, water demand in EPWSim is individually calculated according to five different use sectors: municipal (including domestic, public supply, and commercial), industrial, agriculture, mining and livestock (thermoelectric water demands are calculated under Task 2). Water use and consumption are tracked separately as are the resulting return flows. Also modeled is the source of the withdrawal, which can be surface water, groundwater, or a non-potable source.

Water use statistics published by the U.S. Geological Survey (USGS) serve as the primary data source for the EPWSim analyses.[17-19] Every five years since 1950 the nation’s water-use data have been compiled and published by the USGS; however, the level of detail at which these data are reported varies from year to year. Data from the 1985, 1990, and 1995 campaigns provide the most comprehensive picture of water use in the U.S., and hence form the basis of this analysis (2000 data lack same level of detail and lack consumptive use estimates, thus are only used in a supporting role for our analysis. The data from 2005 were reported after this model was assembled). Specifically, the 1995 data provide the initial conditions, while all three data sets are used to estimate trends in water use rates. These rates are further modified by changes in population and economic activity (as measured by gross state product) where quantifiable correlations exist. In this way water use projections are a function of population change, economic growth and trends in historical water use rates (i.e., reflecting changing use/conservation practices). Historical trends alone are used to project the source mix (e.g., groundwater vs. surface water) for future water withdrawals.

Demands are calculated as daily averages. Calculations are made at the county level but can be aggregated to the watershed, county, state, or interconnection level. The user can accept the default growth rates and/or source of diversion in the model or specify their own.

NEED: Currently there are no “off the shelf” tools for modeling water demands at the scale of the western US. EPWSim provides an existing framework for modeling water demands that is consistent with that utilized in the previously noted water demand studies. Additionally, EPWSim can easily be integrated with other water resource modules (e.g., thermoelectric demand as in Task 2, biofuels water demand as noted below, water supply Task 4 and water institutional rules Task 4). The key limitation of EPWSim is that the water demand model is based on data collected by the USGS. Given that each state has ongoing efforts toward state/basin wide water planning they will prefer their data be used in our energy-water planning exercises. As such, there is significant opportunity to update water demand projections using the state-specific data.

PROPOSED WORK: Through interactions with the Western States Water Council (WSWC), which is comprised of water managers from each western state, we will gain access to each state’s water data and reports. This information will be used to update and develop alternative growth scenarios of future water demand. Additionally, we will work to update the initial conditions in the model to reflect that recently published in the 2005 USGS Water Use Report (augmented with state input) and ongoing efforts by the USGS relative to their National Water Census.[21] We will also review the U.S. Corps of Engineers’ (COE’s) recently-completed, state-by-state assessment of integrated water supply planning. Throughout this process we will also work to broadly vet the water demand model with the cooperative modeling team and as needed with stakeholders convened by WSWC, WECC, WGA, and ERCOT.

In developing the water demand and availability models for the energy demand and support system, it is proposed that Sandia National Laboratories begin with three or four western states as part of a pilot project to extract information from their water plans regarding water use and supply projections. The purpose of this pilot effort will be to better understand the types of information available in various state’s water plans, to determine the level of effort necessary to extract the information from the plans, and determine how best to vet the resulting supply and demand models with respective state water managers. Based on the results of the pilot study a framework will be developed that can then be extended to the remaining western states. Ideally, the selected states would be actively engaged in the project and would have water plans that serve as a representative sample of the various water plans found throughout the western states. An effort should also be made to consider those states where the connection between energy and water is significant.

One possible way to select states to participate in the project is for the Western States Water Council to survey its member states to determine the extent of their willingness and ability to participate in the pilot project. Such a survey could also generate information on the structure and organization of each state's water plans. In appropriate cases, Sandia may be able to alleviate the financial and human resource needs that states may experience if they participate in the project by performing the bulk of the information extraction. In such cases, states will need to appoint a contact person to provide guidance and assistance as needed.
Sandia will lead the effort to collect and integrate data from the Western Interconnection region while the University of Texas will lead efforts within the ERCOT region. The Western States Water Council includes governor-appointed water managers from all of the states in the Western interconnection as well as Texas; as a result, the Council is well-positioned to provide a seamless perspective on the project approach to water demands. As noted above, a water demand model at the county level currently exists for the entire WECC and ERCOT regions. As such, water demand projections will be available for planning efforts at the beginning of the project. However, these estimates will be changing and improving over the course of the project.

Sandia will ensure that the updated EPWSim model is approved by WGA and the Western States Water Council before delivering a final product.

Deliverable 3.1.1:	Update EPWSim water demand model with state provided data and additional data from the USGS surveys
Responsible Partner:	Sandia National Laboratories
Start Date:	October 1, 2010
End Date:	November 30, 2012
Budget:	$250K

Deliverable 3.1.1:	Update EPWSim water demand model with data from Texas
Responsible Partner:	UT
Start Date:	October 1, 2010
End Date:	May 1, 2012
Budget:	$15K

BENEFIT TO INTERCONNECTION PLANNING: Performing this work will provide the most up-to-date projections on water demands for municipal, industrial, mining, livestock, and agricultural purposes. It is necessary to understand how future demands in these other sectors will compete with growing thermoelectric water use demands. By working directly with each state we will improve project transparency and consensus in project results.

Subtask 3.2: Biofuel Water Use.

CURRENT STATE OF KNOWLEDGE: The National Academies of Science[22] were the first to take a comprehensive look at the nexus between water and biofuels. While the report provides a solid overview of the issues, there are a couple of important deficiencies. First, the report is not the product of a quantitative analysis; rather, findings are based on broad general trends. Second, the report is largely focused at the national level with limited reference made to regional details (with such regions representing the aggregate over 5-10 states). Finally, the report ignores water requirements associated with biofuel processing.

Using a basic water balance approach Argonne[23] examined the growing issue of water use in energy production by characterizing current consumptive water use in liquid fuel production. Water requirements are evaluated for five fuel pathways: bioethanol from corn, ethanol from cellulosic feedstocks, gasoline from Canadian oil sands, Saudi Arabian crude, and U.S. conventional crude from onshore wells. The analysis was applied on a regional basis according to 10 USDA farm-production regions.

Higher resolution studies have been conducted looking at the potential to use roadway buffer strips, brownfield sites, and marginal agricultural land to produce feedstock.[24] Additionally considered was the use of degraded water for irrigation. This study was limited to the State of Nebraska.

The GAO recently performed an overview of the potential for biofuel water use.[25] Based on interviews with experts they report that the extent to which increased biofuels production will affect the nation's water resources depends on the type of feedstock selected and how and where it is grown. The use of certain agricultural practices, alternative water sources, and technological innovations can mitigate the effects of biofuels production on water resources, but there are some barriers to their widespread adoption. This was largely a review exercise with no effort to independently estimate water use.

A system dynamics model has been developed to investigate potential market penetration scenarios for cellulosic ethanol, and to aid decision makers in focusing government actions on the areas with greatest potential to accelerate the deployment of biofuels.[26] The model considers the broad supply chain from feedstock production, transportation, fuels processing, and final fuel distribution. Unfortunately this tool does not currently consider the spatial implications of water demand for feedstock irrigation and fuels processing.

A biofuels water use model was recently developed through collaboration between Sandia and General Motors.[27] The model calculates annual water withdrawal and consumption for both irrigation and feedstock conversion. Feedstocks modeled include corn, switch grass, short rotation woody crops, forest residue, and agricultural residues. The model estimates growing water use to meet biofuel production goals on a state level basis. This model has the advantage that it is spatially resolved at the state level, deals explicitly with water withdrawal and consumption issues, and projects how water demands will vary in time reflecting the changing mix of feedstocks and fuel processing technologies.

In addition, a Texas-specific spatially-resolved (at the county level) integrated biological growth and engineering model was created that estimates growth of biofeedstock (namely algae, in this case) on a monthly basis.[28] This model incorporates water availability, CO_2 use (from ambient air or flue gases), and solar insolation, and the general framework can be adapted for other biofuels or other regions.

Key to the aforementioned models and analysis is an accurate estimate of water use by existing and rapidly evolving energy crops. Energy crops require different amounts of water depending on the location's soil and climatic conditions. These conditions contribute to determining whether or not energy crops require irrigation, how much irrigation, and when it will be needed. A key player in Bioenergy feedstocks is the DOE biofuels program, managed by DOE EE&RE in cooperation with the USDA. The lead DOE laboratories include INL, NREL and ORNL. The Bioenergy Feedstock Information Network (BFIN)[29] is a consolidated website used to maintain biomass feedstock information generated by this organization and others. Significant research and development is being conducted on many aspects of biomass growth and biofuel production and DOE and the laboratories have initiated some nascent work on the impacts of growth and production on water resources. However, water-related research is rather limited at this time. All water-related publications documented on this site are focused on water quality impacts of biofuels (which are extensive[30]) rather than water supply and demand.

Currently under development at NREL is a system dynamics model to assess the water footprint of energy crops based on crop type, ambient climatic conditions, and soil type. [31-32] This model makes use of methods and data from the UN Food and Agriculture Organization (FAO) and the U.S. Department of Agriculture (USDA) Cligen weather generator.[33-35] This model improves upon previous work analyzing the water footprint of energy crops by achieving a higher spatial resolution and having the flexibility to adapt to a dynamic climate regime.[35-38] This model also has the benefit of being applicable at any spatial scale required for modeling and planning purposes.

NEED: Currently there are only two biofuel models that provide water use trends at the scale of the western US, the Argonne[23] and the Sandia-GM models.[27] The Sandia-GM model has the advantage of considering a broader range of feedstock materials, higher spatial resolution, it is dynamic in time, and the model is constructed in the same system dynamics framework as EPWSim. Although these models are developed in the same software, the two models need to be integrated. The spatial resolution of the Sandia-GM biofuel model also needs to be improved to the county level. Additionally, energy feedstock technology is evolving rapidly and thus feedstock data in the Sandia-GM model needs to be updated. Specifically, new feedstocks need to be added, where they are most likely to be grown, and what their water requirements are likely to be under different climate conditions.

PROPOSED WORK: This activity will expand the water demand model in EPWSim to consider irrigation and fuels processing requirements for biofuels. The first step is to integrate the Sandia-GM biofuels model into EPWSim. This will require improving the spatial resolution of the GM-Sandia biofuel model from the state to the county level. Additionally, new modules will be developed for additional energy feedstocks.

Improved data on potential feedstock water use will also be integrated into the EPWSim. Specifically, INL will develop a GIS-coverage map for known and projected locations of biofuel crops in the U.S. According to these projected coverages NREL will focus on assessing current and potential biofuel water demands utilizing national/west-wide data collected/currently being collected by DOE, U.S. Department of Agriculture (USDA) and other researchers and utilizing the life cycle assessment and water footprint tools being developed at NREL.[31] These climatic- and geographic-specific water requirements for energy crops will consider unique crop attributes, soil type, and climatic conditions and general western crop growth factors (e.g., growing season, temperature, precipitation and soil data), and biofuels feedstock data and information currently being developed at INL. The University of Texas will work with INL and NREL to develop similar Texas wide biofuels water use projections. Funding for this effort will support scaling of current coverages, which are at the USDA Production Region level, down to the county level. Additionally, funding will support integration of the data and models into EPWSim and to work with our interconnection partners to include any state-specific energy feedstock data that may be available.

Deliverable 3.2.1:	Biofuel-EPWSim model integration.
Responsible Partner:	Sandia National Laboratories
Start Date:	November 1, 2010
End Date:	May 2, 2011
Budget:	$50K

Deliverable 3.2.2:	Geographic and climate specific water requirements for energy crops
Responsible Partner:	NREL
Start Date:	June 1, 2011
End Date:	June 1, 2012
Budget:	$44K

Deliverable 3.2.3:	Geographic locations for energy crops
Responsible Partner:	INL
Start Date:	November 1, 2010
End Date:	June 1, 2012

Budget: $65K

Deliverable 3.2.4: Estimate water use for energy crops in Texas
Responsible Partner: UT
Start Date: June 1, 2011
End Date: June 1, 2012
Budget: $20K

BENEFIT TO INTERCONNECTION PLANNING: Historical trends on water use for agricultural irrigation are not sufficient to project future demands because of the potential growth in the biofuels industry (there is no historical precedence). As such we cannot simply rely on the agricultural demand projections from the state planning efforts (subtask 3.1). With the data and models developed here we will estimate the total biofuel water demand (in terms of rainwater and irrigation water) and produce related water footprint maps. By integrating this data within EPWSim we will be able to project alternative biofuel growth scenarios for comparison with other water demand sectors (including thermoelectric).

Subtask 3.3: Water Use for Energy Extraction.

CURRENT STATE OF KNOWLEDGE: Argonne staff has investigated the energy-water relationships for components and lifecycles of energy resource extraction and processing. As noted above, water requirements were evaluated for five fuel pathways: bioethanol from corn, ethanol from cellulosic feedstocks, gasoline from Canadian oil sands, Saudi Arabian crude, and U.S. conventional crude from onshore wells.[23] The analysis was applied on a regional basis according to 10 USDA farm-production regions.

In a similar study estimates of domestic freshwater demand were developed as expressed by consumption (not withdrawal) to the year 2030 in five-year increments at the national and regional levels for energy and non-energy uses.[39] Energy sectors for which water consumption estimates were made in this study include coal (mining and slurry transportation), oil (crude oil exploration and production, liquids from conventional sources, and refining), gas (processing, pipeline transport, and gas from tight sands and shale), biofuels (biodiesel and ethanol production), and hydrogen production. Water consumption estimates for these sectors were developed by multiplying energy-production projections that come from the DOE's Energy Information Administration (EIA) by sector specific coefficients that relate water consumption to energy production.

Heavy oils (e.g., oil shales, tar sands) represent a possible important energy source in the future. Water use can be realized both directly through the processes involved in extracting the oil as well as through the substantial amount of energy required for removing the heavy oil from the ground, processing it, and transporting it off-site. General estimates for such water use have been made for a range of reservoir conditions and extraction technologies.[40] Los Alamos National Laboratory has also recently developed an integrated oil shale-water-economics model to investigate potential evolution of oil shale reserves in Colorado and Utah,[41] while Argonne has conducted related Environmental Assessments for many reservoirs in the west.[42]

Large-scale deployment of electric vehicles is likely to have an impact on water use. Such impacts may occur through increased demand on thermoelectric power generation as well as changes in demand for traditional and emerging (e.g., biofuels) transportation fuels. A number of studies have been conducted to look at potential water use scenarios from a national perspective.[43-45]

NEED: As noted above, significant efforts have been made to quantify water use and consumption supporting energy extraction and processing. However, there is no "off the shelf" tool for broadly estimating future water use for energy extraction. As such there is a need for a comprehensive compilation of this data into a single source that makes this information available for comparison within the context of broader water demand (e.g., task 2, subtasks 3.1 and 3.2) and supply issues (e.g., task 4).

PROPOSED WORK: We will expand the EPWSim water use module to consider potential growth in the withdrawal and consumption of water for energy resource extraction and processing throughout the western U.S. This will include conventional oil, gas and coal extraction as well as other potentially important energy sources such as gas shales, tar sands and others. A consistent lifecycle treatment of these various fuels and their supporting extraction and processing technologies will be pursued. This task will largely involve integration of existing data and algorithms developed by Argonne, University of Texas and others into EPWSim. Additionally, choices on future electric power generation will be reflected in the demands for the associated fuels and their related water use. This analysis will also support development of alternative scenarios that differ in terms of future fuel utilization and extraction/processing technologies.

Deliverable 3.3.1:	Integrate water use/consumption data for energy extraction into EPWSim
Responsible Partner:	Argonne National Laboratory
Start Date:	November 1, 2010
End Date:	September 1, 2011
Budget:	$15K

Deliverable 3.3.2:	Integrate water use/consumption data for gas shale extraction into EPWSim
Responsible Partner:	UT
Start Date:	June 1, 2011

End Date: June 1, 2012
Budget: $20K

BENEFIT TO INTERCONNECTION PLANNING: Like water demand for biofuels, historical water use trends associated with mining and processing of energy fuels are not sufficient to project future demands because of the rapid changes in fuel sources, technologies and demands (there is no historical precedence). As such we cannot simply rely on the demand projections from the state planning efforts (subtask 3.1). With the data and models developed here we will estimate the total water demands for energy extraction and processing. By integrating this data within EPWSim we will be able to project alternative energy growth scenarios for comparison with other water demand sectors (including thermoelectric).

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Task 4: Water Availability Model

PURPOSE: The water availability model provides a regional measure of water supply for surface water, groundwater, and non-potable resources. The model has two principle components, “wet” and “paper” water. Wet water provides a measure of the physical water available in a basin for use, while paper water addresses the institutional controls (policies) that define access to the water.

Ultimately, each of the deliverables developed under this task will be integrated with deliverables from all other project tasks into an Energy Water Decision Support System (EWDSS). The DSS will be fitted with an interface that allows one to combine information from the various models to explore the wide range of dimensions important to the Energy-Water nexus. Output from the EWDSS will form the basis for the interconnection wide planning.

BENEFIT TO INTERCONNECTION PLANNING: Siting of future power plants needs to be made with a clear understanding of available water resources. Future availability of such resources will depend on many factors. One of these factors is the sustainable water supply. This task will develop interconnection wide coverages of current and projected water supply for surface water, groundwater and non-potable resources. Also considered are the institutional controls that may limit access to surface and groundwater supplies. Estimates will be available at the interconnection, state and watershed levels. Through the EWDSS this data can be combined with other data coverages (e.g., water demand) to evaluate the suitability of various locations for power plant siting.

TASK BUDGET: $894K

Subtask 4.1: Update EPWSim Water Availability Model.
CURRENT STATE OF KNOWLEDGE: Water supply/availability modeling is typically an integral element of water resource or water operations modeling. As described in Subtask 3.1 there are a wide range of water resource models that vary greatly by water source, physical fidelity, spatial scale, and time step (see Subtask 3.1 for examples). Again, recognizing that the objective of this project is to assist with interconnection wide planning, which encompasses the entire western U.S., it is not feasible over these scales to integrate existing water resource models with their differing assumptions, spatial/temporal scales, and software architectures. Additionally there are basins in the West that currently lack any detailed management modeling.

Depending on the type of questions being addressed, estimates of water supply can require very detailed data such as high resolution river hydrographs (daily or 15-minute gauge data); reservoir operations; rainfall-runoff-watershed modeling; water rights and allocation rules; environmental flows and habitat impacts; aquifer characteristics and groundwater flow modeling; surface water and groundwater interaction; and potentially many others. As noted above, collection of such data and development of accompanying models is infeasible at the scale of the western U.S. To make water supply modeling tractable over the western U.S. simpler metrics are necessary. Similar to the case of water demand (Subtask 3.1), there are several studies that have been conducted to date in which water supply projections have been developed over broad spatial scales.[1-10] Examples of metrics used in these studies include available precipitation[6,7]; mean gauged river flow[1,5]; average groundwater base flow[5]; and, average low month gauged river flow[1]. These metrics are then combined with measures of water demand to identify regions of potential water stress.

EPWSim is a model that was developed to explore the nexus between water supply, water demand, and thermoelectric power generation across the entire US. [11] The water supply model within EPWSim follows a very similar approach and utilizes similar sets of data as that of the studies noted above. Specifically, EPWSim models surface and groundwater availability at the accounting unit (6-digit Hydrologic Unit Code [HUC]) level. The basis of this modeling is the USGS National Hydrographic Dataset (NHD). Specifically, the USGS has stream flow data from 23,000 gauges in which the available sampling record has been statistically analyzed to give the minimum and maximum daily flows, mean daily flow, key percentiles (1, 5, 10, 20, 25, 50, 75, 80, 90, 95, 99) of daily flow, and the base flow index.[12] For each watershed we have identified the NHD gauge with the longest record and which is the closest to the point of discharge. As activities upstream of the gauge will affect the measured flow, the NHD long term statistics are constantly adjusted in the model for changes in consumptive use upstream of the gauge (projections of water consumption from Task 3). Specifically, changes in water consumption (post 2004) are sequentially aggregated across watersheds from headwater to the gauge. The aggregated consumption is then subtracted from the long term gauge statistics to yield an adjusted measure of water availability.

The model combines historical gauge data and other information to project surface and groundwater availability. Mean daily flow provides a good measure of the average surface water supply available at the gauge location, while the accompanying exceedence flows provide a measure of the variability in supply at that point. Likewise, the gauged average daily baseflow index (that portion of the stream flow contributed by groundwater discharge) provides a good measure of the sustainable groundwater recharge available for use. Each of these metrics is used to estimate available “wet” water at a given location. Demands are represented as daily averages. Algorithms have been developed to allow scaling and relating data between the watershed and county levels (e.g., relating metrics of water supply to metrics of water demand [Task 3]).

NEED: Currently there are no “off the shelf” tools for modeling water supply at the scale of the western US. EPWSim provides an existing framework for modeling water supply that is consistent with that utilized in the previously noted studies. Additionally, EPWSim can easily be integrated with other water resource modules (e.g., thermoelectric demand as in Task 2, biofuels water demand as in Subtask 3.2, and water institutional rules as below). As with the water demand model (Task 3), EPWSim is based on data collected by the USGS. As such, water supply metrics used in EPWSim need to be vetted with state level data collected as part of ongoing efforts toward state/basin wide water planning. As in the case of water demand, states will want to see their own data used in the model. Additionally, EPWSim would benefit from the addition of other water supply metrics, like effective precipitation.

PROPOSED WORK: Through interactions with the Western States Water Council (WSWC), which is comprised of water managers from each western state, we will gain access to each state's water data and reports. This information will be used to update and develop state approved water supply metrics. Additionally, we will cooperate with the USGS, using pertinent information derived from their ongoing efforts relative to National Water Census[13] and the WGA's Water Needs and Strategies for a Sustainable Future Program.[14] We will also review the U.S. Corps of Engineers recently-completed, state-by-state assessment of integrated water supply planning. Throughout this process we will also work to broadly vet the water supply model with the cooperative modeling team and as needed with stakeholders convened by WSWC, WECC, WGA, and ERCOT. We will also work with these same teams of stakeholders to develop and implement other appropriate water supply metrics.

As a first step we will poll or interview Western state water managers to identify hot spots for water competition. This information will give us a head start on highlighting issues and identifying specific basins for a potential 'deep dive' analysis. In addition, the polling results will serve as a check on future analytic results.

In developing the water availability model for the EWDSS, it is proposed that Sandia National Laboratories begin with three or four western states as part of a pilot project to extract information from their water plans regarding water supply projections. The purpose of this pilot effort will be to better understand the types of information available in various state's water plans, to determine the level of effort necessary to extract the information from the plans, and determine how best to vet the resulting supply models with respective state water managers. Based on the results of the pilot study a framework will be developed that can then be extended to the remaining western states. Ideally, the selected states would be actively engaged in the project and would have water plans that serve as a representative sample of the various water plans found throughout the western states. An effort should also be made to consider those states where the connection between energy and water is significant.

One possible way to select states to participate in the project is for the Western States Water Council to survey its member states to determine the extent of their willingness and ability to participate in the pilot project. Such a survey could also generate information on the structure and organization of each state's water plans. In appropriate cases, Sandia may be able to alleviate the financial and human resource needs that states may experience if they participate in the project by performing the bulk of the information extraction. In such cases, states will need to appoint a contact person to provide guidance and assistance as needed.

Sandia will lead the effort to collect and integrate data from the Western Interconnection region while the University of Texas will lead efforts within the ERCOT region. The Western States Water Council includes governor-appointed water managers from all of the states in the Western interconnection as well as Texas; as a result, the Council is well-positioned to provide a seamless perspective on the project approach to water demands. As noted above, a water supply model at the 6-digit watershed level currently exists for the entire WECC and ERCOT regions. As such, water supply projections will be available for planning efforts at the beginning of the project. However, these estimates will be changing and improving over the course of the project.

Sandia will ensure that the updated EPWSim model is approved by WGA and the Western States Water Council before delivering a final product.

Deliverable 4.1.1: Complete pilot water supply metrics study with 3-4 western states
Responsible Partner: Sandia National Laboratories
Start Date: October 1, 2010
End Date: September 30, 2011
Budget: $100K

Deliverable 4.1.2: Update surface water supply metrics for the WECC
Responsible Partner: Sandia National Laboratories
Start Date: October, 2011
End Date: November 30, 2012
Budget: $150K

Deliverable 4.1.3: Update surface water supply metrics for Texas
Responsible Partner: UT
Start Date: October 1, 2010
End Date: September 30, 2011
Budget: $15K

BENEFIT TO INTERCONNECTION PLANNING: Performing this work will provide broadly vetted metrics of water availability across the West. These measures of water supply can subsequently be combined with measures of water demand and various resources constraints to project regions of potential future water stress. Identification of such locations is critically pertinent to interconnection wide transmission planning and the broad siting of future power plants. Also, by working directly with each state we will improve project transparency and consensus in project results.

Subtask 4.2: Expand Water Availability Model.

CURRENT STATE OF KNOWLEDGE: Through DOE's Hydropower program INL has developed the Virtual Hydropower Prospector (VHP).[15] The synthetic watersheds and stream networks contained in the VHP are a unique approach developed by the INL and the USGS to assess hydropower potential throughout the U.S. for the purpose of locating potential new hydropower sites in both gauged and un-gauged watersheds in the U.S. The synthetic watersheds were designed to capture precipitation and evapotranspiration information from regional models (e.g., PRISM) and watershed runoff regression curves were developed to assess the timing of runoff, and to entrain the runoff to the synthetic stream system. The synthetic stream-flows are then evaluated against topographical data extracted from digital elevation models to assess potential hydropower head in any given synthetic watershed within the U.S. This is a unique process that is shared by INL and the USGS and is only available in the VHP and is being incorporated into the USGS National Hydrography Dataset (NHD).

NEED: The surface water supply metrics developed under subtask 4.1 are reported at the 6-digit HUC watershed level. This level was adopted because it is the highest HUC resolution in which every watershed has a long term gauge record. The VHP's synthetic watersheds and stream network provides unique insights to un-gauged watersheds thus allowing estimation of mean annual stream flows at the 8-digit HUC level. The VHP also provide a means of identify and estimating the hydropower potential at the 8-digit HUC level throughout the West.

PROPOSED WORK: In this task we will work to integrate the VHP into the EPWSim framework. Currently, the 3 to 5 mi^2 synthetic watershed and stream data contained within the VHP is at a scale that is not directly comparable to current regional-scale modeling and assessments; for this reason we will scale the synthetic watershed data so as to be compatible with USGS 8-digit HUC level watersheds for regional and west-wide assessments. Additionally, synthetic data within the prospector currently supports mean annual flows. INL will add seasonal flows and exceedence flows if sufficient data are readily available from regional/national databases (e.g., PRISM data).

Initiation of this subtask is currently being delayed until later in the project. This delay is necessitated in part by the need to coordinate this activity with Task 5: Environmental Controls Model and Task 6: Climate Change Calculator, who's SOWs, will be negotiated at a later time. It is under these tasks that the value of the improved spatial resolution and enhanced data products will be fully realized. Based on the evolution of Tasks 5 and 6 we may decide to move the timing of this effort up or alternatively reduce/eliminate the task completely.

Deliverable 4.2.1	Integrate the VHP into EPWSim
Responsible Partner:	Idaho National Laboratory
Start Date:	October 1, 2012
End Date:	July 31, 2013
Budget:	$70K

BENEFIT TO INTERCONNECTION PLANNING: Integration of the VHP will provide measures of mean and possibly seasonal stream flow at the 8-digit rather than 6-digit HUC watershed level. This means higher spatial resolution on estimates of surface water availability. The VHP will also help locate and bound likely expansion of hydropower in the West.

Subtask 4.3: Expand Groundwater Availability Model.

CURRENT STATE OF KNOWLEDGE: Groundwater is assessed and managed by local, state and federal agencies; however, groundwater data are neither easily compiled nor readily accessible across political boundaries and data are also not gathered in many areas. That is due to the fact that no one agency is responsible for providing a nationwide assessment and evaluation of the conditions, availability or water-quality trends of the country's groundwater resources. Therefore, the USGS, EPA and state partners from Illinois, Indiana, Minnesota, Montana, New Jersey and Texas have initiated five pilot projects to test the concept of developing a National Ground Water Monitoring Network.[16] The purpose of the collaboration is to assess existing data, review data collection and storage methods, analyze data gaps and to test the feasibility of sharing data between agencies.[17] This program is just beginning with its first evaluation scheduled to be available in 2011.

USGS has developed a national atlas of aquifer in the US, which provides estimates of the size, location and hydrology and geology of the major aquifers in the US, Puerto Rico and the U.S. Virgin Islands. This information is available digitally for use via national.atlas.gov.[18]

USGS is responsible for estimating water use, including groundwater use. This information is summarized and published every 5 years, including 1950 through 2005.[19] Until 2000, these estimates were summarized for watersheds, aquifers and counties; however, budget cuts required USGS to reduce its analysis and therefore, the summaries focused on county-level data. This information will be utilized for the proposed work.

There are a number of USGS reports available for selected groundwater resources in the West. These include research on recharge in the southwestern U.S.,[20] and Regional Aquifer-System Analysis (RASA) studies[21] to define regional geohydrology and established geologic, hydrologic and geochemical frameworks and provided regional assessments of ground-water resources in support of detailed local studies. The RASA studies were conducted from 1978 to 1995, with about 20 being conducted in the west.

NEED: Groundwater supplies a majority of the nation's community water systems and almost half of its irrigation, but there is currently no system that can provide a nationwide assessment and evaluation of the conditions, availability or water-quality trends of the country's groundwater resources. While there are a number of datasets with information pertinent to groundwater resource availability, these data have yet to be collated into a single comprehensive dataset.

PROPOSED WORK: Mapping of groundwater availability will be expanded by consolidating existing groundwater information (as noted above) within a standardized GIS coverage. The USGS base map of aquifers in the western U.S. will be used to collect and consolidate available information on general aquifer type (e.g., freshwater, brackish water, saltwater), and more specific information on the classification and use of economically viable aquifers (e.g., sole source and drinking water aquifers).[22-25] Additional groundwater availability information will include EPA's wellhead protection/sole source aquifer programs and USGS and/or state saltwater intrusion maps. We will also use the CMT along with WECC, WGA, and ERCOT stakeholder teams, to gather and incorporate regional specific groundwater data. All combined, this information will be used to estimate the potential for groundwater depletions in a given basin.

Deliverable 4.3.1:	Integrate groundwater data available from Federal sources into EPWSim
Responsible Partner:	Idaho National Laboratory
Start Date:	October 1, 2010
End Date:	June 1, 2011
Budget:	$35K

Deliverable 4.3.2:	Integrate groundwater data available from state sources into EPWSim
Responsible Partner:	Idaho National Laboratory
Start Date:	June 2, 2010
End Date:	July 17, 2012
Budget:	$45K

BENEFIT TO INTERCONNECTION PLANNING: This subtask will generate additional metrics useful to assessing groundwater availability. This will greatly improve insight into groundwater supply over the single metric currently in EPWSim (base flow index).

Subtask 4.4: Non-Potable Resources.

CURRENT STATE OF KNOWLEDGE: With increasing competition for and restrictions on withdrawals from freshwater resources,[36] it is becoming more commonplace for electric utilities to evaluate alternate or degraded water sources to meet power plant water needs. There exists a large body of literature that pertains to the assessment of these issues.[26-65] Potential alternate sources include reclaimed municipal wastewater, agricultural drainage, saline groundwater, oil and gas produced water, water from mine drainage, water from industrial processes and stormwater. Key issues that must be addressed in evaluating the use of alternate water supplies for power plant use, include: quantity, quality, treatment requirements, discharge requirements, transport, acquisition, and regulations.[40]

For single cycle Rankine generation (be it fossil, nuclear, geothermal, biomass or solar), cooling is the dominant water use; however, depending on the type of generation, power plants also use water for scrubbing, ash handling, landscape irrigation, toilet flushing, drinking, gas turbine operation, and solar cell and mirror cleaning.[39] Although the quantity of stormwater that can be collected onsite will not be sufficient to meet cooling needs, it can be used to meet other uses. Conceivably, stormwater collected onsite could be augmented by stormwater collected offsite. Because the production of stormwater is intermittent, a retention basin is required for its use.[41]

Municipal effluent is currently being use by approximately 60 generation facilities.[64] The greatest numbers of facilities using municipal effluent are located in Florida, Texas, California and Arizona. The amount used varies from 0.1 to 55 mgd.[40] Volume of municipal effluent produced by a treatment facility is a function of surrounding population density; hence, potential for power plant use is greatest for urban-sited plants. In general, in comparison to other high volume sources of degraded water, sewage treatment effluent has the best quality which is a function of treatment level and technologies. In Ohio in 2000 the total flow of sewage effluent was equal to 55% of cooling requirements of Ohio generation plants, for Illinois the percentage was 43% and for Michigan, 33%.[40]

In general, produced water is not as commonly available as sewage treatment plant effluent. Produced water quality is highly variable. Constituents of concern include: oil, grease, total dissolved solids, chloride, barium and boron. States having the highest produced water production are Texas, Oklahoma, Louisiana, Nebraska, Wyoming and California.[40]

Based on 1995 calculations by USGS, daily agricultural return flow in the U.S. is about 27,000 mg.[40] Quality varies depending on geology, soil, hydrology, fertilizer and pesticide use, and management practices. Potential for use is greatest in the western U.S. and Florida.

There is no national data base for volumes on saline groundwaters, only depths; however, some western states have volume estimates. Quality depends on geology and is likely to be similar to produced waters in the same basin.

Use of degraded water sources might require pre- and post-treatment that would not be needed with freshwater. Waters with high dissolved solids will probably need pre-treatment to reduce scaling, corrosion and fouling potential. Because cooling water constituents will be concentrated during recycling, blowdown may require treatment. For instance, discharge of nutrients by a waste treatment plant may be below receiving water quality criteria; however, after the same water is used in the power plant cooling system, the elevated concentrations of nutrients in the blowdown may not meet the criteria.

Power plant design and materials are tailored to anticipated water chemistry. Switching to new water sources after construction can result in new treatment needs, new operation procedures and replacement of existing construction materials. Ammonia in waste water treatment effluent can cause cracking in certain alloys such as admiralty brass. [40] Cooling tower film fill is less tolerant than splash fill to degraded waters. [40] Temporal variation is waste water treatment effluent can create problems. Treatment technologies include reverse osmosis, ion exchange and evaporative processes. There are energy and dollar costs associated with the additional treatment required by the use of degraded waters, which create a research need to develop more energy and dollar efficient treatment technologies.

There are numerous factors associated with the transport of degraded waters from their source to the power plant. These include pump requirements and costs, pipeline materials and costs, installation costs, pipe routing, water chemistry, secondary containment systems, pretreatment prior to pumping, system redundancy for reliability, shutoff valves, access shafts and pipe cleaning. As with additional treatment, transport creates energy and dollar costs.

Issues with respect to acquisition of alternate water sources include volume and quality guarantees, water rights of other stakeholders, who pays for delivery, will other users share the source and delivery system, backup source in case of system failure, length of contract, present and future competition for the source, and cost. Examples of acquisition costs for waste water treatment plant effluent are $0.15-0.26 per thousand gallons in Chandler, Arizona and $3.04 per thousand gallons in Cary, North Carolina. [40] As with freshwater acquisition costs, acquisition costs for degraded waters are not necessarily correlated to imbalances in supply and demand of freshwater. In addition, there are important energy implications from using reclaimed or saline water because of the need for it to be treated and transported.[66-68] In some cases the waste treatment plants can capture energy thereby mitigating these effects. [69] As a major electricity user, water treatment plants can be integrated into transmission planning.

USEPA has suggested guidelines for water reuse for industrial cooling but not regulations. A few states do have regulations; California, Florida, North Carolina, Oregon, Texas and Utah. States having guidelines but no regulations are Hawaii, New Jersey and Washington. [40] Regulatory issues include quality, treatment, monitoring, treatment facility reliability, storage and setback distances.

NEED: The evaluation process of alternate water supplies is very complicated and involves numerous factors which interact in multiple ways. After one has located a possible water source for a power plant that has a fixed location and determined that both quantity and quality are acceptable, there are multiple transport, treatment and operating variables to consider. Clearly the overall evaluation process would benefit from the availability of a decision support system. If one is considering the construction of a new power facility, so that location is now a variable, possible decisions increase exponentially. Now, not only is the location a variable but also the type of generation and overall plant design, all of which determine the water needs of the plant. The decision support system, is only as good as the data base upon which it rests; hence it needs as much data as possible regarding location and quality of degraded water sources, treatment technologies, power plant water demands (quantity and quality), power plant water conserving technologies and strategies, degraded water transport systems, degraded water acquisition costs and relevant regulations. Currently there are no off the shelf tools available to do such an integrated analysis.

PROPOSED WORK: Analysis of water availability in EPWSim will be expanded to include non-potable resources. Here we will make use of the extensive analyses by EPRI; basically, integrating the results into EPWSim. Integration will require considerable data manipulation, interpretation, scaling and development of key relational algorithms. Expanding on this work, INL will conduct a search for other federal and state GIS coverages and databases on brackish, produced, and waste water, to assess their viability and, where appropriate, incorporate that information into the EWDSS. We will likewise integrate the energy-water-desalination work of UT.

Deliverable 4.4.1:	Integrate the non-potable source data into EPWSim
Responsible Partner:	EPRI
Start Date:	December 1, 2010
End Date:	March 1, 2012
Budget:	$74K

Deliverable 4.4.2:	Integrate non-potable source data beyond that collected by EPRI into EPWSIM
Responsible Partner:	Idaho National Laboratory
Start Date:	January 4, 2011
End Date:	June 1, 2011
Budget:	$20K

Deliverable 4.4.3:	Collect non-potable source data for Texas (wastewater, produced water and saline groundwater)
Responsible Partner:	UT
Start Date:	January 4, 2011
End Date:	June 1, 2011
Budget:	$20K

BENEFIT TO INTERCONNECTION PLANNING: This task will enable interconnection planning to take advantage of utilizing alternate water sources in designing the electric power infrastructure of the future. The project results will enable evaluation of changes in the infrastructure to take greater advantage of alternate water sources in an energy and dollar efficient manner.

Subtask 4.5: Water Institutions Tool.

CURRENT STATE OF KNOWLEDGE: Physical availability of (wet) water alone is insufficient to assure that water will be available for power production needs. In general, a water right or permit issued by the state is required to use water in the western U.S. In many basins in the west, especially in arid regions with large and growing populations, water is already fully allocated (and in some cases over-allocated) to existing uses, requiring that water for new uses must be transferred from existing uses. The price of water rights is also increasing rapidly in some of these areas.

The laws and processes governing water rights, permits, and transfers are complex and vary widely by state.[70] In many areas, additional local or basin-specific rules apply as well.[71] Native American tribes often hold the largest most-senior water rights with their own sets of rules. Unless a tribe has received U.S. congressional approval, tribal water rights may generally not be used outside tribal lands.[72]

In many basins in the west, water rights have not been adjudicated, leaving large uncertainties in the validity or certainty of rights. Legal protests by other rights holders are also increasing in some basins. Navigating the various processes to acquiring water for a new use can be an expensive and time consuming process, and particularly where transfers are involved there are no guarantees that the investment of time and money will result in success.[73]

To date efforts to look broadly across states at the complicated and varied institutional controls pertaining to water use has not been accomplished. The closest has been a review conducted by the GAO,[74] which provides a preliminary analysis of differences in permitting requirements for power plant siting across the U.S. This review was very narrow in its focus and only looked at a few selected states.

NEED: While such information is available from each state, it has not been compiled in a uniform and searchable format. An effort is currently needed to compile this information for individual states, WSWC and WGA and integrate it within the broader context of the EWDSS.

PROPOSED WORK: This task will build on efforts by the WSWC and the individual states to define and catalogue the myriad of institutions and policies governing water withdrawal. As a first step we will work closely with the WSWC, WGA and cooperative modeling team (CMT) to assess and map the major institutional controls that govern state water rights in the west. Working with this same team we will prioritize and/or identify the set of institutional controls most important to interconnection wide planning. We will then work to make these priority institutions and controls accessible to the planning process. For any given location, the mapping tool will identify what state-level water rights regimes are in place for surface water and groundwater, the extent to which the water rights have been adjudicated, and what additional controls may apply, such as those relating to Tribal lands, acequias, irrigation districts, or special water districts. The tool will identify which basins are closed to future appropriation and indicate what rules are in place for water transfers. If feasible, the tool may incorporate information about water conflict in the basin, using the number of water-related lawsuits or other suitable metric. The tool will also identify basins where some or all water use is subject to interstate compact limitations.

While the mapping tool will be valuable for visualizing how key institutional controls vary by state and basin, there is a need to synthesize this information into a single integrated metric (e.g., a single map aggregating the multiple institutional layers into one value). Calculation of this metric is likely to involve some particular weighting and aggregating of the individual institutional measures (e.g., water rights regimes, degree of adjudication, Tribal lands). The weights applied to the individual measures are expected to be a matter of different opinion across stakeholders. For this reason the EWDSS will be designed to allow different weights to be applied and thus their impact on the integrated metric assessed. Thus, the goal is to develop the EWDSS so as to provide a venue for visualizing each institutional measure as well as a means of synthesizing the data into a single metric with the option to use personally derived weights. The resulting information will provide a basis for comparing water basins in terms of the expected difficulty in obtaining necessary permitting/water rights to support future expansion in electric power generation.

Development of the water institutions tool will be pursued in a manner consistent with that used in Subtask 3.1 and 4.1. Specifically, it is proposed that Sandia National Laboratories begin with three or four western states as part of a pilot project to extract information available from state water managers regarding institutional controls related to water allocation. The purpose of this pilot effort will be to better understand the types of information available from state water managers, to determine the level of effort necessary to extract the information, and determine how best to vet the results with respective state water managers.

Given the complexity of this effort and the fact that such a tool has not been developed before there is some uncertainty whether it is possible to accomplish this task. As such, results of the pilot project will be reviewed by the WSWC, WGA, WECC and ERCOT to determine whether the developed tool and data is of sufficient value to the project to extend to the other states. If there is not interest in extending the work then efforts toward Deliverables 4.5.2 and 4.5.3 will be discontinued and the funds redirected to more pressing issues. Alternatively, if this activity is pursued then the water institutions tool will be extended to half the remaining western states under Deliverable 4.5.2 with the remaining half finalized under Deliverable 4.5.3.

Sandia will lead the effort to develop the water institutions tool. The University of Texas will support this effort with data collection and synthesis associated with the ERCOT region, while INL will support data collection and synthesis for states in the Northwest U.S.

Deliverable 4.5.1:	Water institutions tool: Phase I
Responsible Partner:	Sandia National Laboratories with support from INL
Start Date	October 1, 2010
End Date:	April 1, 2011
Budget:	$125K

Deliverable 4.5.2:	Water institutions tool: Phase II
Responsible Partner:	Sandia National Laboratories with support from INL
Start Date	April 4, 2011
End Date:	April 2, 2012
Budget:	$125K

Deliverable 4.5.3:	Water institutions tool: Final
Responsible Partner:	Sandia National Laboratories
Start Date	April 3, 2012
Milestone(s):	April 1, 2013
Budget:	$100K

Deliverable 4.5.4:	Water institutions tool in Texas
Responsible Partner:	UT
Start Date:	April 4, 2011
End Date:	April 3, 2012
Budget:	$15K

BENEFIT TO INTERCONNECTION PLANNING: The varied and complex web of laws and rules governing water allocation and use can pose formidable financial and legal challenges to the siting of new energy facilities and in some cases to the operation of existing facilities. This task will provide for the development of a Water Institutions Tool that will enable an initial assessment of the institutional hurdles a potential project is likely to encounter as a function of location. The Water Institutions Tool will be integrated with the water availability model (Task 4.1) so that the user can determine which locations might be best suited for a project from both a wet water and paper water perspective. It will also be used to assess prospective locations to determine whether there are likely hurdles to particular projects and will provide an initial assessment regarding locations to be avoided.

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Task 10: Study Case Analysis

PURPOSE: The purpose of this task is to support the Western and Texas Interconnections in their responsibilities for identifying potential implications of water stress related to transmission and resource planning. This effort will proceed by utilizing the Energy Water DSS (EWDSS) to evaluate alternative future Study Cases developed by WECC, WGA and ERCOT. Sandia will lead the Study Case analysis task for WECC and WGA, while the University of Texas will lead analyses for ERCOT. The entire project team will participate in Study Case exercises for both interconnections.

BENEFIT TO INTERCONNECTION PLANNING: Using energy production Study Cases developed by WGA, WECC, and ERCOT we will calculate the water stress implications and report results back to our interconnection partners.

TASK BUDGET: $155K

Subtask 10.1: Study Case Development.
CURRENT STATE OF KNOWLEDGE: There have been a number of recent studies exploring the nexus between energy and water. Numerous DOE laboratories collaborated to prepare the Report to Congress.[1] This report looked broadly at the energy-water nexus, describing the various ways in which water is used in energy production and provided high-level estimates of the intensity of water use. To address emerging energy and water interdependency challenges identified in the Report, Congress directed the DOE in 2005 to “initiate planning and creation of a water-for-energy roadmap”. This roadmapping process relied heavily on stakeholder input gathered through three regional needs workshops and two technology identification workshops. Almost 500 stakeholders from over 40 states participated in the five Energy-Water workshops representing a broad range of energy and water agencies, developers, regulators, users, managers, utilities, industry, and academia. Participant input and suggestions were used to define the future research, development, demonstration, and commercialization efforts needed to adequately address emerging water-related challenges to future, cost-effective, reliable, and sustainable energy generation and production.[2]

To support these previous studies with quantitative data, NETL prepared a series of reports estimating water withdrawals and consumption associated with thermoelectric power generation.[3-5] Their analyses extend to the year 2030 and considered a variety of cases that differ according to the mix of fuel and cooling type employed in the future thermoelectric power plant fleet. These analyses were performed on a 13-NERC region basis (including 3 WECC subregions) spanning the entire continental US. The study did not consider water for other energy production needs such as transportation fuels.

Using county-level data on rates of population growth, utility estimates of future planned electricity capacity additions in the contiguous United States, and scientific estimates of anticipated water shortages, 22 counties were identify as the most likely locations of severe shortages brought about by thermoelectric capacity additions.[6-8] While these studies raise important issues and potential solutions, they are limited to a narrow set of assumptions and only consider thermoelectric water use.

Through interviews with subject experts, the GAO recently published a report on the energy-water nexus.[9] From these interviews they made three overarching conclusions. First, advanced cooling technologies that rely on air to cool part or all of the steam used in generating electricity and alternative water sources such as treated effluent can reduce freshwater use by thermoelectric power plants. Second, oversight of water use by thermoelectric facilities varies by state and is influenced by state water laws, related state regulatory policies, and additional layers of state regulatory review. Third, improvements to Federal water use data would increase understanding of the trends in power plant water use.

Recently Sandia, INL and DOE's Office of Policy and International Affairs have teamed to investigate the water supply implications of growth in the thermoelectric power industry.[10] This effort will utilize EPWSim to provide an interactive analysis environment for exploring the nexus between future water supplies and impacts associated with various energy technologies from a national and regional perspective. We will also utilize data from INL's Virtual Hydropower prospector to enhance the scope of analysis. In this exercise efforts will largely focus on analyses with no real model integration or improvements to the models or data. The scope of analysis includes the entire U.S.

The Union of Concerned Scientist is in the process of developing a project to look at implications of the energy-water nexus.[11] In particular they intend to explore prior analyses on energy production options (improved electricity conservation and expanded renewable) to evaluate how such approaches could help mitigate energy sector growth impacts on water stress. We have been collaborating with the project team as they work to frame the problem and evaluate alternative modeling and analysis options.

Beyond these nation-wide efforts to explore the energy-water nexus, several regional analyses have been conducted and/or are in progress. The Environmental Defense Fund and Western Resource Advocates conducted an overview of the Energy-Water Nexus in the West. This study relied on existing data and analyses to promote seven water/energy/planning policies aimed at mitigating future problems.[12] Texas[13] and California[14] each have conduced state specific analyses of the implications of expanding water needs for thermoelectric cooling and its potential to lead to water stress within each state. Similarly, the Great Lakes Commission,[15] supported by Sandia, EPRI, and Argonne, is sponsoring a study to investigate alternative futures for electric power generation in this region and their implications on water supply and environmental quality.

Several models have likewise been developed to analyze the interplay of thermoelectric power production and water resources at the regional scale. EPRI has developed a framework to evaluate water demands and availability for electrical power production on a watershed basis.[16] This framework to date has been applied to a handful of basins across the U.S. Other studies include the investigation of wind driven groundwater pumping to shed excess electrical power production by local wind farms.[17] Similarly, detailed modeling of water-energy tradeoffs on the American River in California,[18] a small closed watershed and water-power tradeoffs in watersheds[19-21] in Texas have likewise been investigated.

NEED: From this brief review it is apparent that numerous energy and water studies have been conducted to date. Certainly the data and analyses will be very valuable to this effort as we move forward. The limitation of these studies and tools is that the broad scale studies do not contain the level of spatial detail needed for this analysis (studies are at national or a multi-state regional basis). Most of these studies focus on a single aspect of the problem (e.g., thermoelectric water use). Also, these studies are not focused on issues specific to WECC and ERCOT transmission planning. This subtask is designed to coordinate efforts between this modeling team and the WECC and ERCOT planning teams.

There are also several detailed studies that focus on a specific region or watershed. These studies are limited in that they do not give a consistent and comprehensive view of the entire Western U.S. Extending these detailed regional analyses to the entire Western U.S. is not practical given the available resources nor are the necessary data available for every watershed. However, to the extent practical we will work to cooperate with ongoing regional analyses.

PROPOSED WORK: Development of Study Cases to be evaluated with the Energy-Water DSS will be the responsibility of WECC, WGA, ERCOT and their associated stakeholder teams. We will work with our interconnection partners through the CMT to support Study Case formulation exercises. In particular, this will involve communicating the limitations of the model, as well as negotiating modifications to the model (within the scope of this proposal) to facilitate the desired range of analyses. In addition, results from early analyses will be available to our interconnection partners to assist in refining subsequent Study Case conditions. Study Cases will largely be defined by the output of the interconnection wide transmission planning process; specifically, the distribution of power production over the entire interconnections. This includes operations of existing facilities as well as new capacity necessary to meet growing demand.

As the project evolves, so to will the nature of the Study Cases. For the WECC, the 2010 Study Program is already well underway. Here we will simply support the ongoing process as well as establish procedures for coordinating analyses and support between the modeling team, WECC, WGA and WSWC. In year 2 (2011-2012 Study Program and Long-term Scenario Driven Studies), the project team will work with interconnection partners more closely in the development of generation and transmission Study Cases. In particular, we will work with the WECC Study Work Group to help to inform the siting and technology mix of new generation based on our assessment of water resource impacts. In addition, we will provide input on a sustained drought or climate change scenario, based on our work under Task 6 of our proposal, for which we are scheduled to develop a scope of work in November 2010.

Deliverable 10.1.1:	Study Case development
Responsible Partner:	All partners will participate in developing Study Cases. This activity will proceed throughout the full duration of the project.
Start Date:	October 15, 2010
End Date:	A set of Study Cases will be developed annually. For WECC Study Requests are due by January 31 of each year. For ERCOT all analyses must be completed by August 2012.
Budget:	Budget is captured under activity 1.2.1 Project Coordination.

BENEFIT TO INTERCONNECTION PLANNING: Coordinated planning Study Case development between this modeling team, WGA, WECC and ERCOT.

Subtask 10.2: Study Case Analysis.

NEED: Currently WECC and ERCOT transmission planning processes do not analyze impacts on water resources. Specifically, an integrated tool set encompassing broad water related issues is not available for quantitative analysis.

PROPOSED WORK: Study Cases developed by WECC, WGA, and ERCOT will be submitted to the project team for analysis. Simulations with the EWDSS will be performed and the results reported back to our interconnection partners. Study Case analysis will provide insight on such factors as: water withdrawal and consumption for thermoelectric power production (locally and interconnection wide); increased demand across other water use sectors; impact of increased water use on water availability; alternative water supply options; potential water policy constraints; as well as many other metrics and or combination of metrics. In addition, for ERCOT, Study Cases that had been independently-developed by the UT team[22-23] will also be considered for examination.

In most cases, Study Case development and analysis will proceed in an iterative fashion. That is feedback on water availability will influence transmission planning conditions, which when adjusted will change the water stress landscape. The interactive nature of the DSS will allow Study Case analysis to be conducted directly with the planning teams. That is the DSS interface will facilitate direct adjustment of Study Case conditions, model simulation, and reporting of results in real-time in a workshop or focus group setting.

WECC, WGA, and ERCOT will be engaged in transmission planning exercises throughout the entire three year project period. In fact, early stages of Study Case development are currently in progress in both the WECC and ERCOT. These early stage analyses will be accommodated with EPWSim in its current state of development. As EPWSim and the broader EWDSS mature so too will our capacity to comment on the broader aspects (e.g., the additions to EPWSim/EWDSS outlined in the project proposal and accompanying scopes of work) of the Study Case analysis. But the positive aspect is that we can accommodate a basic level of Study Case analysis from the very beginning of the project.

Deliverable 10.2.1:	WECC Study Case analysis
Responsible Partner:	Sandia National Laboratories
Start Date:	October 15, 2010
End Date:	Deliver Study Case results to interconnection partners. For WECC Phase I results will be delivered by March 25, 2011, Phase II results by December 24, 2011, Phase III results by December 24, 2012 and final results by December 24, 2013.
Budget:	$90K.

Deliverable 10.2.2:	ERCOT Study Case analysis
Responsible Partner:	UT
Start Date:	October 15, 2010
End Date:	Initial results will be delivered by March 25, 2011, followed by intermediate analyses by December 24, 2011. Final analyses are to be completed by August 2012.
Budget:	$45K.

BENEFIT TO INTERCONNECTION PLANNING: This task will provide quantitative analyses concerning the water implications of various interconnection wide planning Study Cases explored by WECC and ERCOT.

Subtask 10.3: Training.

NEED: The EWDSS is being developed in such a way that it is directly accessible to all project participants, thus allowing them the flexibility of exploring particular Study Cases of personal interest. This will allow stakeholders the opportunity to explore and learn from Study Cases beyond those studied under Subtask 10.2.

PROPOSED WORK: Our goal is to develop a DSS that is easily accessible to project partners, in terms of both computer platform and the interface with which the user interacts with the tool. As such, we will provide our partners with the option of conducting Study Case analysis on their own. This will potentially allow a wide range of stakeholders to test their personal Study Cases and learn from the exercise. To facilitate this exchange, training workshops will be offered to provide interested stakeholders the EWDSS operational skills they will need to perform Study Case analysis. The UT Austin team is already engaged in training hundreds of professionals annually through executive education and CEU (Continuing Education Unit) coursework for professional engineers, policymakers, entrepreneurs, lawyers, accountants and analysts; it will be straightforward to include the EWDSS training in future short courses.

Deliverable 10.3.1:	WECC Training
Responsible Partner:	Sandia National Laboratories
Start Date:	March 1, 2013
End Date:	May 13, 2013
Budget:	$10K.

Deliverable 10.3.2:	ERCOT Training
Responsible Partner:	UT
Start Date:	March 1, 2012
End Date:	May 11, 2012
Budget:	$10K.

BENEFIT TO INTERCONNECTION PLANNING: This effort will provide interested stakeholders the opportunity to learn how to operate the EWDSS on their own to explore Study Cases of personal interest.

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