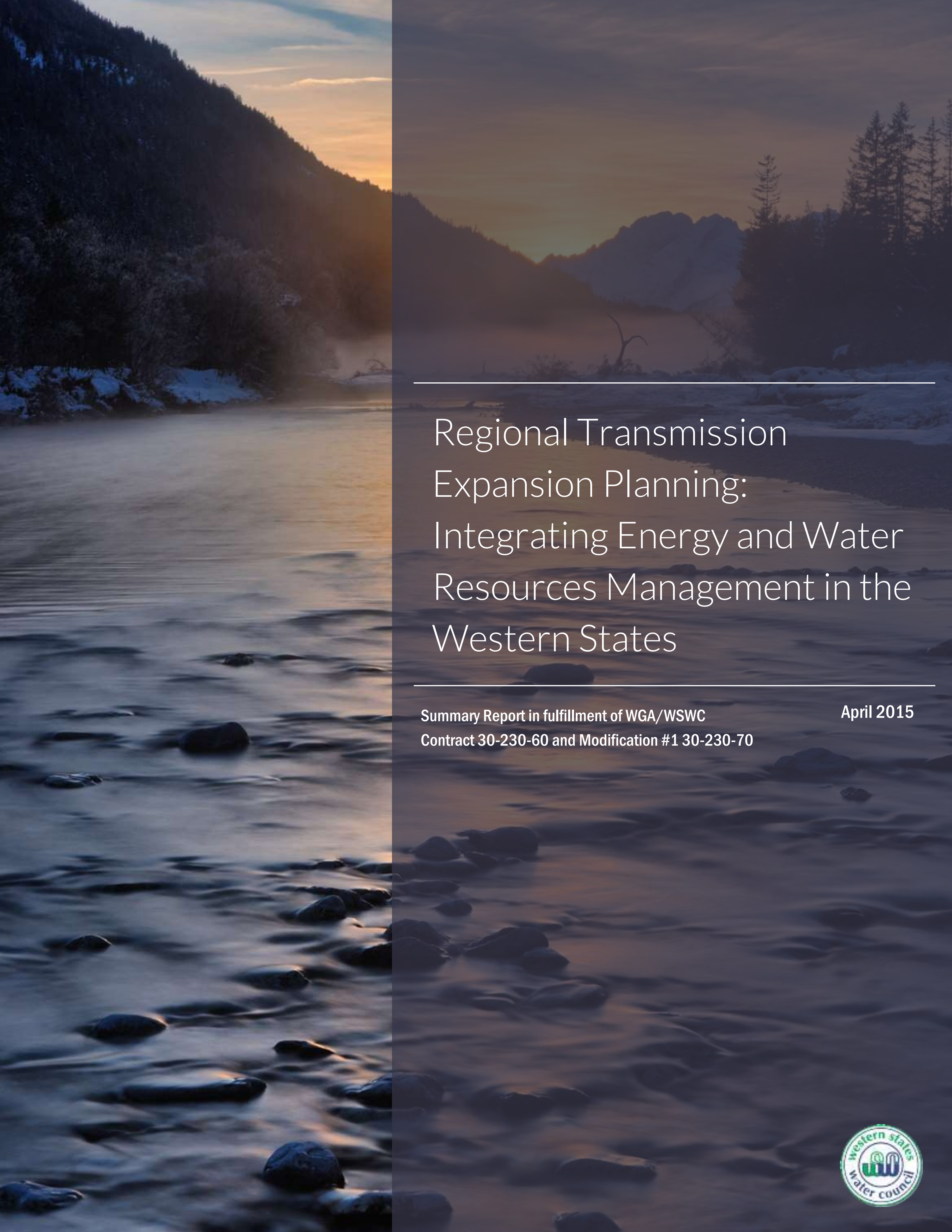

Regional Transmission Expansion Planning: Integrating Energy and Water Resources Management in the Western States

Summary Report in fulfillment of WGA/WSWC Contract 30-230-60 and Modification #1 30-230-70

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Photo Credit - Pg. 5: P. Tyrrell
Boulder Lake Drainage, Wyoming

Executive Summary

In the West, water is a scare resource, subject to increasing demands from growing uses. Water defines the quality of our lives and our environment. It can also circumscribe economic opportunities, including the development of our energy resources. There is no substitute for water. In comparison, western energy resources are abundant and diverse, and play a critical role in meeting the nation's needs for fuel and electricity. Increasing demands for new uses related to energy extraction, production, and transmission has and will have impacts on existing users and uses, including the environment. Many western rivers and aquifers are already fully appropriated, meaning there are more rights recognized to the use of water than the available supply. New energy development will have to compete with existing uses with prior rights such as irrigated agriculture, as well as growing municipal and industrial uses, and environmental demands.

Scarcity has led to the development of an appropriative system of rights to the use of water that provides economic and social stability and reduces conflicts. It recognizes a senior right to the first use to which water is put. This "first-in-time-first-in-right" principle has been criticized, but it provides certainty and a reasonably efficient market in water rights, that may allow energy companies to secure access to water even in dry years through leasing and other agreements. Water for energy may also be acquired through permanent transfers, sometimes over long distances, or the use of municipal wastewater or brackish waters. Treatment and transport of water consume energy and increase costs.

Drought impacts water and energy resources and exacerbates the allocation and management challenges. Both water and energy demands and supplies are effected. Air conditioning, irrigation and other water and power demands rise with temperatures. Hydropower accounts for twice the percentage of power generation in the West as the national average, and drops with flows. Also, higher temperatures negatively impact thermoelectric power generation efficiencies.

Executive Summary (con't)

Power production is expected to be a major driver of new water demand over the next decade.[1] The National Electricity Technology Laboratory has estimated that between the years 2005 and 2030, thermoelectric water consumption will increase by 42-63 percent.[2] While still small compared to total western water use, this is significant. The magnitude of the impact of future energy demands for water on other western water uses is at present uncertain. This is largely due to the general lack of accessible, reliable, and comprehensive data and information related to existing water uses, water supplies, and water availability, as well as summary data on market transfers of water from one use to another. For example, comprehensive information on transfers of water between uses, including agricultural use to electric power production and related energy needs, is currently not generally compiled by state water right administrators in any systematic way.

As part of the Council's deliberations related to the work described in this report, a policy position was adopted and forwarded for WGA's review that suggested numerous actions for further consideration to better integrate water and energy planning and policy.[3] Each, with illustrative examples, is included in the Recommendations section of this report. Three are highlighted here.

Figure 1. Lake Mead Generators
Photo: Southern Nevada Water Authority

First, western states and federal agencies should support new and continued data gathering, analyses, and research needed to better understand the extent and limitations of our water and energy resources, specifically existing and projected future supplies and demands. Without a clearer understanding of present consumptive uses of water regionally, as well as refined projections of future energy development, an accurate and comprehensive assessment of the impacts to existing water users, and the cost of acquiring water for specified energy projects, is problematic. With WGA support, the WSWC initiated a Water Data Exchange (WaDE) program as a part of the Regional Transmission Expansion Project (RTEP) discussed in this report, to improve accessibility to available state data and information. WaDE deployment will be a significant step forward in understanding and evaluating our water resources and future changes in demands.

Second, better integration of water and energy policies and programs will require a concerted effort and the governors' continuing leadership, including continuing state participation in forums such as the State Provincial Steering Committee (SPSC), Scenario Planning Steering Group (SPSG), and Environmental Data Task Force (EDTF) as well as other similar groups.

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[1] Western Electricity Coordinating Council (WECC), 10-yr Regional Transmission Plan: Plan Summary, 2011. See: http://www.wecc.biz/library/StudyReport/Documents/Plan_Summary.pdf.

[2] National Energy Technology Laboratory, Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements, 2008. See: http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2008_Water_Needs_Analysis-_Final_10-2-2008.pdf.

[3] Western States Water Council, 2015. POSITION #378 of the WESTERN STATES WATER COUNCIL regarding Integrating Water and Energy Planning and Policy, adopted in Tulsa, Oklahoma on April 17, 2015. See: http://www.westernstateswater.org/wp-content/uploads/2012/10/WSWC-Resolution-regarding-Integrating-Water-and-Energy-Policy-and-Planning_2015Apr17.pdf.

Additional joint meetings, workshops, symposia, and webinars would be helpful in bringing water and energy planners together more regularly to better understand the energy/water nexus and consider appropriate collaborative actions to improve management of both resources.

Third, a public education effort is needed to communicate the value of energy and water conservation, and to encourage the use of “smart” technologies to improve the measurement and management of water and energy consumption, in the short and long-term. Consumers often don’t understand or appreciate the fact that when they turn on their faucet they use energy as well as water, and conversely when they switch on the light they are also consuming water. Sometimes the best way to reduce residential energy use is through water conservation measures.

Water is critical to energy development and its distribution. Hydropower and thermoelectric generation and transmission are two examples. Unlike energy resources, water is only “consumed” when it is rendered unavailable for other uses, such as through evaporative cooling. Water withdrawals from rivers and streams for thermoelectric power production may be considerable, but depending on the cooling technology used, the water may largely be returned to the hydrologic system where it is available to reuse. Power production accounts for some 41 percent of U.S. water withdrawals, but only about three percent of consumption. In the West, irrigated agriculture is the predominant water use in an arid climate, accounting for most of the withdrawals and diversions, as well as consumptive use through evapotranspiration from fields.

It has been said that “water runs uphill to money,” and money can move water geographically and between uses. In general, when it comes to decisions regarding where to site a power plant or other energy project, water-related costs are usually not now sufficiently high enough to “move the needle.” New investment in energy development will likely provide sufficient capital to acquire the necessary water resources. However, money does not always dictate the highest and best use of water, which is generally considered public property, until it is put to use in private enterprise. The public interest as expressed by social values and environmental protections will continue to be important considerations. Moreover, economic markets for water are limited both by the willingness of existing users to sell, and also the availability of the infrastructure needed to move water. Compared to electricity, water is much more difficult to move, given its volume and weight. It is also important to note that water withdrawals, transfers and treatment consume significant amounts of energy in the West.

Proposed water transfers and related markets are regulated by western states, which apply appropriative principles designed to protect existing users, including third parties, from injury.
Water right information, specifically data on consumptive use, is another limiting factor. Western water law defines, measures and limits the exercise of water rights based on consumptive use. Transfers of water between uses are limited to the amount consumptively used in the past. However, consumptive

use is often difficult to determine, even on a case-by-case basis. Little data and no comprehensive summary of consumptive uses exist.

Against this backdrop, the Western States Water Council (WSWC) entered into an agreement with the Western Governors' Association (WGA) to assist with a Regional Transmission Expansion Project (RTEP) funded by the Department of Energy and designed to "enhance the states' capacity to effectively participate in [energy] transmission planning and development, and substantially improve the quality of information available to state and federal policy makers and regulators, as well as industry planners." [45] Regarding the energy and water nexus, WGA committed to work with state water managers and other agencies, as well as experts on water requirements of electric generation technologies to evaluate water issues associated with the siting, transmission, and mix of energy supplies, with a goal of anticipating challenges and assisting with development of future energy scenarios within existing and future water resource constraints. A more complete explanation of the RTEP effort is included in Appendix A.

Of note, the water availability models developed and enhanced through the RTEP efforts are valuable scoping level planning tools, but not sufficiently refined to provide reliable information for site-specific and project-specific decision-making, due largely to the limited availability of data on consumptive water uses and marketability. This has been a consistent RTEP theme, and the work was focused on planning considerations, not siting level information for new thermoelectric generation. Obtaining such information is a laborious and expensive process as there is no westwide database on water rights and water uses. However, the work undertaken by RTEP partners and the Western States Water Council (WSWC) described in this report, with the support of the Western Governors' Association (WGA), has been a significant step forward in the development of such a repository. WaDE deployment will facilitate more refined modeling in the future. This work will also provide valuable assistance in the development of a national assessment of water availability and uses, presently being undertaken by the U.S. Geological Survey (USGS), as well as future studies of energy and water needs.

The WSWC, representing state water managers appointed by the governors, agreed to assist in undertaking a number of tasks, the completion of which are described in detail in this report. These included: Task 1(a) assisting in compiling assessments from western states regarding water availability, water consumption and withdrawals, and projected water demands for municipal/industrial, agricultural, recreational, and environmental uses; Task 1 (b) assessing current and projected water scarcity by large river basin or aquifer system in the West, including both a physical and legal perspective; Task 1(c) considering drought and the potential implications of climate change and how they may affect river flows and water supply availability for energy development; Task 1(d) seeking to identify opportunities for the use of non-potable water resources; Task 2 preparing an analysis of legal, institutional, and administrative issues associated with new permits or transfers of water for energy development; Task 3(a) identifying policies that promote water-efficient energy technologies; Task 3(b) considering likely impacts to other water users and ways to mitigate or otherwise minimize those impacts; Task 3(c) convening water managers, electricity generators and regulators to make recommendations to the Governors for how electricity and water providers can better coordinate; and Task 4 participating in work with the national laboratories, and other efforts under RTEP, including the State and Provincial Steering Group, Scenario Planning Steering Group, and Environmental Data Task

[4] WGA Statement of Project Objectives, 2009.

Force, which advise the Western Electric Coordinating Council (WECC) and its Transmission Expansion Planning Policy Committee (TEPPC). The WSWC served as liaison to ensure incorporation of water interests, and convened its members to assist in a review of the national labs' modeling efforts.[6]

In undertaking these tasks, it became apparent that much of the data and information needed to accomplish the anticipated work were simply not available or not easily accessible, and that obtaining such information would be a laborious and expensive process. Therefore, the WSWC initiated a westwide effort that would include making available information from WSWC member states on state water rights and water uses, as well as derived data and summary information on water availability from state and federal sources. This initiative became the WSWC's Water Data Exchange (WaDE) and a major focus of much of the WSWC's work under the WGA service agreement.[7] This effort has included the development of a data exchange framework, database schemas, data exchange methods, mapping tools, web services, and data access portals. Beta testing with data from Colorado, Utah, and Wyoming is underway. As noted hereafter in detail, the WSWC's work with WGA's leadership has been essential in identifying and implementing the initial steps necessary to improve the water information and data available for sound decision-making related to future electric power generation and transmission planning, as well as to better integrate water and energy resources planning, conservation, development and management. The RTEP effort has helped develop a clearer understanding of the interrelated nature of our water and energy resources, and the importance of a collaborative approach to their conservation, development, management and wise use. It has also led to the development of valuable relationships that need to be encouraged.

[6] WGA Service Agreement/Contract Number 30-23—60, Exhibit A – Western States Water Council Scope of Work , executed November, 24, 2010. See Appendix C.

[7] Modification #1 to WGA Contract, executed on January 3, 2012.

Table of Contents

RTEP Project Execution

WSWC Tasks

In November 2010, the Western States Water Council (WSWC) entered into an agreement with the Western Governors' Association (WGA) to assist with the review of a Regional Transmission Expansion Project (RTEP) undertaken with the support from the U.S. Department of Energy (DOE). Separately, the DOE supported a consortium of national laboratories providing technical assistance (See Appendix C). Consistent with the governance structure developed to coordinate RTEP efforts, much of WSWC's work initially involved assisting with the development of metrics for the water availability assessment with Sandia National Lab and its partner labs, and subsequent efforts to ensure the information presented was vetted through state water managers and reviewed as necessary. As this work progressed, it became apparent that there was no single west wide source of data on water supplies, water demands, water uses, and water rights. Therefore, the WSWC proposed and the WGA agreed to modify their original agreement to hire a program manager to assist in the development and deployment of a new tool, which has come to be referred to as the Water Data Exchange (WaDE). A beta version is now being tested with a number of states, and deployment will continue in the future with other funding support. When released, it will allow real-time access to water supply and availability estimates, water allocation and water use data, as well as other state agency-generated data that the states choose to share, with the phasing in of observed data from instrumentation. WaDE will be an important tool for future water availability assessments. The following addresses how each of the tasks enumerated in the original WSWC scope of work have been fulfilled (See Appendix B).

Water Availability Assessment

Task 1(a)

Assist in compiling assessments from western states regarding water availability, water consumption and withdrawals, and projected water demands for municipal/industrial, agricultural, and recreational/environmental uses.

The WSWC and WGA November 2010 contract (30-230-60) outlined a comprehensive program of work related to the DOE grant and RTEP project. WSWC began working extensively with WGA staff and Sandia National Laboratory to begin a pilot study with four participating states that would gather the water data needed for the development of a water demand and availability model (as also described in Subtasks 3.1 and 4.1 of the National Laboratories' scope of work – See Appendix C). The pilot project was designed to provide a better understanding of the types of state data available for water consumption and water availability, as well as water use/supply projections for municipal, industrial, agricultural, recreational, and environmental needs in the future. The WSWC created a Water-Energy Subcommittee that facilitated discussions and provided contact information for representatives from each of the states to work on the pilot study with WSWC and Sandia. Over the course of the study, the pilot effort was expanded to include the seventeen contiguous member states of the WSWC.

During 2011, WSWC, WGA, and Sandia began holding update/briefing meetings on the third Wednesday of each month to coordinate efforts and ensure good communication between all parties working on the larger RTEP project. WSWC and Sandia jointly proposed an initial study scope of work and schedule for data-gathering at the 2011 Spring Council meeting. As part of the foundation work for the project, and with the help of its WestFAST liaison, WSWC completed a survey of state water availability studies.

The WSWC coordinated with USGS and other federal agencies on how water availability estimates from the states could inform the RTEP effort. WSWC staff also prepared a state-by-state matrix outlining the various types of state water demand and availability data that were accessible (See Appendix F).

Water Availability Metrics

Through 2012, WSWC staff worked closely with Sandia to facilitate communication and the transfer of state data between the states and the lab's project team. To assist with the communication between the states and labs, WSWC helped to convene a multidisciplinary group of state and federal water agency experts to assist in the creation and review of water availability metrics, and estimates for large river basins (For a listing of members and workgroup information, see Appendix H). Currently, there are no broadly accepted measures of water availability and costs that span the entire western region. Rather, metrics that could provide a relative measure of water availability and demand needed to be developed from the raw data collected from the states and federal agencies. These metrics were developed for five different water supply source types: appropriated surface water, unappropriated surface water, groundwater, brackish groundwater and waste water reuse.

The analysis made use of multiple datasets from multiple sources reported at differing geographic resolutions (e.g., point, count, watershed, and state). For the purposes of the analysis, a consistent reference system was required, and an 8-digit Hydrologic Unit Code (HUC) watershed classification was adopted. Where a watershed was divided by a state boundary, individual water availability/cost metrics were developed for each state's portion of the watershed. Both spatial and temporal adjustments had to be made to the data. The challenge for Sandia and the metric development team was to formulate water availability and cost metrics that appropriately balanced the underlying complexity of the system (e.g., physical hydrology, climate, use characteristics, technology, and water management institutions) with the data that were consistently available across the entire western U.S. The metrics team assembled by WSWC assisted in defining the metrics and developed an approach for the study over a two month period. The final categories of water supply sources were assembled as metrics for over 1,500 watersheds across the West. The metric team also defined associated cost estimates for each water supply sources' development, such as costs to drill a well field, treatment of wastewater or brackish water, and costs to transfer appropriated water to another use. The associated unit cost to develop any given water supply source was a significant potential parameter for WECC's least cost energy transmission planning models.

Unappropriated surface water - Estimating the availability of unappropriated surface water was a difficult task because of its inherent complexity: characteristics of the physical water supply, water rights structure in relation to supply, interstate compacts, international treaties, and state policies all play a part in how and whether water can be appropriated. Fortunately, many western states have developed measures of unappropriated surface water availability to manage both water allocation and development within their state. Where available, those values were used in the study. In remaining basins, streamflows tended to lack regulation by interstate compacts, and flows tended to be large with respect to water use. Studies that have evaluated the health of streamflow ecosystems relative to average streamflow estimate that a range between 30-60% of the average annual streamflow is needed to maintain ecosystem integrity. A conservative threshold of 50% of a reach's annual average streamflow was adopted. Thus, where state agency data were unavailable, 50% of the annual average streamflow was calculated using streamgage data. When the interim data were under reviewed by state managers, they differed on the preferred streamflow statistic percentage to use when calculating unappropriated surface water availability, and the metric was adjusted further to suit these differences. The adopted streamflow amounts ranged from those derived from the 50th percentile average annual streamflow to the 10th percentile (representative of drought conditions).

Unappropriated groundwater - Except in very limited cases, the states had not broadly estimated and published data on the availability of unappropriated groundwater. Where state data were available, they were used, while other basins required a water balance approach. Unappropriated groundwater was calculated as the difference between annual average recharge and annual groundwater pumping. Recharge rates were taken from USGS data, which are derived from stream baseflow statistics, while pumping rates were taken from state data or from USGS. With this approach, unappropriated groundwater availability was set equal to a basin's sustainable recharge, or equivalently to a condition of zero groundwater depletion. To account for unique groundwater management and/or aquifer characteristics, further restrictions on unappropriated groundwater availability were introduced. Specifically, availability was set to zero in watersheds located within state defined groundwater protection zones (these regulations were acquired directly from each state). Groundwater availability was likewise set to zero in watersheds realizing significant groundwater depletions (groundwater declines exceeding twelve meters from predevelopment conditions). Lastly, groundwater availability was set equal to zero in any watershed where 10% or less of its land area was underlain by a principal aquifer.

Appropriated water - Permanent transfers have traditionally involved the sale of water rights made available through abandonment of the prior use or through water savings achieved through improved system efficiency. The availability of appropriated water is strongly influenced by the price of water – as the price increases, more water rights holders would theoretically be willing to sell their rights. To maintain consistency with the other water supply source categories and metrics, the study assumed no 'disruptive' changes to water rights markets in the West. In the absence of major price changes for water rights, an estimated decrease of about 5% in total irrigated agriculture over the next 20 years due to loss of land to urban development and permanent sales of water rights was assumed. These sales are most likely from irrigated lands of lower value crops. States differed on what percentage of agricultural conversion they believed would take place over the proposed timeframe, and the metrics were adjusted accordingly.

Municipal wastewater - Not all wastewater discharge is available for future use, as a considerable fraction is currently reused by industry, agriculture, and thermoelectric generation. Reuse estimates were determined both from USGS data, and EPA databases, as they record the point of discharge, e.g., stream, agriculture, power plant, and in some cases these points are designated as discharging to "reuse." Reuse estimates were subtracted from the projected discharge values. Another consideration for western states regarding availability of municipal wastewater is that of return flow credits. Municipalities that discharge to perennial streams may receive return flow credits for treated wastewater. Return flow credit water is not available for new development as it is already being put to use downstream. Unfortunately, there are no comprehensive data on wastewater return flow credits. In efforts to identify plants that are likely credited for their return flows, those plants that directly discharge to a perennial stream were identified (point of discharge was identified in the databases noted above as being a stream with average flow of 0.028 cubic meters per second or more). These plants were excluded as a source of available municipal wastewater.

Shallow brackish groundwater - Estimates of brackish groundwater resources across the western U.S. were of limited availability. To cover the entire study area required the use of multiple sources of information. The best quality data were state estimated volumes of brackish groundwater that were potentially developable; however, these data were only available for Texas, New Mexico, and Arizona. States typically limit appropriation of the resource by applying allowable depletion rules. In the study case, it was assumed that only 25% of the brackish water resource could be depleted over a 100-year period of time (annual available water was determined by multiplying estimated total volume of brackish water by 0.0025). Other sources for brackish groundwater data included real-time groundwater well depth and quality maintained by USGS. To avoid including brackish water that may contribute to potable stream flow, availability was set to zero when the average depth to brackish water was less than 15 meters. For the purposes of the RTEP study, brackish groundwater was considered to be any groundwater monitored and reported as having a salinity value of less than 10,000 parts per million (ppm) total dissolved solids (TDS). Seawater was not included as a potential water supply source in the study, and it was assumed that water with a TDS greater than 10,000 ppm would be too costly to develop and treat. To avoid brackish water that was possibly in connection with potable streamflow, availability in the watershed was set to zero when the average depth to brackish water was less than 50 feet and had a salinity of less than 3,000 ppm TDS.

Water cost metrics - Each of the five potential sources of water had very different associated cost. The goal related to including a unit cost estimate was to establish a consistent and comparable measure of the cost to deliver water of potable quality to the point of use, in this case an electric generation facility. As with water availability, costs were resolved at the 8-digit HUC level. Both capital, and operating and maintenance (O&M) costs were considered. Capital costs captured the purchase of water rights as well as the construction of groundwater wells, conveyance pipelines, and water treatment facilities, as necessary. All capital costs were amortized over a 30-yr horizon and assumed a discount rate of 6%. O&M costs included expendables (e.g., chemicals, membranes), labor, and waste disposal, as well as the energy to lift, move and treat the water. As the cost estimates were derived from a variety of sources published over a range of time, all costs were adjusted to constant 2012 dollar values based on the consumer price index.

Water demands - The metric development group also reviewed available water demand data, and projected shortages were calculated by comparing the projected available water supply from the various sources and consumptive use demand estimates provided by the states. Projected changes in the consumptive use of water between 2010 and 2030 were geographically distributed and mapped using the same scale as water availability. While the states projected little growth in irrigated agriculture, increased use in the municipal and industrial sectors, including thermoelectric energy generation, were expected. Many of the largest increases projected for consumptive use were clustered around metropolitan areas.

The final metric set was made available by the Sandia project team using a graphic and mapped format, as well as tables and spreadsheets.[8] These preliminary results, including estimates of water availability for the five different water supply sources, current and future demand, and future water shortage and surplus for each 8-digit HUC were provided to WECC for inclusion in their long-term planning models.

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[8] Sandia National Laboratory. "Energy and Water in the Western and Texas Interconnects," final release May 2014. Website: http://energy.sandia.gov/climate-environment/water-security-program/energy-and-water-in-the-western-and-texas-interconnects/.

WSWC staff presented the research methods developed by the metric team, as well as some of the interim results to the council at the 2012 Summer WSWC Meeting.

Later that year, Vince Tidwell, the Sandia principal investigator, presented the interim metric results for the entire western region to the WSWC at their 2012 Fall Meetings. WSWC members expressed a desire to review the estimates more closely using a mapped format, as opposed to a tabular format. To accomplish this, WSWC staff created and tailored a Sandia Data Review online mapping application specifically for in-depth review, where state representatives could evaluate the metrics, methods, and estimates of water availability basin-by-basin. A phased review of the Sandia data by state water managers continued through August of 2013. This comprehensive review was accomplished with the expenditure of significant state resources, primarily from staff time.

Coincident with this effort, the WSWC assisted in reconvening the original water metric development team to work on a final "environmental" water metric that addressed energy development water impacts on riparian areas and sensitive species. The results of this team's work were also incorporated into Sandia's map application results and made available for download. They were also used to create a separate application, hosted by Argonne National Lab, called "Ecorisk." Through 2013, WSWC, WGA, and Sandia collaborated on potential dashboards/applications that would facilitate the display and access to data from Sandia's water availability study, and how these would be presented along with WaDE data.

As part of a final review, WSWC members expressed concern over the possibility of users misconstruing or using conflicting information that was different from the states', as well as long-term maintenance of the water availability metric results. Members were primarily concerned that the water metric results could be misconstrued as state-generated water data. As a result, at the WSWC Fall Council Meeting in Deadwood, South Dakota, members decided that the WSWC would not host these datasets or maps on WSWC servers, but would instead provide support and training to the Sandia research team, assisting its personnel with uploading, customizing, and hosting their data on Sandia and ArcGIS online servers.

In early 2014, the Sandia research team published their final mapping application and the related databases and publications on their project website. They also provided a link back to the WSWC's WaDE information page (which will redirect to the WaDE portal in the future) from their website. The peer-reviewed journal Environmental Research Letters also published the Sandia research team's study findings in an article, titled, "Mapping Water Availability, Projected Use and Cost in the Western United States." WSWC was added as a co-author on the paper because of their involvement and assistance.

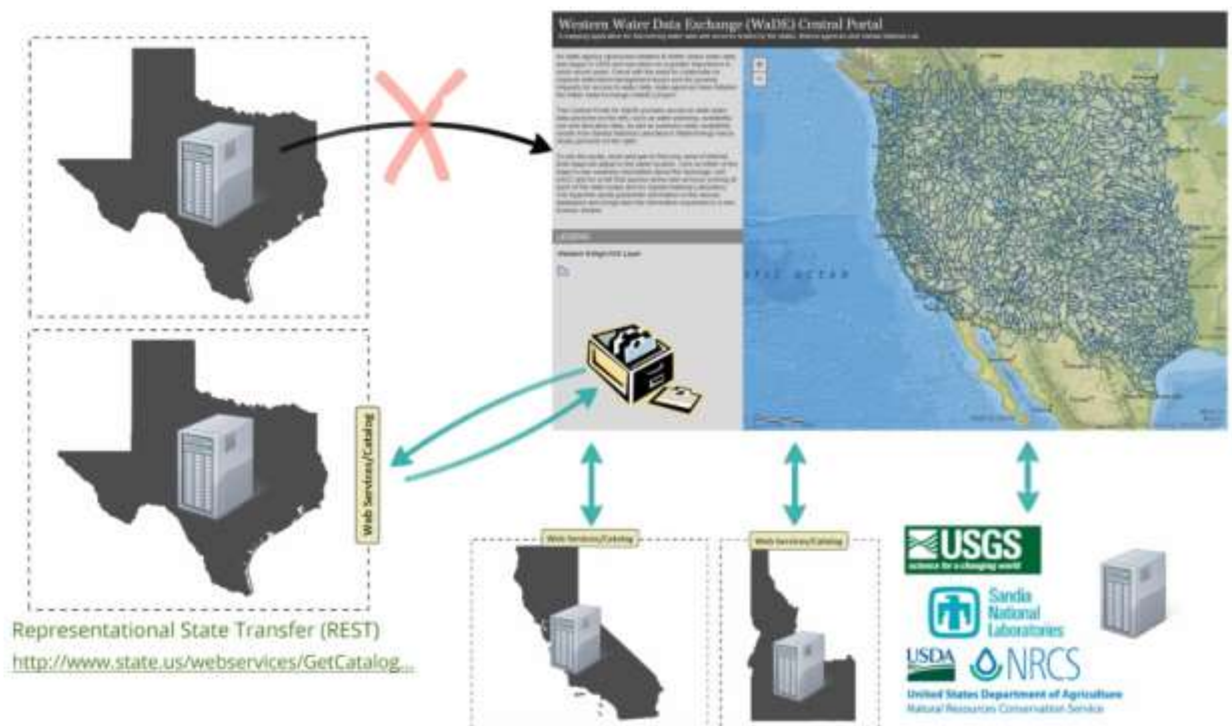
Water Data Exchange (WaDE)

To address long-term issues related to water data availability, WSWC initiated a related but separate water data exchange project that would ensure the sustainability and repeatability of the RTEP project by allowing real-time access to state water data with varying temporal characteristics. WSWC created and coordinated workgroups for analysis of state data capabilities and methodologies, as well as the data schema (format) and technical approach for a data exchange project that would support the Sandia water availability assessment and similar studies in the future. To assist with the related data-exchange effort, WSWC proposed and the WGA approved the creation of a new position to work with WGA and

Sandia on the water availability assessment project, and oversee the development of the data exchange project.[9]

Initial work conducted in 2012 on the WaDE project included a survey of states' capabilities related to what data they collect, how they collect it, and how they store it.[10] The WSWC conducted an inventory of current practices and IT capabilities in order to make recommendations on policies that will need to be put into place to support a framework for more refined water availability estimates. Initial work also included significant outreach efforts to engage the individual western states.

The WaDE Program Manager, the WestFAST liaison and, when available, the WSWC Executive Director, traveled to the state agencies to explain and discuss the RTEP Project and the WaDE program, its framework, schema and goals, with state agency staff members. The outreach visits helped to identify individual state issues and enlist support for the project. The visits also allowed the WSWC to review each state's data infrastructure and needs on a more thorough, one-on-one basis. Using the state surveys and the information gathered directly from the state visits, WSWC staff and workgroups developed a draft data schema version 0.1. This was the original basis for facilitating access to water availability, allocation, use, and planning data from the various states in a common format. Following all outreach interviews, the information gathered was used and incorporated into a newer version of the data schema, released later in 2012.[11] Outreach efforts also included visits with federal agency staff to encourage them to adopt standardized formats for openly publishing their datasets.



[9] To effect these changes, the WSWC and WGA drafted and signed Contract # 30-230-70 Modification #1. The new position was published and the WSWC hired a Water Data Exchange (WaDE) program manager in December 2011.
[10] Western States Water Council, 2014. Western State Water Program Capabilities Assessment Survey & Report. See: http://www.westernstateswater.org/wp-content/uploads/2014/06/Western-State-Water-Program-Capabilities-Assessment-Survey-Report-FINAL-June2014.pdf.
[11] The most recent version, available under the 0.2 nomenclature, can be found on the WSWC's website under the WaDE project tab, and by selecting "Draft Items."

A significant portion of WaDE development (framework, schema, databases and web services) was also undertaken in 2012. Sample data from the states and from Sandia was entered into the draft schema and accessed using a mapping application prototype. The mapping application was built to access the web servers over the internet, make requests of the sample data, and return it to the user in a platform-independent format called eXtensible Mark-up Language (XML). This is also human-readable, by using stylesheets super-imposed over the returned XML. The component framework and the customized mapping application prototype capabilities were demonstrated to WSWC members in the fall of 2012.

During the outreach phase of the WaDE effort, a majority of state agencies expressed their support for the project and its goals of enabling easy, cost-effective, near real-time water data sharing. However, due to drastic budget cuts and a downsized workforce, they also expressed concerns about available resources. Many of the agencies had reduced staff, and could only address absolutely mission-critical tasks. To address this, the WSWC proposed assisting the states with some contract or grant-solicited funds to help make the WaDE deployment less burdensome.

Coincident with RTEP-related efforts, the WaDE project received a major overhaul of its infrastructure/schema components to accommodate more partners and to improve the robustness of the web service query results and speed. During the early part of 2013, at the suggestion of WaDE workgroup members, the web service code was re-written to match the National Environmental Information Exchange Network's (NEIEN) REST service specification. The recommendation stemmed from a desire to have a well-established, standardized URL format, both for integration into the Exchange Network (EN) dataflow and also for increased discoverability. Other tasks included updating databases to reflect the v0.2 schema and the creation of a flow configuration document (FCD), which serves as a map or set of guidelines for partners who wish to implement the WaDE node within their server environments. At the request of one of the WaDE workgroups, the ability to host a centralized "Methods Repository" and more comprehensive Geographic Information System (GIS) support was developed and implemented in the databases, schema and web service programming.

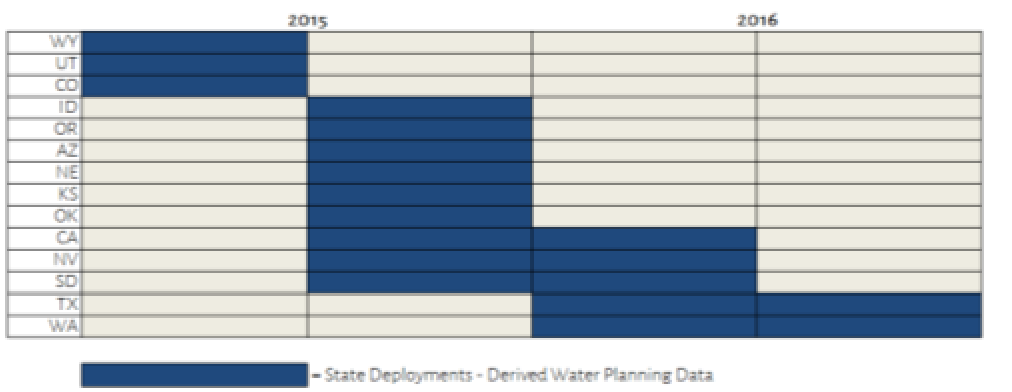
Further, a final document was published containing all of the survey results from the state agencies regarding their water data program data gathering and IT capabilities. The final state capabilities report is available on the WSWC's WaDE website under the WaDE and "Governance" tabs, and includes a series of companion maps that illustrate the status of water data information and IT capabilities for the western states.

WaDE Deployment

During 2014, a few states began the database deployment and data mapping efforts with minimal financial assistance, including the purchase of server capacity from Utah's central IT department and a SQL Server database license funded by WGA. Documentation to assist with initial deployment efforts within state IT environments was written and made available to other states through the WSWC website. WaDE project infrastructure components, such as schema adjustments, database tables, and web services code, were adjusted further to accommodate additional methodology/metadata and GIS information. The databases and web services code and documentation for implementing WaDE for states "in house" or "on premises" (within their local IT environments) were made available to selected states for download from the WSWC website. However, during subsequent deployment-related interviews, several states raised concerns related to their lack of scalability to network traffic and difficulty addressing security concerns through their central IT departments. To find a solution to this issue, WSWC staff performed an evaluation of the primary cloud vendors to determine if they could support the states interested in possibly deploying to a "cloud" setting.

Based on this preliminary analysis, WSWC asked one of the larger vendors for a "proof of concept" demonstration of how they might go about facilitating WaDE on their cloud solution. During September and October 2014, WSWC worked to set up the initial proof of concept and demonstrated this new approach to investigating states. As a result of the new option several states decided to use a "cloud" approach for hosting their WaDE-related data.

Utah, Wyoming, and Colorado were the first to enable sharing of their selected WaDE-related data and are part of the WaDE Central Portal Beta demonstrated in April of 2015 and scheduled for wider release. The majority of the remaining states are either proceeding with the initial steps for deployment, are planning to begin deployment in the summer of 2015, while three states are awaiting potential funding assistance.



Task 1(b)

Assess current and projected water scarcity by large river basin or aquifer systems in the West, including from a physical and legal perspective.

As discussed above in Task 1(a), the WSWC assisted Sandia in the development of study models and the water availability assessment tool and metrics. The water demand and availability models discussed in Tasks 3 and 4 of the National Laboratories' Scopes of Work accomplished these objectives (See Appendix C)[12].

Task 1(c)

Consider drought and the potential implications of climate change and how they may affect river flows and water supply availability for energy development. Ideally, this will result in the development of a drought/climate change scenario that can be implemented as part of Topic A.

In 2010, WGA and WSWC staff began working on a drought scenario study request that was proposed to WECC and accepted in early 2011. The drought study was planned to evaluate the potential implications of drought and how it may affect river flows and water supply availability, hydropower and other energy production in Texas and the Western Interconnection. The WSWC participated in a number of meetings

[12] Sandia National Laboratory. "Energy and Water in the Western and Texas Interconnects," final release May 2014. Website: http://energy.sandia.gov/climate-environment/water-security-program/energy-and-water-in-the-western-and-texas-interconnects/.

and conference calls with WGA staff, Sandia, WECC, and other RTEP partners to assist in the development of the proposal. Support for the study was also provided by Argonne and Pacific Northwest National Labs and the National Renewable Energy Lab. The WECC study: (1) conducted a thorough literature review of studies of drought and the potential implications for electricity generation; (2) analyzed historical drought patterns in the western United States; (3) used the results to design three drought scenarios for further analysis; and (4) quantified the risk to electricity generation for each of eight hydrological basins under the three drought scenarios and considered the implications for transmission planning. The study was published in 2013 in the proceedings of the ASME 2013 Power Conference.[13]

Further, the WSWC continues to work with WECC on a proposed water-related transmission planning scenario including a proposed Energy-Water-Climate study that was a result of an October 2014 WECC workshop.

Task 1(d)

Seek to identify opportunities for the use of non-potable water resources.

As described above, WSWC staff and members worked with the Sandia research team on metrics for the use of brackish groundwater and municipal wastewaters, as well as related costs, as part of the water availability assessment and Sandia model development. During the initial development of the brackish groundwater and wastewater metrics, it was noted by the water metric team members that data related to the potential sources for non-potable reuse were a significant data gap. In order to identify opportunities for the use of non-potable water resources, more work needs to be conducted to quantify and measure their availability. The best data related to brackish water analyses were assembled by the states' water agencies, while the best data related to water reuse were databases developed by USGS and the EPA.

As noted in the wastewater source metric, much of the water currently discharged is likely already allocated to another use downstream from the discharge point. Because of this phenomenon, identifying potential wastewater for is complicated. Another obstacle to a better understanding of reuse is the lack of information on consumptive uses of water, as opposed to simple water withdrawals. More thorough tracking of consumptive uses by western states, and by USGS in their Estimated Water Use reports, would lead to better measurement and tracking of discharged waters that return to the hydrologic system.[14]

Task 2

Legal and Institutional Analyses

From the outset, the pilot project discussed in Task 1(a) was intended to provide information from the states on their institutions, laws and policies that govern water withdrawals, transfers, and development for energy purposes. At the 2011 Spring WSWC Meeting, the Sandia research team proposed a mapping tool/model for the WSWC to consider that would identify and incorporate the legal and institutional availability of water. It would identify which basins were closed to future appropriation and indicate

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[13] Eugene Yan, Y., et al. "Potential Drought Impacts on Electricity Generation in Texas," ASME 2013 Power Conference, published July 2013. See: http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleID=1831868.

[14] U.S. Geological Survey, 2010. Estimated Use of Water in the United States in 2010. See: http://pubs.usgs.gov/circ/1405/.

what rules were in place for water transfers, etc. For example, availability was set to zero in watersheds located within state defined groundwater protection areas (with such data acquired directly from each state). State agencies also reviewed the resulting metric results methods for the percentage each state projected would be transferred from the agricultural sector to municipal and industrial uses.

WSWC, WGA, and Sandia collaborated on the best approach to presenting the metric information, such as GIS and numerical formats similar to the work being done by the EDTF, in which the WSWC participated (See Task 4 below). This facilitated the Sandia research team's incorporation of legal and institutional constraints into their models and map application results.

In April 2015, the WSWC also completed a report, "Water and Energy in the West: the Legal and Institutional Issues that Affect Water Availability for Energy-Related Activities."[15] This report, funded as part of the DOE/RTEP grant from WGA, was intended to help inform WGA's water and energy policy. The report analyzed the legal and administrative issues associated with new permits or transfers of water to the energy generation or development sectors. It included two case studies related to water use and development for one renewable and one non-renewable energy project. Specifically, the case studies included water-related regulations surrounding solar energy development in Arizona, and non-renewable energy resource development in the State of Texas. It explored the different types of water that may be used during energy-related activities, such as fresh water, brackish groundwater, reclaimed water and effluent, and produced water (a water byproduct of oil and gas development activities). The laws and regulations that govern the use of these categories of water for energy and other purposes vary from state to state and different provisions often apply to each source of water.

Aside from the RTEP work, the WGA and WSWC together produced a report of water transfers in the West and opportunities to facilitate water banking transfers between uses to meet future demands, given water scarcity. The WSWC relied on the results of this work in preparing the Task 2 report on legal and institutional constraints to securing water for energy development.[16]

Task 3

Policy Development

Given its experiences with the RTEP work, and more broadly other water and energy related work, the WSWC drafted, considered, and adopted a policy position supporting water research and development programs at DOE national labs in the summer of 2013 (Position #355).[17] An extensive if not exhaustive listing of recommendations as part of a policy statement (Position #378) related to the integration of energy/water planning was adopted at the 2015 Spring WSWC Meeting in Tulsa, Oklahoma. Both were noticed and later submitted to the WGA for its consideration.[18]

Task 3(a)

[15] Western States Water Council, 2015. Water and Energy in the West: the Legal and Institutional Issues that Affect Water Availability for Energy-Related Activities. See: http://www.westernstateswater.org/wp-content/uploads/2012/10/Institutional-Report-Review-Draft-41015-Final.pdf.

[16] Western Governors' Association and Western States Water Council. "Water Transfers in the West." Webpage: http://www.westernstateswater.org/wp-content/uploads/2012/12/Water_Transfers_in_the_West_2012.pdf.

[17] Western States Water Council, 2013. Position No. 355. See: http://www.westernstateswater.org/wp-content/uploads/2012/10/355_Resolution-Supporting-E-W-Research_2013Jun26.pdf.

[18] Western States Water Council, 2015. Position No. 378. See: http://www.westernstateswater.org/wp-content/uploads/2012/10/WSWC-Resolution-regarding-Integrating-Water-and-Energy-Policy-and-Planning_2015Apr17.pdf.

Identify policies that promote water-efficient energy technologies such as: (1) incentives to direct energy development toward places with a sustainable supply of water; (2) facilitating water banking and trading mechanisms; and (3) encouraging energy and water conservation.

No single policy solution exists given the variability among the states related to hydrology, climatology, water and energy resource availability, and related demands, as well as demographics and political preferences. General policy statements for consideration by the governors are addressed hereafter, under Recommendations, with examples.

- 3(a)(1) – Arizona – In Arizona, the Gila Bend Concentrated Solar Project (CSP), a wet-cooled plant using groundwater was built on previous irrigated land and represents a net savings of water in this particular instance. However, the Arizona Corporation Commission denied the use of groundwater for cooling purposes for the proposed and now scuttled Hualapai CSP, which would have been construction on raw land. Rather it was required to rely on effluent for cooling purposes, due to the scarcity of water supplies for other purposes, including municipal use.[19]
- 3(a)(2) – WSWC – The WSWC also completed a report, "Water and Energy in the West: the Legal and Institutional Issues that Affect Water Availability for Energy-Related Activities," which analyzed the legal and administrative issues associated with new permits or transfers of water to the energy generation or development sectors.[20]
- 3(a)(3) – California – A 2013 Independent Technical Panel's report to the California legislature recommended that the Department of Water Resources develop methodologies for estimating and reporting energy intensity. The California Public Utilities Commission has been tasked with developing a partnership framework between investor-owned energy utilities and the water sector, along with methodologies to measure the embedded energy savings and the cost-effectiveness of water/energy efficiency projects.

Task 3(b)

Consider the likely impacts to other water users and ways to mitigate or otherwise minimize those impacts.

The water availability metric work and related modeling performed during the RTEP study by the metric team, WSWC and Sandia included estimates of future demands through 2030. Some assumptions related to the impacts on other water uses were included, such as the amount of water currently appropriated for agricultural use that might be transferred to energy development. However, given the lack of comprehensive and consistent west-wide data on water use, particularly consumptive water use, only a broad overview was possible. More specific information to compare power generation and siting options will require case-by-case investigation.

A system to comprehensively track west-wide changes among and between different water use sectors does not exist. State water right transfer and water use data may be mined for clues on changes in the "purpose of use," but there is rarely any summary reporting. However, the deployment of the WaDE tool is a major first step towards the development of such data. As described under Task 1(a), it will help

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[19] Ibid., pp. 24-28.

[20] Western States Water Council, 2015. Water and Energy in the West: the Legal and Institutional Issues that Affect Water Availability for Energy-Related Activities. See: http://www.westernstateswater.org/wp-content/uploads/2012/10/Institutional-Report-Review-Draft-41015-Final.pdf.

fill a void that became obvious over the course of the RTEP study related to the lack of reliable and readily assessable data related to water use in general and water for energy in particular. Without such information it is difficult if not impossible to identify changes and trends in existing and future water uses and monitor physical, economic, and social impacts. The RTEP study and WaDE development will go a long way in the future towards adding pieces to the water use "puzzle" and providing decision-makers with a more complete picture.

Separately, as noted above, the work of the WGA and WSWC on the impacts of water transfers in general included consideration of the means to minimize impacts of water transfers on rural agricultural communities and the environment. It identified many policy options and tools that the states and other stakeholders could use to avoid impacts from transfers of water from agricultural to other uses, including ways to facilitate water banking and water conservation. Again, this work was considered in the report prepared pursuant to Task 2(a).

WSWC's RTEP outreach and collaboration with USGS was essential to fulfilling Task 3(b) with respect to considering the likely impact of future energy use on other water uses and ways to mitigate or minimize such impacts. As described above, the WaDE tool will be invaluable in the future and a key component of USGS work on a national water assessment.

Task 3(c)

Assist in convening water managers, electricity generators, and regulators to make recommendations to the Governors for how electricity and water providers can better coordinate to ensure compatible development of these important resources.

Related to the development of policy recommendations, the WSWC hosted a Water/Energy Nexus Workshop the day prior to its 2013 Spring WSWC Meeting, in Denver, Colorado. This meeting was held to convene water managers, electricity generators, and regulators in a forum for the exchange of information and to discuss how electricity and water planners and providers can better coordinate and integrate their development and conservation activities. The workshop was attended by some sixty participants in person and another ten attendees via webinar. The WSWC published a summary report of the workshop (see Appendix G), and used the findings in developing the policy position mentioned above and the examples used in the Recommendations section hereafter. Further, over the course of the study, numerous updates and reports were made to the WSWC that helped to raise awareness of the increasing need to integrate water and energy policy considerations.

Other policy development work included a WSWC report entitled, "Concentrating Solar Power and Water Issues in the U.S. Southwest," released in March of 2015[21]. This publication describes water-related impacts of concentrated solar power (CSP) energy development in the West. It also provided a comprehensive analysis of CSP water requirements by major technology, energy cooling system tradeoffs, and comparisons of CSP to other electricity generating technologies used throughout the West. Although separate from the RTEP grant, the report contributed to the identification of policies that promote water-efficient energy technologies.

Task 4

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[21] Western States Water Council, 2015. Concentrating Solar Power and Water Issues in the U.S. Southwest. See: http://www.nrel.gov/docs/fy15osti/61376.pdf.

Participate in the State and Provincial Steering Group (SPSC), the Scenario Planning Steering Group (SPSG) and Environmental Data Task Force (EDTF), the work of the national laboratories, and other efforts under RTEP.

Task 4(a)

The WSWC will serve as a liaison to the SPSC and EDTF to ensure that water impacts are incorporated into transmission scenario development and planning efforts.

Former WSWC member, Alexandra Davis, then Assistant Director for Water in the Colorado Department of Natural Resources, served as the WSWC's initial liaison to WECC's SPSC, and was succeeded by Dennis Strong, former Director of the Utah Division of Water Resources. WSWC Executive Director Tony Willardson served as an alternate and WECC's primary point of contact, as well as a member of the EDTF. WSWC actively participated in numerous SPSC, SPSG, and EDTF meetings, webinars and calls (as regularly noted in WSWC's progress reports), raising awareness of water and water right related constraints and processes. The WSWC continued to support WECC, SPSC, SPSG, and EDTF work for the duration of the RTEP effort. In the future, WSWC staff will continue this work using its own resources. The WSWC is now participating in SPSG discussions on a newly proposed Energy-Water-Climate Change scenario.

Task 4(b)

The WSWC will convene its membership to assist WGA and the national laboratories in assembling a model for water use by electric generation. This will include review of inputs to the model, its assumptions and methodologies, as well as results from the model.

The WSWC's Water-Energy Subcommittee, under its Water Resources Committee, assisted the WGA and the national laboratories in developing the water demand and availability model discussed above under Task 1(a). The Subcommittee's Chair was Alexandra Davis from Colorado. It also consisted of other WSWC members and water managers from Arizona, California, Idaho, New Mexico, North Dakota, Texas, Utah, and Wyoming. Later chairpersons included Jennifer Gimbel formerly with the Colorado Water Conservation Board, and Dennis Strong, formerly with the Utah Division of Water Resources.

Among other things, the Subcommittee worked with Sandia in developing metrics for the model in response to Task 1(a) above. Discussions with and among WSWC member representatives focused on the data and information presented to WECC by Sandia, and more detailed refinements of the state data and information to refine their developed models and tools. It continued to assist Sandia in the development of the models throughout the duration of the RTEP effort. The WSWC's continued support of the WaDE project ensures that any future analyses similar to the RTEP study will benefit from better information and incorporate states' shared water planning, water supply, water use, and water rights data. WaDE will provide such support in a consistent, cost effective, and efficient manner.

Recommendations

Given the WSWC's work on the RTEP project, a related WSWC policy position was developed, reviewed and adopted that included the following policy recommendations for the governors and others to consider for western water and energy planning, development, regulation, and decision-making.

(1) **Integrating water and energy policies and engaging water and energy planners to maximize program and project effectiveness and efficiencies.**

- In December 2006, the U.S. Department of Energy presented a report to Congress entitled "Energy Demands on Water Resources," on the interdependency of energy and water, which highlighted the fact that energy generation almost always requires water and can impact water quality, while supplying water requires energy also. Water is used for hydroelectric and thermoelectric power generation, energy extraction, and fuel production. Conversely, energy is needed to supply, treat, convey, distribute and use water.

- A 2007 nationwide survey by the Center for Energy and Environmental Policy found few states with some type of integrated water-energy program. California was one such state. The report found limited programs in several other states, including in the West, Alaska, Hawaii, Idaho, Nebraska Nevada, New Mexico, and Texas.[22]

- An example of the need for integrated water and energy planning and decision-making involves the large-scale deployment of electric vehicles, which is projected to have an impact on water use, through increased demand on thermoelectric power generation as well as changes in demand for traditional and emerging transportation fuels, such as biofuels. A number of studies have been conducted to look at potential water use scenarios given transportation developments from a national perspective.[23]

- In January 2014, California Governor Jerry Brown released the California Water Action Plan, which lays the groundwork for a sustainable and resilient water and water-energy future in 2050 and is consistent with California's goal of reducing greenhouse gas emissions by 80% from 1990 levels.[24] The 2050 vision emphasizes water and energy conservation, including rate structures that reward sustainable use, maintain assistance for low-income ratepayers, and give utilities the necessary operating revenue to do a

[22] Young-Doo Wang, Integrated Policy and Planning for Water and Energy, Universities Council on Water Resources Journal of Contemporary Water Research & Education, Issue 142, pp 46-61, August 2009. See: http://www.ucowr.org/files/Achieved_Journal_Issues/v142Integrated_Policy_and_Planning_for_Water_and_Energy.pdf.
[23] C.W. King, M. E. Webber and I. J. Duncan, "The Water Needs for LDV Transportation in the United States," Energy Policy, Vol. 38 (2), pp 1157-1167 (2010).
C.W. King and M.E. Webber, "The Water Intensity of Transportation," Journal of Environmental Science and Technology, November 2008. See: http://pubs.acs.org/doi/abs/10.1021/es800367m.
C.W. King and M.E. Webber, "The Water Intensity of the Plugged-in Automotive Economy," Journal of Environmental Science and Technology, February 2008. See: http://pubs.acs.org/doi/abs/10.1021/es0716195.
[24] California Governor's Office, 2014. California Water Action Plan. See: http://www.arb.ca.gov/cc/scopingplan/2013_update/water.pdf.

good job. It identified the need for regional and local integrated water and water-energy management and governance, based on statewide standards; a portfolio of investments and incentives for multiple benefit water supply, water quality, and water-energy programs; efficient data collection; and a robust, ongoing outreach and education program that results in strong support for the vision from the public and business, economic, agriculture, and environmental sectors. The water sector working group included the California Energy Commission, State Water Resources Control Board, California Public Utilities Commission, Department of Water Resources and the Air Resources Board.

(2) **Supporting new and continuing data gathering, analyses and research related to better understanding water and energy supplies and demands, and related science.**

- For example, WaDE deployment represents a significant step forward in understanding and evaluating our water resources and future changes in demands, including energy, but will require a continuing commitment of resources from its partners. The Council has also consistently supported federal water data programs and projects that are critical for present and future decision-making.[25]

- The results of the RTEP study by Sandia integrated deliverables from different tasks, but future refinements will require updated data on water use and water supplies that WaDE deployment will facilitate. Moreover, continuing efforts such as the State of Texas' General Algebraic Modeling System (GAMs) models for each river basin and MODFLOW models for each aquifer system for regional water planning need support, will be beneficial.[26]

(3) **Promoting integrated water and energy conservation and use efficiency.**

- For example, a 2013 Independent Technical Panel's report to the California legislature recommended that the Department of Water Resources develop methodologies for estimating and reporting energy intensity. The California Public Utilities Commission has been tasked with developing a partnership framework between investor-owned energy utilities and the water sector, along with methodologies to measure the embedded energy savings and the cost-effectiveness of water/energy efficiency projects.

- The Energy Star and WaterSense programs provide consumers with information on water and energy related appliance choices. Many utilities, such as Southern California Edison, provide rebates for water and energy saving practices. State and local government agencies provide tax and other incentives to promote conservation.

- The Southern Nevada Water Authority (SNWA) offers a range of free services and rebate programs to homeowners and businesses. SNWA also offers free professional landscape designs, and under its Water Smart landscape rebate program, pays up to $1.50 per square foot of grass converted to xeriscape. Because energy resources -- like water

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[25] WSWC Position No. 345 regarding Federal Water and Climate Data Collection and Analysis Programs (October 12, 2012). http://www.westernstateswater.org/wp-content/uploads/2012/10/345-Position-on-WATER-CLIMATE-DATA_12Oct201211.pdf.

[26] Texas Water Development Board, 2006, Regional Water Planning. See: http://www.twdb.state.tx.us/ wrpi/rwp/rwp.asp.

resources -- are limited, SNWA continually strives to develop renewable energy options to treat and deliver water. SNWA renewable energy projects, primarily solar photovoltaic projects, reduce the use of fossil fuels.[27]

(4) **Seeking to minimize economic, environmental, and other costs of providing adequate, reliable, and sustainable supplies of water and energy.**

- As noted above, integrating water and energy conservation programs, such as joint energy/water audits, can help alleviate stresses on both resources and has the potential to save money, reduce waste, protect the environment, and strengthen the economy.[28] More efficient use can lower utility bills, reduce or delay the need for supply-side projects, and/or costs related to the withdrawal of water or extraction of energy resources, with resulting environmental and economic benefits.[29]

- For example, the California Energy Commission has stated that it will approve the use of fresh water for cooling purposes only where alternative water supply sources, alternative cooling technologies, and "zero-liquid discharge" technologies are "environmentally undesirable" or "economically unsound."[30]

(5) **Expanding public education, engagement, and outreach to highlight the importance, vulnerability, and interrelated nature of our water and energy resources.**

- The Foundation for Water & Energy Education provides balanced information regarding the use of water as a renewable energy resource in the Northwest by working with the general public, opinion leaders, teachers, school age children, and other interested groups. The public has become increasingly concerned with the costs and benefits of operating hydroelectric facilities. Environmental impacts, operational issues, economic needs, preservation of benefits such as flood control and recreation, and an increasingly complex regulatory and legislative atmosphere contribute to a public often lacking the clarity and information needed to make informed choices on water and energy issues.[31]

(6) **Ensuring decisions related to the siting, construction and operation of water and energy development projects include an evaluation and appropriate consideration of the interrelated impacts of such development.**

- Analyses of the water supply for power plants that are part of the Electric Reliability Council of Texas (ERCOT) found that as streamflows and reservoir storage drop in response to serious single and multi-year drought, thermoelectric generation could

[27] Southern Nevada Water Authority, 2013. SNWA Annual Report. See: http://www.snwa.com/assets/pdf/about_reports_annual.pdf.
[28] Young-Doo Wang, p. 50.
[29] Ibid, pp. 47-48.
[30] California Energy Commission, 2003. California Integrated Energy Policy Report. See: http://www.energy.ca.gov/reports/100-03-019F.PDF.
[31] Foundation for Water & Energy Education. See: http://fwee.org/about-fwee/about/.

be at risk of being de-rated due to the loss of cooling water.[32] Future siting decisions, as noted below, should consider water availability and the reliability of water supplies.

(7) **Tailoring the use of alternative cooling technologies and other energy-related options to the availability of water, and the opportunity costs related to other water uses.**

- In Arizona, the Gila Bend Concentrated Solar Project (CSP), a wet-cooled plant using groundwater was built on previous irrigated land and represents a net savings of water in this particular instance. However, the Arizona Corporation Commission denied the use of groundwater for cooling purposes for the proposed and now scuttled Hualapai CSP, which would have been construction on raw land. Rather it was required to rely on effluent for cooling purposes, due to the scarcity of water supplies for other purposes, including municipal use.[33]

- SNWA owns a 25% stake in NVEnergy's 570-megawatt Silverhawk Power Station, a clean-burning natural gas-fueled power plant that uses dry-cooled technology and supports SNWA's conservation efforts by using 90% less water than a typical water-cooled plant.[34]

(8) **Seeking to develop a diversified portfolio of water and energy resources and assets to maximize reliability and flexibility.**

- The WGA's 10-Year Energy Vision is a blueprint that adopts an "all of the above strategy" for diversifying our energy resources portfolio, and "promotes economic growth while protecting valued natural and environmental resources."[35]

- Falling reservoir levels at Lake Mead (which supplies 90% of Las Vegas' water and much of its power), coupled with limited local water supplies, have forced the Southern Nevada Water Authority (SNWA) to undertake extraordinary measures to diversify and secure a reliable future water supply by "banking" recharged water in Arizona, initiating a pipeline project to bring groundwater from eastern and central Nevada aquifers. SNWA is also completing construction of Intake No. 3, a 3-mile long tunnel to the bottom of Lake Mead that is one of the most complex and challenging tunneling operations ever attempted as part of a $2.9 billion capital improvement program. SNWA also provides tips for saving water and energy, as well as rebates.

- SNWA relies of hydropower from the Hoover, Parker and Davis dam system for approximately 12% of its energy needs, as well as employing energy recovery projects, rate-of-flow control stations, small turbines and induction generators. Since 2009, SNWA has incorporated photovoltaic technologies into its water system

[32] Y. Eugene Yan, Yonas K. Demissie, Mark S. Wigmosta, Vince C. Tidwell, Carey W. King and Margaret A. Cook, Potential Drought Impacts on Electricity Generation in Texas, American Society of Mechanical Engineers, ASME 2013 Power Conference, Paper No. 98318.
[33] Ibid., pp. 24-28.
[34] Ibid.
[35] Western Governors' Association 10-Year Energy Vision, 2013. See: http://www.westgov.org/images/dmdocuments/10%20Year%20Energy%20Plan%202013.pdf.

operations. SNWA joined with Sandia National Lab and the University of Nevada, Las Vegas, in establishing a solar photovoltaic regional test center at its River Mountains water treatment facility, which produces 180 megawatt hours of energy each year. Other solar facilities are incorporated into its Alfred Merritt Smith water treatment facilities and Wahoo Ranch in Spring Valley. These include solar covered-parking structures, and dual-axis tracking systems that adjust for the movement of the sun so as to capture 30% more energy than fixed panels.[36]

(9) **Taking advantage of synergies and economies of scale related to integrating water and energy conservation, development and protection programs and projects.**

- For example, water as a byproduct of energy production, such as various oil and gas production techniques, offer opportunities to address both water quantity limitations and water quality concerns related to energy. The WGA Drought Forum Webinar Series included a session entitled: Once Marginal, Now Crucial: The Growing Demand for Reused, Produced, and Brackish Water. However, some market opportunities have yet to be fully realized given challenges related to the capture, storage, and conveyance of produced waters, as well as sufficient demand to make large scale operations cost effective.

- The SNWA has forged partnerships with other agencies through the Silver State Energy Association to realize cost-efficient power purchases allowing for lower rates through shared costs, as well as jointly working to plan, develop, own and operate energy resources to meet their own needs and those of their customers, including pursuing alternative energy resources.[37]

(10) **Evaluating and integrating life-cycle costs related to water and energy supply development, conveyance, and transmission.**

- In California, water-related energy use, including water pumping for irrigation, consumes nineteen percent of the electricity produced in the state, as well as 30 percent of its natural gas, and 88 billion gallons of diesel fuel annually.[38]

- Another study estimated the energy and greenhouse gas footprint for seawater desalination versus imported surface water. Utilizing life-cycle analysis (LCA) techniques, they estimated that meeting the annual water needs of a typical Californian would require significantly greater energy compared to surface water, and that meeting the state's additional water demand in 2030 using desalination instead of less energy-intensive sources would result in 52% of California's total energy budget being allocated to water-related processes and activities.[39]

(11) **Integrating short and long-range water and energy supply planning.**

[36] Western States Water Council, 2015. Concentrating Solar Power and Water Issues in the U.S. Southwest. See: http://www.nrel.gov/docs/fy15osti/61376.pdf.
[37] Ibid.
[38] Lon W. House, Will Water Cause The Next Electricity Crisis? Water Resources Impact 9 (1), January 2007.
[39] Stokes, J., Horvath, A, Energy and Air Emission Effects of Water Supply, 2009. See: http://pubs.acs.org/doi/pdf/10.1021/es801802h.

- The recognition that growing competition for water could significantly impact the reliability and security of future energy production and electric power generation led Congress to direct the U.S. Department of Energy to develop an Energy-Water Research and Development Roadmap to identify current and emerging national issues and summarize some of the major challenges.[40] The lack of integrated long-term resources planning was identified as a critical need for effectively addressing energy-water interactions at a state, watershed, and regional level. As noted above, few states have any type of integrated water-energy program. California is an exception and may serve as a model for other states.

(12) **Promoting the development and use of "smart" technologies for management of water and energy demands and production.**

- SNWA provides rebate coupons for rain sensors that shut down your irrigation system, during and after rain, when it is not needed (50% of the purchase price up to $25), as well as smart irrigation controllers that adjust watering schedules according to the weather (50% of the purchase price up to $200). As water use declines, SNWA saves on energy for pumping from local groundwater supplies or Lake Mead, the level of which continues to fall due to drought.

(13) **Ensuring that the West maintains sustainable, reliable, and robust infrastructure systems necessary to deliver adequate supplies of clean water and energy to meet present and future needs.**

- Aging water supply and wastewater treatment and distribution infrastructure is a critical issue faced by every western state, and limitations on the conveyance of water from areas of abundance to areas of scarcity impacts energy development and other uses. Significant electric energy generation, transmission, and distribution problems constrain markets for traditional and renewable energy resources. Additional research and a commitment of financial and other resources is needed to evaluate and effectuate infrastructure improvements.

[40] Mike Hightower, Chris Caeron, Ron Pate, and Wayne Einfeld, Emerging Energy Demands on Water Resources, Water Resources Impact 9 (1), January 2007, p. 8.

Next Steps

WGA's leadership during the RTEP Project has been essential in bringing to light and taking the initial steps necessary to improve the information and data available for sound decision-making related to past, present, and future electric power generation and transmission planning, as well as highlighting the integrated nature of water and energy resources conservation, development, and management.

As described above, since adoption of Modification #1, a portion of the WSWC work performed in fulfillment of the Contract has been focused on the development and deployment of WaDE. Recently, under their RTEP grant, WGA has provided separate support to a few individual states to facilitate their connection to and deployment of WaDE.

With the completion of the RTEP work, WSWC member states and staff have pursued and secured grants from the EPA National Environmental Information Exchange Network (NEIEN or EN) program to continue WaDE work. WSWC staff will continue to assist member states in identifying other opportunities and securing potential grants to deploy WaDE.

Five partner states were selected – Texas, Oklahoma, Idaho, Oregon, and Washington – to participate in the EN grant application. Grant funds were also requested for the continuance of the WaDE program manager position through the partner state effort timeline. Incorporation of the WaDE data schema as a primary data flow would establish a vested interest in WaDE as a fully-fledged and rigorously documented web service within the EPA's existing data exchange framework. In fall of 2014, another NEIEN grant partnership was formed between California, South Dakota, Nevada, and WSWC to assist with the deployment costs and to continue coordination of the program. These grant partners are awaiting the NEIEN decision for grant awards.

Moreover, the WSWC and USGS have discussed the potential use of state WaterSMART grants, as part of a federally authorized national water use and availability assessment (Nation Water Assessment) and the National Water Use Information Program (NWUIP) to further assist states with data development.

Conclusion

Water scarcity in the West continues to define our economic opportunities, including development of our energy resources, consistent with environmental protection goals and our social values. A general lack of easily accessible data on water supply and demand limits policy and decision-makers' ability to budget for different water uses and balance energy and water demands. The metric team, WSWC, and Sandia's model work under the RTEP project has been very valuable. The development and the deployment of the WSWC's WaDE tool is a major step forward also, and the momentum built with the WGA's support and leadership will carry this effort far into the future.

APPENDIX A

Contractual Background and Governance Development

On September 4, 2009, the WSWC wrote to the WGA Executive Director committing to assist with the fulfillment of a number of tasks described in a WGA proposal, submitted in response to a Department of Energy (DOE) Funding Opportunity Announcement (FOA) subsequent to the federal Recovery Act (ARRA), related to Resource Assessment and Interconnection-Level Transmission Analysis and Planning.

DOE Secretary Steven Chu had announced the release of the FOA at the June 2009 WGA Annual meeting. The WGA FOA proposal was coordinated with the Western Electricity Coordinating Council (WECC), an entity representing private utilities, which managed Topic A, while WGA managed Topic B. Under Topic B, WGA proposed involving non-governmental organizations and regional stakeholders in "shaping the future of the Western Interconnection," as outlined in a September 30, 2009 letter to Secretary Chu. This work became known as the Regional Transmission Expansion Project (RTEP).

The letter to Secretary Chu noted that the WGA and WECC proposals would "…not only evaluate transmission needs of the West, but also assess impacts on critical natural resources, such as water and wildlife."[41] The proposed budget requested funds to support the Western Governors' Wildlife Council and pilot studies to help develop decision support systems. Similarly, WGA requested funds to support efforts to begin to integrate water resource constraints into regional electric power generation and transmission planning. The governors suggested that the "WGA proposal will go a long way toward helping identify, better define and promote policies, technologies and development to ensure the sustainable use of our water and energy resources."[42]

A WGA/WSWC agreement (WGA Contract Number: 30-230-60) was signed in November 2010, allowing for costs for work performed beginning November 20, 2009 and ending on April 29, 2015. The Scope of Work under Exhibit A outlined four specific areas of emphasis. The Council was to be reimbursed for staff time, travel and other allowable expenses, with compensation not to exceed certain limits as modified by mutual agreement. Other specific terms and conditions required semi-annual reports to WGA and quarterly ARRA-related expenditure reports. Reimbursement requests included approved budget figures, current expenses and cumulative expenditures.

Modification No. 1 (WGA Contract No: 30-230-70) was approved by WGA on January 3, 2012 and provided for a significant expansion of the initial agreement in order to provide for a new hire to assist in fulfilling certain tasks necessary to complete the work, and serve as the primary point of contact with DOE, Sandia and the other national laboratories, as well as WECC and other participants. The primary product of the expanded agreement was the development and deployment of a Water Data Exchange (WaDE) to help fill gaps in information, and synthesize and present data in a standard format related to water allocations, water use and water availability. The intent of WaDE was and is to "support the sustainability and repeatability of the National Labs' study, and help secure the most accurate and complete state water data available."[43] This work included the development of tools, data exchange schemas, exchange methods, web services and data access portals. The agreement also provided for

[41] Joint WGA/WECC letter to the Honorable Steven Chu signed by Montana Governor Brian Schweitzer, WGA Chairman, Idaho Governor Butch Otter, WGA Vice Chairman, and Louise McCarren WECC CEO.
[42] Ibid.
[43] WGA/WSWC Contract Modification No. 1, Exhibit A, Tasks

the acquisition of a server to house the data and host the application, which was determined to be the least costly option, compared to contracting out the hosting environment.

The initial WGA FOA Topic B and subsequent Statement of Project Objectives (SOPO) outlined specific water-related tasks to be performed with WSWC assistance (see Appendix B for final WGA SOPO Task 6.0). Those tasks included compiling information on the availability of existing water supplies (including water availability for energy development), current water uses and related demand projections, implications related to drought and climate change, as well as impacts on other future water uses. Other anticipated tasks included updating existing energy-water demand models and proposed scenarios to guide energy development and siting of transmission facilities so as to avoid conflicts, to the extent possible, with other water users. Topic B also included tasks in support of Topic A and WECC actions, including the creation of a State/Provincial Steering Committee (SPSC) and various workgroups, including the Scenario Planning Steering Group (SPSG) and Environmental Data Task Force (EDTF). WSWC members and staff have participated as SPSC and workgroup members.

Of note, the original WECC and WGA proposals included funding for technical assistance from the National Renewable Energy Laboratory (NREL), but subsequent discussions led both WECC and WGA to remove from their proposals any funds for work to be completed by the national laboratories. Rather, WECC and WGA communicated to DOE their need for technical support that the national laboratories might be uniquely suited to provide, with their hope that "funding will be available through other means to support this important work."[44]

Among other tasks, WGA was awarded funding to examine how water supply considerations may affect current and future electricity generation and transmission. Subsequently, DOE released a "Lab Call," and a consortium, with Sandia National Lab as the lead investigation team, was selected and funded to provide such support as WECC and WGA might need, under a separate DOE contract (See Appendix C). The national labs then developed their own related list of tasks, identifying deliverables, responsible partners (lead labs and others) and budgets. Those tasks related to water were performed in collaboration with the WGA and WSWC, with WGA oversight and the WSWC providing advice and assistance as described hereafter.

Initial Scoping Work

On April 7, 2010 a WGA webinar was held to inform WSWC members about the Regional Transmission Expansion Project (RTEP), provide an overview of the relationship between energy and water, introduce the work being done by the DOE national labs on this topic, and solicit feedback on the proposed approach. Tom Iseman and Alex Schroeder (WGA staff) provided an overview of the RTEP scope, timeline, and deliverables. Alex Davis, a WSWC member and Assistant Director for Water, Colorado Department of Natural Resources, provided information on the WGA proposal for incorporating water into regional electrical transmission planning. She described the potential role for WSWC members. Tom Carr, with the Western Interstate Energy Board (WIEB), provided an overview of the transmission planning process and the working groups established to provide input on the development of related scenarios, as well as opportunities for the incorporation of water information. Lastly, Vince Tidwell, Sandia National Lab and the consortium team lead, described a model to predict the impact of energy choices on water supply. He provided an overview of the energy-water model and past results,

[44] Resubmitted WECC Response to DE-FOA000068, Topic A, page 17 of 32.

explaining model capabilities and key inputs. Subsequent discussion focused on identifying resources for refining the model using state water supply and demand information.

Governance Structure

In a December 2010 memo from WGA to the State-Provincial Steering Committee (SPSC), RTEP participants were informed of the tasks and work plan for addressing the energy-water nexus as part of regional transmission planning, and the varying roles and responsibilities of the WGA, WSWC and Sandia National Lab were highlighted as part of a proposed governing structure for managing stakeholder engagement (Figure 1 and see Appendix D).

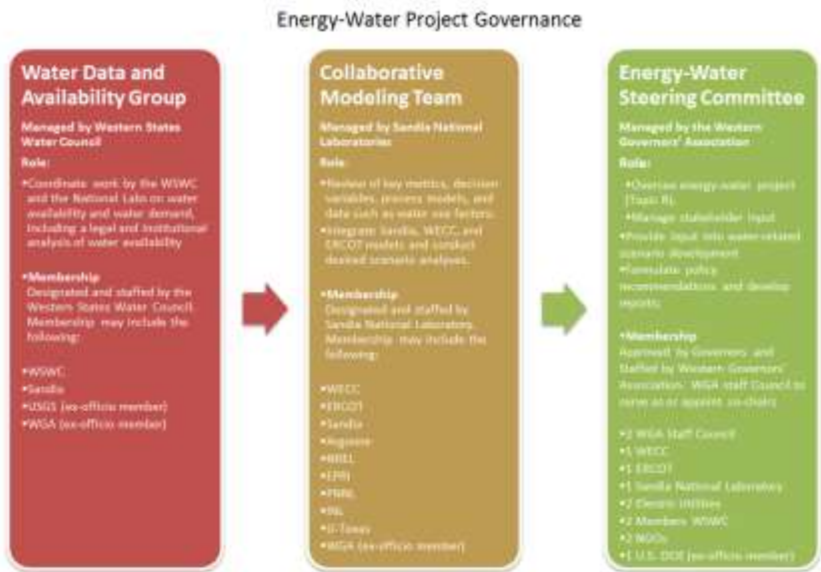

Figure 2. Governance Diagram from WGA December 2010 Memo

As part of the RTEP Project, WGA and WSWC were to work with WECC, DOE and the National Labs, and other stakeholders to "evaluate water resource issues associated with the siting, transmission and mix of energy supplies…. The goal is to understand the interconnections between energy and water and to develop strategies to promote generation and transmission plans that are compatible with available water supplies."

WGA and WSWC worked with the National Labs and WECC to incorporate technical information about water supplies, demand and availability into transmission planning, with the National Labs developing a water withdrawal and consumption calculator for various types of electricity generation technologies – then working with WECC to analyze the relative water consumption of different transmission study cases developed through the WECC scenario planning process. Data and preliminary analyses were developed for the WECC 2010 transmission reference case completed in early 2011. WGA and WSWC also worked with the National Labs, WECC and the SPSC to develop an extended drought study request that was accepted and used to evaluate the impacts of changes in temperature and precipitation on electricity generation under different transmission plans.

WGA and WSWC also worked with the National Labs to develop and refine state data for a regional model of water supply availability and future water demands. The model considered the physical, legal and institutional availability of water, with the intent of helping WECC and electric utilities identify and avoid areas of water scarcity. Initial state water supply information was used in WECC's transmission planning modeling efforts, including incorporating water availability as a limiting factor or cost, which appeared best suited to the 20-year model, which outlined broad considerations for future electric power generation and transmission.

The WGA and WSWC also worked together to identify best management practices and assess policy options for promoting electricity generation and transmission plans that are compatible with water supply availability. This included hosting a workshop of water and energy planning officials.

In order to accomplish all these tasks, a governance structure was established with a Water Data and Availability Group managed by WSWC to coordinate work with the National Labs on water demand and availability, with a legal and institutional analysis. Staffed by the WSWC, this group included WSWC members (and state agencies' staff), together with Sandia staff, with WGA and the U.S. Geological Survey as ex-officio members. Sandia managed a Collaborative Modeling Team that included WECC, a number of other National Labs, the Electric Reliability Council of Texas (ERCOT), the University of Texas and WSWC with WGA and DOE as ex-officio members. The team worked to integrate Sandia, WECC and ERCOT models and conduct desired scenario analysis, with the WSWC providing advice and review of key metrics. The WGA managed an Energy-Water Steering Committee overseeing the RTEP project and stakeholder input, including providing input into WECC's water-related transmission planning scenario development. WGA's role also included overseeing development of policy recommendations.

Outreach

Related to outreach efforts, the WSWC was invited to speak about the WaDE project at the National Ground Water Association (NGWA) annual meeting in May 2013. WSWC staff was also invited to speak on both the use of Landsat thermal data and the WaDE project at the Universities Council on Water Resources (UCOWR)/National Institutes for Water Resources (NIWR) annual conference in June 2013. These invitations included the submission of articles to UCOWR's peer-reviewed journal on water data initiatives and management, published in mid-2014. WSWC staff attended several conferences in 2013 – 2015 to further engage partners, and for additional outreach and exposure.

Policy Development

The WSWC role in assisting WGA with the development and implementation of potential policy recommendations included the work described under Task 1(a) to characterize water availability on a basin-by-basin planning level scale so as to direct energy development towards areas where more water is likely to be available and away from areas already closed to further appropriation or otherwise stressed. The national labs, with the expertise to evaluate the water efficiency of various technologies, also reviewed and compared different wet and dry-cooling options, with related costs, including estimates of lost power production efficiencies. Such work has led to some states in certain circumstances requiring power generation use less water intensive cooling option.

APPENDIX B

Western States Water Council Scope of Work

WGA and the Western States Water Council (WSWC) will work with state and provincial water managers and other agencies or regional authorities with responsibility for water supply management as well as experts on water requirements of electric generation technologies to evaluate water availability associated with the siting of electric generation and transmission in the Western Interconnection. The goal will be to anticipate challenges associated with water supply and energy demand by examining interrelated impacts. The information generated by this task will be important to the development and evaluation of electric transmission and generation scenarios generated under Topic A to ensure that they are feasible within existing and future water resource constraints of the West.

The WSWC will perform the following tasks to meet this objective:

1. Water Availability Assessment:
    a. Assist in compiling assessments from Western states and provinces regarding water availability, water consumption and withdrawals, and projected water demands for municipal/industrial, agricultural, and recreational/environmental uses.
    b. Assess current and projected water scarcity by large river basin or aquifer systems in the West, including from a physical and legal perspective.
    c. Consider drought and the potential implications of climate change and how they may affect river flows and water supply availability for energy development. Ideally, this will result in the development of a drought/climate change scenario that can be implemented as part of Topic A.
    d. Seek to identify opportunities for the use of non-potable water resources.

2. Legal and Institutional Analysis of Water and Energy: The WSWC will prepare an analysis of legal and administrative issues associated with new permits or transfers of water for energy development in Texas and the states of the Western interconnection, i.e., Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington and Wyoming. The analysis may include a handful of case studies on how water supplies are being provided or may be acquired for new energy projects and on how energy development is affecting water supply and management in the West.

3. Policy Development: Given the water supply impacts of proposed electricity scenarios, this task will seek to develop recommendations for policies and/or programs to facilitate sustainable energy development by:
    a. Identifying policies that promote water-efficient energy technologies such as: (1) incentives to direct energy development toward places with a sustainable supply of water; (2) facilitating water banking and trading mechanisms; and (3) encouraging energy and water conservation.
    b. Considering likely impacts to other water users and ways to mitigate or otherwise minimize those impacts.
    c. Assisting in convening water managers, electricity generators and regulators to make recommendations to the Governors and premiers for how electricity and water providers can better coordinate to ensure compatible development of these important resources.

4. Participate in the State and Provincial Steering Group (SPSC), the Scenario Planning Steering Group Environmental Data Task Force (EDTF), the work of the national laboratories, and other efforts under RTEP.
    a. The WSWC will serve as a liaison to the SPSC and EDTF to ensure that water impacts are incorporated into transmission scenario development and planning efforts.
    b. The WSWC will convene its membership to assist WGA and the national laboratories in assembling a model for water use by electric generation. This will include review of inputs to the model, its assumptions and methodologies as well as results from the model.

WESTERN GOVERNORS' ASSOCIATION

Contract Modification Form

MODIFICATION NO. 1

to the Agreement between
Western Governors Association
and
Western States Water Council

WGA Contract Number:	30-230-70	
Start Date of Original Contract	November 20, 2009	
Termination Date of Contract	April 29, 2015	
Purpose of this Modification	• Add funds ($251,363) to pay for a new hire (hydrologist/programmer) and acquire equipment necessary to complete work (see Exhibit A) • Add tasks to be completed by new hire (see Exhibit A)	
Previous Contract Amount: $102,082	Modification Amount: $251,363	Total Contract Amount: $353,445

IN WITNESS WHEREOF, the parties have executed this Modification to the above referenced Agreement as of the 20th Day of December, 2011 (Effective Date).

Western Governors' Association (WGA):

Pam O. Inmann 1/3/12
Pam O. Inmann DATE
Executive Director

Western States Water Council (WSWC)

BY: Tony Willardson

NAME: Tony Willardson

DATE: 12/23/2011

Exhibit A
Western States Water Council
Proposed Contract Amendment

The following is a written narrative to explain the scope of work and allowable expenses in hiring a Water Data Exchange Program Manager (hydrologist/programmer) to perform work under the terms of the agreement with the Western Governors' Association on Sub-Award Number: 30-230-70.

Agreement with WGA

The WGA and the Western States Water Council (WSWC) are working with state and provincial water managers and other agencies or regional authorities with responsibility for water supply management as well as experts on water requirements of electric generation technologies to evaluate water availability associated with the siting of electric generation and transmission in the Western Interconnection. The goal will be to anticipate challenges associated with water supply and energy demand by examining interrelated impacts. The information generated by this task will be important to the development and evaluation of electric transmission and generation scenarios generated under Topic A to ensure that they are feasible within existing and future water resource constraints of the West.

In order to fulfill the agreement and related tasks as outlined below, the WSWC proposes to amend the existing agreement to provide for a new hire and acquire equipment necessary to complete the work.

New Hire

The Western States Water Council will hire a hydrologist/programmer under a temporary (2-year) agreement with a potential extension subject to available program funding as mutually agreed upon by the WGA and the WSWC. This position is subject to a 6-month probationary period after which time the person will be evaluated to determine their ability to fulfill the assignment.

This individual will work under the direct supervision of the WSWC Executive Director and in close coordination with the WGA. They will also work in close coordination with the Federal Liaison staffed in the WSWC office, and with individual State water agency personnel in gathering and presenting water and energy related data. The position will also provide the primary point of contact with Sandia and other national laboratories, as well as WECC and DOE and other federal agencies.

Tasks

- **Develop an assessment of water supply, allocation, and demand (needs and uses) for the purpose of evaluating the potential impacts of electric generation and transmission on water supplies in the West**

- **Work closely with the DOE National Labs, the Western Electricity Coordinating Council, and the U.S. Department of Energy (DOE) for the purposes of completing a study of regional transmission planning in the Western interconnection**

  The hydrologist/programmer will be responsible for establishing a data exchange framework for use among the western states and with the Federal Government related to water allocations, water use, and water availability. This data exchange framework will support the sustainability and the repeatability of the National Labs' study, and help secure the most accurate and complete state water data available. The hydrologist/programmer will provide the necessary collaboration between the National Labs, WGA, WSWC, and the western states.

- **Collaborate with the states, the National Labs, and the Federal Government on ways of making data available in a standard format that can be synthesized and presented in order to understand the intersection of water and energy in transmission planning in the Western states using a services-based approach**

  The data and assessment that are developed should support national, state, and local decision makers – allowing them to better incorporate the availability of clean water into their water and energy planning efforts. (The western states have each developed various mechanisms for tracking, storing, and disseminating water information.)

  Part of the effort will be to work closely with the National Labs that are currently conducting state assessments, in order to identify the data necessary to support these assessments, identify methods to provide that data in a standard format using automated responses, and work with the states to develop methods to provide that data in this fashion. The individual will also work with the states and labs to ensure this information is incorporated into WECC's transmission planning and modeling, in order to evaluate the impacts of energy generation on water supplies in the West.

- **Work with Federal agencies to identify methods for exchanging their data in support of this effort**

  Various Federal agencies have data that contribute to the understanding of water availability and water use, particularly as it relates to energy. This individual will work with the Federal agencies to ensure coordination and collaboration between the collection and presentation of federal and state data.

- **Coordinate western state water information data exchange efforts**

  As part of their responsibilities, this individual will evaluate existing state water and water rights management data systems, identify similarities and differences between state systems, and work with a WSWC subcommittee to identify common data elements for data exchange and propose and document common methods for data exchange. This individual will also provide support and advice to states on modifications that they could make to their existing data management systems to better support the exchange of data

- **Develop tools, data exchange schemas, exchange methods, web services, and data access portals**

  As needed to help demonstrate the concept of a state-to-state water resources data exchange, and to provide support to the states to develop the capability to exchange data, this individual will develop data gathering, presentation and distribution tools.

The individual will also work through the WSWC Western Federal Agency Support Team (WestFAST) Liaison to engage in other national data exchange efforts, being led by various groups, including the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI), the U.S. Environmental Protection Agency's Exchange Network, and USGS's Water Census.

Also, in coordination with the WSWC's WestFAST Liaison, the individual will work with various Federal agencies that make up the Western Federal Agency Support Team (WestFAST) to identify Federal data sets that are critical to water planning and work with the Federal agencies to identify common exchange mechanisms that will support a broader water resources data exchange effort in addition to providing the data necessary to support the National Labs' study.

Salary/Compensation

The initial base salary estimate is $60,000/year, which with fringe benefits and taxes is approximately $93,000/year, for a two year total of $186,000. [We anticipate an initial salary offer below $60,000 with a promise of a 2% increase at six months and another 2% at twelve months. Moving costs and other related inducements related to the hire will be negotiated, but could range from $3,000-$5,000.]

Travel

Travel will be required approximately once a month, estimated at about four days/month. Travel expenses for work performed in this position will be paid with grant funds.

Calendar Year	Trip Location	Number of Days	Estimated Cost
2012	Albuquerque, NM	2	$800.00
2012	Salem/Portland, OR	3	$1,200.00
2012	Denver, CO	4	$1,200.00
2012	Austin, TX	2	$740.00
2012	Washington, DC	4	$1,750.00
2012	Washington State	4	$1,300.00
2012	San Antonio, TX	4	$1,200.00
2012	Phoenix, AZ	2	$790.00
2012	Boise, ID	2	$840.00
2012	Sacramento, CA	2	$710.00
TOTALS: 2012			**$10,530.00**
2013	Carson City, NV	2	$700.00
2013	Helena, MT	2	$1000.00
2013	Colorado[1]	4	$1,200.00
2013	Wyoming[2]	4	$1,380.00
2013	South Dakota[3]	4	$1,500.00
TOTALS: 2013			**$5,780.00**
TOTALS			**$16,310.00**

1 – Spring 2013 WSWC meeting. Budget estimate is for travel to Denver, CO. Meeting location has not yet been determined.

2 - Summer 2013 WSWC meeting. Budget Estimate is for travel to Jackson Hole, WY. Meeting location has not yet been determined.

3 – Fall 2013 WSWC meeting. Budget Estimate is for travel to Rapid City, SD. Meeting location has not yet been determined.

Estimated Costs for Equipment

Item Description	Cost
Laptop	$2,000
Windows 7 Professional	$300.00
Microsoft Office Professional 2010	$500.00
Microsoft Visual Studio	$800.00
Java Eclipse	Free

Item Description	Cost
Database Development Software	Free
TOTAL	**$6,100.00**
Optional: ESRI ArcGIS Desktop	$1,500.00
Optional: ESRI ArcGIS Explorer	Free

Development Servers

In order to demonstrate the capabilities of the tools developed under this project, the WSWC will need to either contract out the database and application hosting to an outside source (Option 1) or invest in two new servers (Option 2). The purpose of splitting the workload across these two servers is for security and performance reasons. It is not expected that we would require high-end servers for this project since storage space would be relatively low and the number of concurrent users would also be relatively low.

For budgeting purposes, we are budgeting for the 'Contract Hosting Environment' option (Option 1). However, once the new hire reports for duty, we will reevaluate Option 2 for its viability. Our preference will be to go with Option 2, but after further evaluation, if we determine that this option is not viable, then the Contract Hosting Option is the best fall-back option. We will choose only one of the following options; therefore, we have not included Option 2 in the proposed budget since the $15,000 proposed cost would cover the cost of those servers.

Option 1: Contract Hosting Environment

Item Description	Cost
Hosting Cost (15 months)	$15,000 ($1,000/month)
TOTAL	**$15,000**

Several companies can provide application hosting. We could contact ESRI to find out if there are options for coordinating this effort with them. Application hosting would not likely be required until the summer of 2012. For the purposes of this budget, we have estimated 15 months of hosting, with the option to extend as necessary.

Option 2: Mac OS 10.7 (Unix)/Oracle Environment (not included in the proposed budget)

Item Description	Cost
Database Server (entry level server)	$1,300
Application Server (entry level server)	$1,300
4 Terabyte External RAID Hard Drive (back-up and extra storage for the database server)	$999
Oracle 10g for Developers	Free, as long as it is only used for development and demonstration purposes.
Mac OS 10.7 Server	Included in price
TOTAL	**$3,599**
Optional: MySQL Database	$2,000 if we choose to go live with the application

Production level database capability could be provided by MySQL if we chose later on. Alternatively, OS 10.7 includes a database server called PostgreSQL which is free open-source database management software.

Exhibit A - Amendment

		2012		2013
Salary & Benefits	$	93,000	$	93,000
Indirect (19%)	$	17,670	$	17,670
Travel	$	10,530	$	5,780
Equipment				
Computer	$	2,000		
Software	$	3,100		
Server*	$	3,600		
Moving Expenses	$	3,000		
Annual Totals	$	132,900	$	118,463
Total			**$**	**251,363**

*Note: Server cost may increase to $15,000 if we need to contract with an outside server host

WESTERN GOVERNORS' ASSOCIATION

Contract Modification Form

MODIFICATION NO. 2

to the Agreement between
Western Governors Association
and
Western States Water Council

WGA Contract Number:	30-230-70	
Start Date of Original Contract	November 20, 2009	
Termination Date of Contract	April 30, 2015	
Purpose of this Modification	• This is a proposed budget modification to add funds ($23,850) to pay for continuation of work specified in this and prior contracts	
Initial Contract Amount: $102,082	Modification 1 Amount: $251,363	Total Contract Amount: $353,445
	Modification 2 Amount: $33,361	Amended Total Contract $386,806

IN WITNESS WHEREOF, the parties have executed this Modification to the above referenced Agreement as of the ____ Day of April, 2015. (Effective Date).

Western Governors' Association (WGA):

Western States Water Council (WSWC)

BY: Tony Willardson

Chris McKinnon DATE

Deputy Director

NAME: Tony Willardson

DATE: 4/10/2015

Exhibit A
Western States Water Council
Proposed Budget Modification 2

The following is a written narrative to explain the scope of work and allowable expenses to continue to perform work under the terms of the agreement with the Western Governors' Association (WGA) on Sub-Award Number 30-230-70.

Agreement with WGA. The WGA and the Western States Water Council (WSWC) have worked closely with state water managers, other agencies, and regional authorities with responsibility for water supply management, as well as experts on the water requirements of electric generation technologies (Sandia National Laboratory, the Western Electric Coordinating Council (WECC), and the Electric Reliability Council of Texas (ERCOT)), to evaluate water availability associated with the siting of electricity generation and transmission in the Texas and Western Interconnection. These activities included convening state and industry experts to develop a set of west-wide metrics that provide a relative, comparable measure of current and projected water availability and water demand for approximately 1,500 large watershed basins (on a HUC-8 scale). These tasks are in support of Task 1(a) (Exhibit A) to develop a water availability assessment. The final report, model interface, and related study data can be accessed on Sandia's *Energy and Water in the Texas and Western Interconnects* website[45]. WSWC has worked with the study team to refine and improve the datasets shared through the interface by coordinating extensive reviews of the data by state agency experts.

In order to provide direct support for this effort and to ensure the sustainability and repeatability of water-energy related studies like Sandia's, the WSWC initiated an affiliated project to work with its member states to establish a framework that will allow for access to state water allocation, availability, use, and planning data through a common portal. The project is referred to as the "Water Data Exchange" or WaDE Program by WSWC staff and council members. Much of the foundation work for WaDE has been laid: workgroups have collaborated on the best approaches and technologies for sharing datasets, a comprehensive survey of state capabilities has been performed, a data schema (common format) for the most commonly generated datasets has been developed, and the IT components for a functioning data exchange platform have been created and made available to the state water resource agencies. The deployment phase of the WaDE project – getting the member states "plugged in" to the system – constitutes the bulk of the work remaining before the WaDE portal can be widely released. A proposed budget modification for the continuation of activities can be accomplished within the timeframe set by this amendment is provided below.

Ultimately, it is envisioned that the models and metrics generated by the Sandia study cited above and the WaDE portal will be important tools for the evaluation and development of electric transmission and generation scenarios proposed under Topic A (FOA Project Narrative), and will ensure that proposed infrastructure development is feasible within the existing and future water constraints of the West. In order to fulfill its obligations and complete the related tasks as outlined below, the WSWC proposes to a budget modification related to the activities proposed in the original contract and within Exhibit A – Amendment.

[45] Sandia National Laboratory, Study of Energy and Water in the Western and Texas Interconnects. Website: http://energy.sandia.gov/climate-environment/water-security-program/energy-and-water-in-the-western-and-texas-interconnects/.

Assisting with State Deployments. As specified in Exhibit A – Amendment (page 2, bullets 3 & 4), the WSWC will continue to coordinate information data exchange efforts. This includes supporting and assisting state IT staff as they work through the process of installing the WaDE databases and web services code, and assisting with data-mapping of their native datasets to the WaDE database. A task that would facilitate this would be to compile and finalize all remaining documentation for "on-premises" and "in the cloud" deployment steps to install the Water Data Exchange (WaDE) application, using both SQL Server and PostgreSQL database management systems (DBMs). States that are currently working on deployments include Colorado, Utah, and Wyoming. Arizona and Nebraska are slated to begin the deployment stages soon. Other states are also working to install WaDE at this time, but are either receiving funds to do that work through an Exchange Network grant or are awaiting a grant award, and thus are not part of this amendment.

WSWC 2015 Spring Meeting. The WaDE project is a large, multi-state, multi-stakeholder effort. It is unique in many aspects. WSWC staff members and the WaDE Program Manager, have only three opportunities each year to personally and collectively interact with the directors of the agencies who have been or who are considering whether or not to participate in the data-sharing initiative. It is critical to maintaining the momentum and viability of the project for the WaDE Program Manager to present the project's status and other valuable information to the council members, and to cultivate relationships with those members. Aside from interacting with and engaging the directors and legal counsellors of the member states on their participation in the WaDE program, the Program Manager will be giving an update and demonstrating the functionality of the WaDE central portal.

WaDE is the single largest project that the WSWC is currently undertaking, and as such, it affects and/or relates to many, if not all, of the WSWC's efforts. As a result, questions regarding WaDE arise throughout the course of the WSWC's meetings and the WaDE Program Manager needs to be in attendance to answer and address them. Given the variability of the settings and interactions with council members related to WaDE, it is difficult to predict when and how these questions come up, and to categorize them as strictly water/energy and WaDE-related tasks or not. As similarly described on page three of Exhibit A – Amendment, the WSWC proposes that the costs for the WaDE Program Manager to attend council meetings continue to be a reimbursable item.

Federal Outreach Efforts. Exhibit A – Amendment (page 2, bullets 1 & 2) asks that the WaDE Program Manager "collaborate with states, the National Labs, and the Federal Government on ways of making data available in a standard format…" and "work with Federal agencies to identify methods for exchanging their data in support of this effort." In the final paragraph of page 2, the Program Manager is requested to work with WestFAST to engage with other national data exchange efforts, including the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI), the US Environmental Protection Agency's Exchange Network, and USGS' Water Census. These efforts allow the WSWC and WestFAST to identify what federal datasets are critical for water planning for western state water agency staff, and collaborate on ways to share those datasets. In Sandia National Laboratory's analysis of water supply and demand – the focus of much of the original DOE grant – federal datasets were utilized, especially where state data was in short supply. The publication of these types of datasets in an open, interoperable and easily discoverable format greatly increases the repeatability and cost effectiveness of Sandia's study. WSWC proposes to continue to work with USGS, the Exchange Network, with CUAHSI and other federal agencies to achieve the goals stated in Exhibit A – Amendment.

Legal and Institutional Availability. Related to Task 1 & 2 in Exhibit A, WSWC staff assisted Sandia National Laboratory to incorporate legal and institutional water availability constraints into their modelling as much as possible; however, WSWC continues to work on this issue by preparing an analysis and report on these and related issues, as specified in Task 2. A draft report has been circulated over the prior reporting period, and one out of three proposed case studies has been concluded. WSWC proposes to continue its work through the period covered by this amendment, to finalize and publish this analysis.

Estimated Budget Items	2015 - Q1	2015 - Q2 (April Only)	Item Total
Q4 2014 Overage	$ 9,511	$ -	$ 9,511
Salary - Sara (1/2 to TCEQ)	$ 12,500	$ 4,700	$ 17,200
Salary - Nathan	$ 2,000	$ -	$ 2,000
Salaries (Tony, Cheryl)	$ 2,000	$ 700	$ 2,700
Travel (see travel expense table)	$ 450	$ 1,500	$ 1,950
Quarter Total	**$ 26,461**	**$ 6,900**	**$ 33,361**

Detailed Budget Items	Estimated
Travel Expenses	
1/20/2015 - 1/22/2015 - Denver Co - 3 Days[1]	$ 450
4/14/2015 - 4/17/2015 - Tulsa, OK - 4 Days[2]	$ 1,500
Total	**$ 1,950**

1 USGS Water Use Strategic Planning Mtg.

2 2015 Spring Council Mtg.

APPENDIX C

NATIONAL LABS' PROJECT MANAGEMENT PLAN

Energy and Water in the Western and Texas Interconnects

October 15, 2010

WORK PERFORMED UNDER AGREEMENT

RC-BM-2010

SUBMITTED BY

Sandia National Laboratories

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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:

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 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.

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.

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).

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

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.

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**

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.

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 C-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

Tidwell, V.C. and Cors van den Brink, 2008, *Cooperative modeling: Linking science, communication and ground water planning*, *Ground Water*, 46(2), 174-182.

Cockerill, K.C., V.C. Tidwell, H. Passell, and L. Malczynski, 2007, Collaborative Modeling Lessons for Environmental Management, *Environmental Practice*, 9(1), 28-41.

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.

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.

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

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.

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.

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.

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.

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.

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

NETL 2007a. 2007 Coal Plant Database. Accessed online: http://www.netl.doe.gov/energy-analyses/hold/technology.html

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.

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.

A.S. Stillwell, C.W. King, I.J. Duncan, M.E. Webber and A. Hardberger, "The Energy Water nexus in Texas," Environmental Defense Fund and the University of Texas at Austin, April 2009. http://www.edf.org/documents/9479_Energy-WaterNexusinTexasApr2009.pdf

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.

M.E. Clayton, A.S. Stillwell and M.E. Webber, "A Model of Implementing Advanced Power Plant Cooling Technologies to Mitigate Water Management Challenges in Texas River Basins," *ASME International Mechanical Engineering Congress and Exposition*, Vancouver, British Columbia, Canada, 2010.

A.S. Stillwell, M.E. Clayton, M.E. Webber, "A River Basin-Based Model of Advanced Power Plant Cooling Technologies for Mitigating Water Management Challenges," *AIChE 20010 Annual Meeting*, Salt Lake City, UT, 2010.

NETL, 2007b. Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements. DOE/NETL-400/2007/1304, 2007.

NETL, 2008. Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements, 2008 Update. DOE/NETL- 400/2008/1339, 2008.

U.S. Department of Energy, National Energy Technology Laboratory, 2007, *Cost and Performance Comparison Baseline for Fossil Energy Power Plants*, May 2007.

Kobos, P.H., Cappelle, M.A., Krumhansl, J.L., Dewers, T., Borns, D.J., Brady, P.V. and A. McNemar, 2008, *Using Saline Aquifers for Combined Power Plant Water Needs and Carbon Sequestration*. 28th USAEE/IAEE North American Conference, New Orleans, LA, December 3-5, 2008.

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.

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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Ongoing project: Daniel Inman is managing a project to identify the water footprint of various energy crops based on a variety of crop, climate, and soil conditions. This work aggregates at the U.S. Department of Agriculture Production Region level. This work will be leveraged and its geographic scope expanded for this project.

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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) studies21 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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APPENDIX D

National Lab Support for the Water-Energy Nexus: WGA Priorities

July 6, 2010

Generally, we believe that the winning proposal on the Water-Energy nexus, submitted by Sandia National Lab and a consortium of partners, is thorough and responsive to WGA needs, and we are pleased that they were awarded the lab call. We use that proposal as a starting point for identifying priority and urgent tasks for WGA.

PROJECT MANAGEMENT:

Task 1: Project Management: Coordinate, communicate, contract, and manage project. We agree this is an important task, particularly given the breadth of tasks and partners who will be working on this project. Here we would emphasize that project management by the Labs must be responsive to the needs of the WGA and the Western States Water Council. This need for coordination is evidenced throughout the tasks described below and will be paramount to the ultimate success and acceptance of this project.

HIGH PRIORITY TASKS

Task 2: Water Withdrawal and Consumption Calculator: Identify the water consumption associated with different generation technologies and develop a tool to analyze the water consumption associated with different scenarios that emerge from the WECC transmission planning models. This will likely be the first task for this project; we plan to calculate the water consumption from WECC transmission scenarios as soon as fall 2010.

- Priority: High
- Timing for Initial Results: Immediate
- Cost Estimate: $100-$300k
- Who? Generally, we defer to Sandia and the project team.

Task 3: Water Demand Projection Model: Estimate future demands for water from a range of sectors, including energy but also agriculture, municipal, industrial, and environmental, in order to identify potential areas of future water scarcity. We support the subtask on energy extraction in particular.

- Priority: High
- Timing for Initial Results: Early 2011
- Cost Estimate: >$300k
- Who? As the proposal acknowledges, USGS has developed nation-wide and consistent data on water use, and this can be a starting point for this task. However, the Western States Water Council will need to be integrally involved in this task to ensure data are consistent with state plans and projections. We also recognize that private contractors may be able to contribute to this task.

Task 4: Water Availability Model: Provide a regional or watershed assessment of available water supply, from both a physical and legal perspective.

- Priority: High
- Timing for Initial Results: Early 2011
- Cost Estimate: >$300k
- Who? Again, USGS streamgaging and other data will provide a starting point for this task. However, the Western States Water Council will need to be integrally involved in this task to ensure data are consistent with state plans and projections. This is particularly true of the 'Water Institutions Tool' subtask, 'Water Policy Model,' and legal rights to the use of water. We also recognize that private contractors may be able to contribute to a water availability model.

Task 10: Scenario Analysis: Participate in the development and analysis of generation and transmission scenarios as part of the broader RTEP planning process. The particularly urgent aspect of this task is the analysis of water withdrawals and consumption from electric generation in the WECC transmission scenarios as soon as fall 2010. Longer term, we will need to work on the development of scenarios (including a drought or climate scenario) and the siting and technology of generation facilities based on water constraints, in addition to calculating the water consumption of WECC scenarios.

- Priority: High
- Timing for Initial Results: Immediate (esp as relates to analysis in fall 2010)
- Cost Estimate: >$300k
- Who? The labs will need to participate in this task, in conjunction with WGA, the Western States Water Council, and other transmission planning stakeholders.

New task: Model Integration: Determine how to integrate non-traditional data and information, for example for water and wildlife, into the WECC transmission model and planning process. Specifically, the lead lab will need to determine how/if to best integrate into both the short and long-term (the latter is currently out for solicitation) WECC transmission and reliability models. This will be addressed in part under the Scenario Analysis (Task 10). This could also relate to a simplified Water Cost Calculator (see Task 7), which could help to integrate relative water costs into planning.

- Priority: Medium
- Timing for Initial Results: Late 2010 or Early 2011

<u>**MEDIUM PRIORITY TASKS**</u>

Task 5: Environmental Controls Model: Identify and assess potential environmental risk associated with growing water use and climate change. We agree that environmental impacts, including to endangered species and water quality, will be one dimension of this analysis. However, this is a secondary question and one we do not expect to answer conclusively in this project. In addition, there may be other impacts, for example to agriculture, that could equally be considered in examining the energy-water nexus.

- Priority: Medium
- Timing for Initial Results: Mid 2011
- Cost Estimate: $100-$300k.
- Who? We would note that many other partners, including the USFWS, state wildlife agencies, and conservation non-profits, may have input on this topic. In addition, the Environmental

Data Task Force under the SPSG will be looking at environmental issues relating to water use and other impacts of electricity development.

Task 6: Climate Change Calculator: Estimate potential changes in water availability due to climate change within the study area. As part of the scenarios, we will want to examine how climate change will affect water availability. However, many other experts are examining this question, including universities and federal agencies. In addition, climate change is only one aspect of the energy-water equation, and yet it could easily consume the entire budget of the lab call. We would emphasize that this task should employ existing research and focus on simple scenarios that can be used for transmission planning, such as how decreased generation from hydro in the northwest would affect the rest of the Western Interconnect and how increased strain on water supply would influence the selection of generation technologies. It should not seek to provide the definitive analysis of climate impacts to water resources in the American West.

- Priority: Medium
- Timing for Initial Results: Early 2011 (for input to WECC scenarios)
- Cost Estimate: $100 - $300k (could be higher, but we recommend limiting the budget for this task)
- Who? We would highlight the climate modeling work underway in other venues and emphasize the need to provide simple and useful scenarios in the context of transmission planning. The budget for this task should reflect this priority.

Task 7: Water Cost Calculator: Develop information on the potential cost of water for new withdrawals, including for electricity generation. Yes, water costs will be a potential factor in electricity development and how it may impact other current water users, especially agriculture. In addition, the current WECC model is a cost-based model, so information on the relative costs of new water supplies will be useful. However, water economics and market transfers will be a secondary consideration to the fundamental analysis of the water associated with different generation and transmission scenarios.

- Priority: Medium
- Timing for Initial Results: Mid 2011
- Cost Estimate: $100k-$300k
- Who? As the proposal describes, academics (including Gary Libecap at the Bren School) are compiling information on water transfers and markets. This information should not be duplicated. Generally, we need high-level information on the relative costs of water for this analysis, not a detailed market analysis.

New Task: Agricultural Impacts Model: Assess magnitude and impacts of potential water transfers from agriculture to energy development. Impacts could include loss of farmland and food production, decline in agricultural/rural economies, loss of open space and habitat, and loss of culture and heritage. This task could relate to the Environmental Controls Model and Water Cost Calculator.

- Priority: Medium
- Timing for Initial Results: Mid 2011

<u>LOW PRIORITY TASKS:</u>

Task 8: Energy for Water Calculator: Assess the amount of energy needed to pump, treat, and distribute water. While this is a critical question with respect to the energy-water nexus, it is not the focus of the WGA project, which examines water needed for energy. Unless the amount of energy used for water is significant enough that water efficiency can be a demand-side strategy in the transmission planning process, we do not see this task as a priority. (Water efficiency could be a demand side opportunity but it's not focus of this transmission analysis which is in water for energy.)

- Priority: Low
- Timing for Initial Results: Long-term.
- Cost Estimate:

OTHER:

Task 9: Decision Support Interface: Develop a user interface that encompasses all of the model inputs and that provides access for use by other stakeholders and future users. We recognize this will be a useful tool long-term and for other applications, and we support the development of a user interface at the completion of this project.

Task 11: Reporting: Report on progress, outcomes, and budgets associated with energy-water project. We recognize the need for reporting.

APPENDIX E

WESTERN GOVERNORS' ASSOCIATION

To: **State-Provincial Steering Committee**
Fr: **Western Governors' Association**
Re: **Project Update: The Energy-Water Nexus and Regional Transmission Planning**
Dt: **December 2010**

This document is intended to inform participants in the Regional Transmission Expansion Project (RTEP) of the tasks and work plan for addressing the energy-water nexus as part of regional transmission planning. As part of the U.S. Department of Energy's (DOE) transmission planning grants, the Western Governors' Association was awarded funding to examine how water supply considerations may affect current and future electricity generation and transmission in the Western interconnection. DOE is also funding a consortium of national labs, an effort being coordinated by Sandia National Laboratories to provide technical assistance to the energy-water analysis. A close working relationship between WGA and WECC and stakeholders will be essential to the success of this project. WGA will work to ensure that its work plan fits seamlessly with the broader transmission planning project.

Background: Water managers in the West are preparing for increased competition for the region's limited and geographically variable water supplies, due to rapid population growth, the lack of new supplies, and the potential impacts of climate change. The siting and transmission of new and mixed energy supplies will be influenced, and sometimes dictated, by the availability of water. At the same time, the siting of new energy supplies will influence the ability of agricultural, municipal, environmental and recreational users of water to meet their needs.

A 2007 report by the National Energy Technology Laboratory (NETL) concluded: "freshwater consumption (for new thermoelectric generation) in 2030 will increase by 42% to as much as 63% compared to 2005." The report noted that the greatest increases in water consumption would occur in several western regions, including California (274%), the Northwest (85%), and the Rocky Mountain/desert southwest region (85%)[1].

As part of the Regional Transmission Expansion Planning Project, WGA and the Western States Water Council (WSWC) will work with the Western Electricity Coordinating Council (WECC), DOE, the National Labs, and other stakeholders to evaluate water resource issues associated with the siting, transmission and mix of energy supplies in the Western Interconnection. The goal is to understand the interconnections between energy and water and to develop strategies to promote generation and transmission plans that are compatible with available water supplies. In conjunction with partners, WGA has developed a work plan for this project:

Assessing the relationship of Energy and Water in Transmission Planning: WGA will work with the National Labs and WECC to incorporate technical information about water supplies, demand, and availability into transmission planning. Specific tasks include:

1. <u>WECC Transmission Plan Analysis:</u> The National Labs are developing a water withdrawal and consumption calculator to assess the amount of water used by various types of electricity

[1] *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements: 2007 Update*, DOE/NETL-400/2007/1304, September 24, 2007, Revised May 8, 2008

generation technologies. WGA and the National Labs will work with WECC to analyze the relative water consumption of different transmission study cases developed through the WECC planning process. The National Labs and WECC are already exchanging data and the preliminary analysis of the WECC 2010 transmission reference case should be completed by early 2011.

2. Extended Drought and Climate Assessment: WGA is working with the RTEP State and Provincial Steering Committee (SPSC), National Labs and WECC to develop an extended drought and/or climate change study request. If accepted by WECC, this study request will allow WECC to analyze the impacts of changes in precipitation and temperature on electricity generation under different transmission plans. The proposed study case will be available in January 2011 for use by WECC in the 10-yr and 20-yr planning models.
3. Water Supply and Demand Model: WGA and the Western States Water Council (WSWC) will work with the National Labs to develop a regional model of water supply availability and future water demands. The model will consider the physical, legal and institutional availability of water. The model will allow WECC and electric utilities to identify areas of available water supply and to avoid water-intensive electric generation in areas of potential water scarcity. WGA, WSWC, and the labs are currently working to incorporate state water supply plans into the model; an initial version of the model will be available in late 2011.
4. Technology Selection and Siting: WGA will work with WECC and its various committees to ensure the transmission planning model appropriately focuses on water availability as a factor in model development. Given recent discussions with WECC, it appears the 20-yr model may be the best venue for addressing technology selection and siting; water can be incorporated as a 'limit' or 'cost' in the 20-yr model. This effort can begin in January 2011.

Formulating regional policies and best practices with respect to the Energy-Water Nexus: WGA and the WSWC will identify best management practices and assess policy options for promoting electricity generation and transmission plans that are compatible with water supply availability.

1. Energy-Water Case Studies: The WGA and WSWC will develop several energy-water case studies to look at current challenges, practices, and options for providing water supplies to new electricity generation projects. We will select a diversity of generation types and geographic settings. A first set of case studies focusing on solar and water should be available by May 2011 with the full suite of case studies should be complete by December 2011.
2. Energy-Water Policy Development: WGA will work with stakeholders to identify best management practices and develop policy options for addressing the energy-water nexus. Options may include new cooling or generation technologies, protocols for coordinated energy-water planning, and alternatives for managing transfers of water among competing uses in water scarce areas. In addition to the technical analysis and case studies, WGA will rely on discussions with the Governors and their staff advisory council to complete this task. Discussions with the Governors will commence at the 2010 WGA winter meeting and will continue throughout the project. This task will culminate with a report and policy recommendations to the governors in June 2012 or after.

Project management and stakeholder engagement: Ultimately, WGA is responsible for performing the Energy-Water tasks as described in Topic B of the DOE Grant. WGA will work to engage and collaborate with partners, manage consultants and tasks, and ensure that energy-water considerations are being incorporated into the WECC transmission planning process for the Western Interconnection. Task management will be organized by three primary teams: 1) *Water Data and Availability Group* led by the WSWC; 2) *Collaborative Modeling Team* led by Sandia National Lab; and 3) *Energy-Water Steering Committee* led by WGA. These groups are currently being populated and are conducting initial meetings. (See figure below)

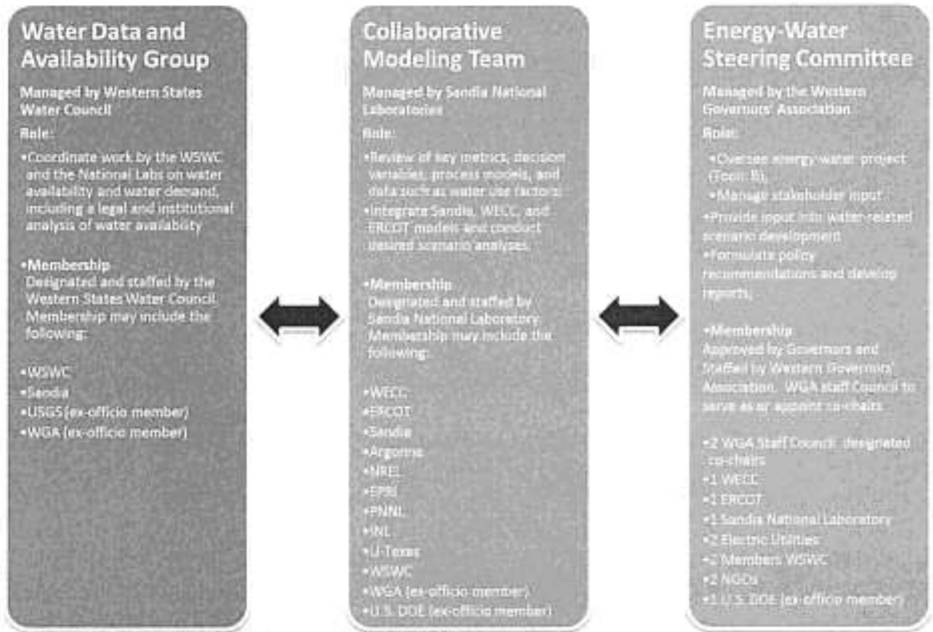

Figure 1 - Proposed Project Governance and Stakeholder Engagement

The *Energy-Water Steering Committee* will include high-level policy staff from the Governors' offices and other participating institutions and is designed to oversee the project, promote stakeholder engagement, formulate policy recommendations, and sign off on work products. One initial step may include a broad stakeholder engagement meeting to kick off this project in spring 2011.

Next Steps: WGA and the Energy-Water project team will brief the WECC, SPSG, and SPSC on progress regularly and as requested. Alexandra Davis will brief the SPSC on the energy-water work at the meeting in San Diego on January 11-12. We will be convening the *Energy-Water Steering Committee* in early 2011. If you have any comments or suggestions or would like a detailed briefing on this project, please contact Tom Iseman (tiseman@westgov.org) or Alex Schroeder (aschroeder@westgov.org) at WGA. briefing on this project, please contact Tom Iseman (tiseman@westgov.org) or Alex Schroeder (aschroeder@westgov.org) at WGA.

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The energy sector is the fastest-growing water consumer in the United States. Projections attribute 85% of the growth in domestic water consumption between 2005 and 2030 to the energy sector.

As part of the Regional Transmission Expansion Planning Project, WGA and the Western States Water Council (WSWC) will work with the Western Electricity Coordinating Council (WECC), DOE, the National Labs, and other stakeholders to evaluate water resource issues associated with the siting, transmission and mix of energy supplies in the Western Interconnection. The goal is to understand the interconnections between energy and water and to develop strategies to promote generation and transmission plans that are compatible with available water supplies. In conjunction with partners, WGA has identified the following key areas as part of its work plan for this project:

Assessing the relationship of Energy and Water in Transmission Planning: WGA will work with the National Labs and WECC to incorporate technical information about water supplies, demand, and availability into transmission planning. Specific tasks include:

1. <u>WECC Transmission Plan Analysis:</u> Sandia is developing a water withdrawal and consumption calculator to assess the amount of water used by various types of electricity generation technologies. WGA and Sandia will work with WECC to analyze the relative water consumption of different transmission study cases developed through the WECC planning process. Sandia and WECC are already exchanging data and the preliminary

analysis of the WECC 2010 transmission reference case should be completed by January 2011.

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4. Technology Selection and Siting: As appropriate, WGA will work with WECC and the transmission planning model, with a particular focus on water availability as a factor in model development. Given recent discussions with WECC, it appears the 20-yr model may be the best venue for addressing technology selection and siting; water can be incorporated as a 'limit' or 'cost' in the 20-yr model. This effort can begin in January 2011.

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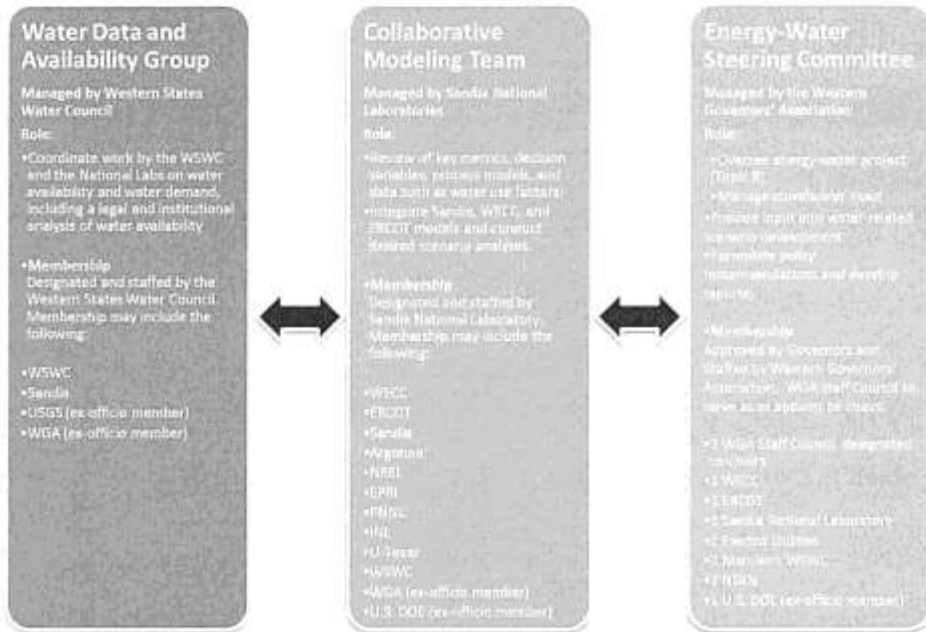

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Next Steps: WGA and the Energy-Water project team will continue to keep the WECC, SPSG, and SPSC apprised of progress as appropriate. Alexandra Davis will brief the SPSC on the energy-water work at the meeting in San Diego on January 11-12. We will be convening the *Energy-Water Steering Committee* in early 2011. If you have any comments or suggestions or would like a detailed briefing on this project, please contact Tom Iseman (tiseman@westgov.org) or Alex Schroeder (aschroeder@westgov.org) at WGA.

APPENDIX F

POSSIBLE WATER DATA SOURCES & CONSIDERATIONS FOR TRANSMISSION PLANNING PROJECT

	State Water Planning Process	Energy-Water Policy or Energy-Water Demand Projections	Ground Water Districts/ Management Areas/Control Areas/Designated Basins, etc.	Basins Closed to Further Approp./Over Approp. Basins	Restrictions or Limits on Transfers	State Energy Office/ Dept.	Moratoriums on Certain Types of Energy Development	Pending General Stream Adjud.	Instream Flow Protections	Compacts-Tribal & Interstate	Prior Approp. or Reasonable Use
AZ	X		AMAs/INAs	X	irrigation district consent needed to transfer water out of district boundaries	X		X	statute	X	reasonable use outside of AMAs/regulated inside AMAs
CA	X		special act districts/local control over gw		temporary transfers cannot unreasonably impact fish, wildlife, and instream uses	X	moratoriums on new nuclear & certain coal plants	X	statute	X	correlative rights but also prior appropriation and prospective rights – no state permits
CO	X		gw management districts & boards/designated basins			X			statute	X	prior appropriation
ID	X		gw recharge districts		corporation consent for transfers of water rights represented by corporate stock	X			statute	X	prior appropriation
KS	X		gw management districts			X			statute	X	prior appropriation

MT	X		control areas	X		X		X	statute	X	prior appropriation
NE	X		natural resources districts	X	consideration of 7 factors for interbasin transfers	X			statute	X	correlative rights
NV	X		designated basins			X		X	case Law	X	prior appropriation
NM	X		designated basins	X	ditch companies can object to transfers/ transfers cannot be detrimental to public welfare or conservation	X		X	AG opinion	X	prior appropriation
ND	X					X			indirect administrative mechanisms	X	prior appropriation
OK	X		basin annual maximum yield surveys		limits on out-of-state water sales	X				X	reasonable use
OR	X		critical GMAs/basin programs		express legislative intent for out-of-basin diversions	X		X	statute	X	prior appropriation
SD	X		?			X			indirect administrative mechanisms	X	prior appropriation
TX	X		gw conservation districts			X			institutional recognition through administrative review process	X	rule of capture
UT	X	provides amount of fresh water used for	gw management plans	X	municipal water districts cannot sell water rights	X		X	statute	X	prior appropriation

		thermoelec. power (58 mgd)[i]									
WA	X		WRIAs/ designated areas			X	moratorium on certain new coal plants	X	statute	X	prior appropriation
WY	X	projections - Ch. 6 of SWP	control areas		temporary restrictions on transfers from agriculture / conservancy districts cannot transfer water outside boundaries unless boundaries are amended	X		X	statute	X	prior appropriation

APPENDIX G

WSWC – WGA Energy-Water Nexus Workshop Summary Report

April 2, 2013 – Denver, CO

The Workshop Scope, Goals and Outcomes

The Western States Water Council (WSWC) and the Western Governors' Association (WGA) co-sponsored a workshop on water and energy nexus topics pertinent to water and energy planners, and utility managers on April 2nd, 2013, in Denver, Colorado. The intended audience of the workshop was a diverse group of energy managers and interests, water district managers and interests, researchers, and environmental stakeholders from private, public and the academic sector. The purpose of the workshop was to present new information on water/energy research being conducted throughout the West and across the nation, that was thought to be helpful and informative to the attendees. The workshop was also intended as a forum for examining topics that the Council or WGA could review for emphasis when making recommendations to the western states' governors. For example, topics covered by the speakers and the breakout sessions included, but were not limited to: water used for energy extraction, different energy supply sources, renewable energy development, water use trends and emerging technologies, new tools for quantifying resource risk, innovations in data sharing, and programs for taking an integrated approach to energy and water resources for statewide water planning efforts.

The workshop was attended by approximately 60 people in person. An additional 10 attendees participated via webinar, for a total of approximately 70 attendees. The invited speakers addressed a wide range of topics, and were able to provide a significant update on the status of water-energy nexus research being conducted. A latter portion of the workshop was reserved for breakout sessions, where attendees would be able to answer questions (either provided to begin discussion or self-selected), and give feedback on what they'd heard during the presentations. These were moderated and directed by group moderators, who summarized the groups' discussions and "reported back" on the results to the other attendees at the end of the workshop.

Speaker Summaries

The workshop began with remarks from Tony Willardson, Executive Director of the WSWC. He welcomed the workshop participants and explained the origin of the workshop and its intended scope and goals. Tom Iseman, the Water Policy Program Manager at WGA, also made remarks on his agency's interest in and support of ongoing water and energy nexus research being conducted. He anticipated hearing more about these efforts, and then hearing the thoughts of the participants during the workshop breakout sessions. Tom then introduced the keynote speaker for the workshop, Commissioner Jim Tarpey.

Commissioner Jim Tarpey, Colorado Public Utilities Commission – Energy and Policy Perspectives on Water in the West

Jim Tarpey began by discussing the regulatory process for the Colorado Public Utility Commission (PUC) and its relationship to other major utilities. He reviewed the statutes within Colorado that relate to public utilities, and the two specific statutes that would relate to water and energy nexus topics. One observation of interest presented by Commissioner Tarpey was that the Colorado PUC is recognized under Colorado's state constitution, as opposed to creation by statute, which gives them the ability to address issues akin to the state legislature. If the state legislature leaves a perceived gap in addressing an emerging issue, the PUC can work to fill those gaps. Commissioner Tarpey described the traditional approach of the PUC for evaluating proposed energy projects, indicating that a cost/benefit approach was used where least economic cost was typically the main criteria that led to new projects. This process was used until the mid-nineties. At that time, Colorado PUC began looking at projects with a new approach that viewed energy development from a portfolio perspective, and considered a wider variety of factors for new development. The Colorado PUC now considers such things as 1) whether the project promotes the development of rural economies; 2) whether the project minimizes water use; 3) whether the project diversifies Colorado's energy portfolio; 4) whether the project reduces the impact of volatile energy pricing; and 5) whether the project improves Colorado's natural environment. Commissioner Tarpey emphasized that debate amongst the interested parties is a good thing, and that the Colorado PUC would like more entities to become involved in the planning process.

Brad Nickell, Western Electric Coordinating Council (WECC) – Incorporating Water into Long-Range Electricity Transmission Planning

Brad Nickell began his presentation by describing the organization of WECC, from the utility level to sub-regional to the interconnection level. The Transmission Expansion Planning Policy Committee (TEPPC) is the governing body of the planning community within WECC, and is charged with building infrastructure such that the system works now and well into the future. This includes compliance monitoring and enforcement when necessary, as well as managing the planning process and standard development, which are brought through various committees. WECC is focused on public policy directives that influence the energy industry, and pulls together state and federal policy for this sector. WECC has the capability to help coordinate the aggregation and dissemination of datasets that are important to long-range transmission planning. They also provide a forum for facilitation and discussion between stakeholders. Water has always been an issue for energy generation planning, but had never been incorporated as a specific modeling parameter until now. Mr. Nickell discussed the scenarios that WECC was reviewing for the coming decade, into 2022. He estimated that 60% of WECC's portfolio at that time would use water for cooling processes and that, even though this was still a relatively small piece of the "water use pie," it was important because energy generation is one of the fastest growing consumers of water. WECC conducts long-range planning and this is where the new water data from a study by Sandia National Lab would be applied. Models show that there is an incremental increase in water usage, and importantly, places where they are running into water availability limitations are in renewable energy zones and major gas-trading hubs. Their models also look at different cooling technologies such as wet versus dry, and what kinds of tradeoffs that result in terms of geography and climate. Mr. Nickell discussed the opportunities presented by WECC's collaboration with Sandia to evaluate water supply sources and cost to develop those sources. Some of the data have been incorporated, while some are still too politically sensitive to ingest into models. He indicated there is a need to take advantage of these collaborative opportunities and leverage them, such that there is increased confidence and reliability in their long-range planning models.

Paul, Faeth, CNA Corporation – Policy Analysis for the Energy-Water Nexus at the Electric Reliability Council of Texas (ERCOT)

Paul Faeth first discussed what kind of entity CNA is, and its role in water and energy planning for ERCOT. CNA is a private, non-profit company that conducts research studies, including work on the energy-water and climate nexus. The study presented at the workshop was funded by a regulatory assistance project focused on helping public utility commissions address water issues. CNA evaluates the results of these studies and has the ability to incorporate water into them. CNA models included 19 different energy generation options and a wide variety of policy scenarios, which were extrapolated out to a 30-year horizon, given fixed costs for certain model parameters (capital and fuel costs). The results from the models will be published in May or June of 2013. A site specific example, the population in Texas is estimated to grow by 4 million people every 10 years, and power demand is project to increase up to 73%. Projections also suggest that wind costs will decrease by 25% over the same timeframe, but CNA models look at both the decrease and no decrease in wind cost scenarios. They also incorporate other policy issues such as a carbon tax or cap. Mr. Faeth presented the baseline scenario as well as several other permutations of the CNA models for the ERCOT region to show what effects these might have on water withdrawals and on carbon dioxide emissions. The takeaway message from the models is that a decrease in the cost of wind would result in a baseline scenario that is favorable to both water consumption and carbon emissions.

Vince Tidwell, Sandia National Laboratory – Energy and Water in the Western and Texas Interconnects

Vince Tidwell, the principal investigator for a major water-energy nexus project funded by the Department of Energy, presented some background information on their study. He discussed the project's goals and how they were working with WECC and ERCOT to supply comprehensive data for their long-range transmission planning (a horizon of 20 years). He presented data on the water consumption factors for various electricity generating technologies, and gave an example of the spatial water consumption factors for coal facility water use (i.e. how local climate can impact water use by the same energy generation technology). He also discussed the climate component of the study. This portion evaluates climate variability, drought scenarios and changes in water demand. This portion also looks at the vulnerability of power generation systems due to lowered lake levels and thermal effluent temperatures. Results indicate that a single year drought (using the drought of record – 2011) would not significantly alter operations, but that multiple year droughts would have some impact on Texas' energy generation. The effluent limitation analysis suggested that operations would be very near their thermal limits in future summers. Mr. Tidwell also presented on a series of water availability metrics that were developed by his research team and a volunteer team of water experts. The metrics included different water supply sources (appropriated and un-appropriated surface water, potable and brackish groundwater, and wastewater reuse), as well as current and future water demand trends. Much of the data was taken from state water agencies via direct interaction or from online sources. These metrics, as well as associated cost for development, were aggregated to an 8-digit hydrologic unit code (HUC) scale to provide a more comprehensive and comparable dataset on water availability and cost across the West. When comparing new water supply sources to the projected change in demand by sector, it was found that just developing un-appropriated water supply sources would not be sufficient to meet demand, but that use of the entire water supply portfolio would meet water demand in most locations. Mr. Tidwell summarized several other facets of the study efforts, including a metric for environmental limitations to water supply development, water for fuel extraction, an energy for water provision calculator, and a water data exchange where the Sandia data would be able to provide their results and access the latest planning data available from state agencies.

Jeanine Jones, California Department of Water Resources – Ongoing Energy/Water Research in California

Jeanine Jones highlighted California's long history of planning for energy and water. In the past, these were not coordinated efforts, but the acknowledgement of climate change impacts resulted in new initiatives to force coordination between the resource planning agencies. State legislation was passed in 2006 that mandated reduction in greenhouse gas (GHG) emissions; in particular, the 2005 Governors' executive order to create a climate action team (CAT), resulted in the creation in a number of "kittens," – subcommittees named RCAT and WETCAT. California became very interested in embedded energy because of a discussion about how much was needed for the movement, treatment and use of water in the state. This high energy use is exacerbated by climate change due to an increase in water demand, and also the energy demand for other parts of the water supply and use cycle, such as groundwater pumping. Snowpack is projected to decline at mid-elevations, which also increases vulnerability. California's Department of Water Resources is the largest energy consumer in the state. Ms. Jones discussed the Public Interest Energy Research (PIER) Program, highlighting their significant contribution to the research surrounding water-energy nexus topics, and indicating that they have been replaced with a new program known as the Electric Program Investment Charge (EPIC). She then discussed some of the new requirements for formal planning within the state for energy and water development, including recommended actions addressing water use efficiency, water recycling, water system energy efficiency, reuse of urban runoff, increased renewable energy production and a public goods charge for water. Ms. Jones also highlighted some of the benefits of state interagency research coordination, such as reduced duplication of effort, standardization of global climate models and emissions storylines used for state planning programs, and facilitation of program implementation.

Eric Evenson, US Geological Survey (USGS) – Federal Perspectives on the Nexus: A Water/Energy Partnership

Eric Evenson began his presentation by pointing out that water and energy are two parts of a three-legged stool, which also includes food production. He suggested that agricultural production should be included when discussing the nexus. USGS would like to better understand the fluxes of material between each, but it would require a level of detail for water use data that is not currently possessed. He discussed USGS' efforts to quantify how much water is used by the thermoelectric power generation sector, including both withdrawals and uses, categorized by fuel type and cooling technology employed. USGS is working with the Energy Information Administration (EIA) to address recommendations made by the Government Accountability Office (GAO) concerning these trends. These efforts also include developing a process to involve stakeholders to improve data collection and dissemination. Their current research elucidates patterns related to withdrawal amounts and cooling type that vary by geography. The East Coast is dominated by a pattern of once-through cooling, while saline water use dominates along coastal areas, and closed loop plants are more prevalent in the West. The overall budget for plants in the continental U.S. is dominated by once-through cooling. However, from a consumptive use standpoint, cooling towers have the greatest consumptive use, with recirculating ponds playing a lesser role.

Doug Larson, Western Interstate Energy Board (WIEB) – Water and the Western Interstate Energy Board

Doug Larson began his presentation by describing the role that WIEB plays in energy planning for the West. They are planning for load growth, and the West has some of the best solar, wind and geothermal energy potential. He also discussed the role of coal, which is inexpensive but in decline. Many coal plants are faced with major retrofits in order to comply with air quality regulations. With regard to water, a lessening of coal as energy generation fuel will reduce water needs in the West. Natural gas is more flexible, and can be located in urban areas with transportation infrastructure. It is also more easily ramped up and ramped down. Mr. Larson also discussed new generation capacity that will be coming online in the next decade, stating that the portfolio presented is a result of a mix of variables that include cost, state policy and resource flexibility. Renewable energy is also expected to increase, most of which is driven by state renewable portfolio standards (RPS) requirements. Within the solar arena, the two available options vary with respect to water resources – photo-voltaic (PV) solar requires very little water, while concentrated solar power (CSP) uses more. A technology to look into with respect to the water sector would be dry-cooled CSP technology. Mr. Larson indicated that the electric sector could benefit greatly if better water information were available.

Richard Belt, Xcel Energy – Long-Term Water Strategies for Energy Utilities

Richard Belt presented on water and energy nexus issues related to a local energy utility, reminding the audience that all water issues are inherently local. He reviewed the projected breakdown of uses for the state of Colorado in 2050, pointing out that, of the 3% projected to be used by self-supplied industries, only 50% was used by thermoelectric energy generation. There are many strategies that can employed by local energy providers concerning water supply. Xcel uses a "little bit of everything" approach to diversifying its water portfolio. These strategies include the procurement of direct flow water rights/storage, self-supplied or contract supply, native basin and trans-basin diversions, and recycled wastewater. Xcel focuses on supply integration and on maximizing supply flexibility. They are also focused on increasing their engagement with stakeholders and water providers. Some strategies employed with regard to drought include cooperative agreements with both the municipal and the agricultural sectors. These can consist of contracts, trades ,"unique" arrangements, interruptible supply, and use of recharge credits. Mr. Belt presented on Xcel's water stewardship program, which addresses plant process improvements and greater incorporation of water reuse. It also includes reviewing new technologies surrounding water use, such as combine-cycle gas generation, hybrid cooling, wastewater recycling, incorporating renewables into their portfolio, and demand side management.

Jordan Macknick, National Renewable Energy Laboratory (NREL) – Energy Production and Water Use Trends

Jordan Macknick began his presentation with a visual review of historic water withdrawals by sector from 1950 – 2005. The graph presented illustrated the dramatic rise in withdrawals for the energy sector over that time span. Energy-water nexus research conducted at NREL has been to quantify both the operational water consumption and the operational water withdrawals necessary for each of the major subgroups of energy generation technologies. NREL has also conducted research on the implications of generating electricity based on various combinations of energy types, from an energy portfolio that had a heavy coal composition, including carbon capture and sequestration, to that with a phase-out of coal to a higher percentage of renewable technologies. This evaluation also broke the projected water use down by 18 different regions across the US. A life cycle analysis (LCA) of water use by major groupings of energy generation was also presented. LCA takes a "cradle to grave" look at the costs or impacts of a specific technology or policy. Mr. Macknick discussed specifically the water use of shale gas extraction during hydraulic fracturing, explaining its variability, but generally less than what is required for operations. He presented a comparison of shale gas wastewater management trends, which indicate that there is a trend away from surface water discharge in Pennsylvania, while that trend is reversed in Colorado. He summarized his talk with a restatement of national trends toward a more constant rate of withdrawal over the past 30 years, and by suggesting that these withdrawals and uses may change depending on various regional factors and the fuel systems and cooling systems chosen.

Jessica Shi, Electric Power Research Institute (EPRI) – Innovative Water Saving Technologies for the Electric Power Sector

Jessica Shi began her presentation by discussing the role EPRI plays in sponsoring innovative technology development through their Water Conservation Program. She provided background information for, and a breakdown on, the membership of EPRI. The Water Conservation Program was initiated in 2011, and seeks to develop "out of the box," game-changing cooling and water treatment ideas with a high potential for water conservation. Their first collaborative round resulted in 114 proposals and several white papers, solicited from national and global collaborators and from all EPRI sectors (environment, nuclear, generation and power distribution unit). Ms. Shi provided several examples of project proposals that had the potential to save significant quantities of water that were currently under investigation. These ranged from the effects of reducing condensing temperature on steam turbines to increase efficiency, to heat absorption by nanoparticles added into a coolant during the cooling phase of energy production. Several other potential projects were presented that dealt with hybrid dry/wet cooling, reverse osmosis membrane self-cleaning techniques, and the integration of membrane distillation and use of degraded water supply sources to decrease the use of potable water. Ms. Shi also discussed the details of an upcoming joint solicitation that will be issued by the National Science Foundation (NSF) and EPRI, before summarizing their joint efforts to date.

Robert Goldstein, Electric Power Research Institute (EPRI) – WaterPRISM: Water Availability and Resource Risk Management

Robert Goldstein presented on WaterPrism, a new decision support framework for managing water resource risk. Drivers for the development of the WaterPrism tool include electric power reliance on water resources, the need to manage environmental, regulatory, reputational and financial risks, and the need to establish a roadmap to sustainability given the complexities of water/energy systems. The design of the software includes data on the available surface water and groundwater storage for a given watershed, as well as population, demand, and land use data. The combination of these supports a regional water balance that compares the projected water demand with the available water. The tool's functionality has been demonstrated by two pilots in the Green River Watershed in Kentucky, and the Muskingum River Watershed in Ohio. The datasets required for the runs were gathered and some demand management strategies were incorporated into the scenarios. The interface has the ability to show the savings of each strategy over a business-as-usual (BAU) baseline. It can also show the impact of decommissioning power plants that are less water efficient and conversion to other energy generation supply sources such as natural gas. WaterPrism allows the modeler to look at scenarios as they are evolving, and provides localized, fine resolution decision support.

Sara Larsen, Western States Water Council (WSWC), WaDE: A Water Data Exchange for Energy/Water Utility Planners

Sara Larsen first described the water/energy nexus work being conducted by Sandia National Laboratory, emphasizing the difficulty that the Labs had gaining access to and aggregating state water data. At the same time, the WGA and WSWC began discussing the possibility of sharing data between the states. State water planning data contains flow records for streamgages, water supply budgets, estimates of use, physical and legal availability and allocation data. These data collection efforts and estimates reflect local knowledge. States want their data to be published, so they agreed to initiate the Water Data Exchange (WaDE) project as a means to do so. WaDE's goal is to enable the states to start sharing water data with each other, the public and with federal agencies, while also encouraging federal partners to adopt standardized data schemas and publish relevant datasets using web services. Ms. Larsen explained how the WaDE framework was distributed so that the data remain at the state hosts' sites instead of transferring databases back and forth. Data are returned in an interoperable format using XML and REST-based web services. It will provide important water planning data estimates. Some data are gathered by the states, some are not, but the schema is something that the states can work toward. The states will continually be asked to answer national and regional questions about water availability and uses in the future. Participation in WaDE allows the states to be proactive about publishing their data to a variety of partners.

Nathan Morris, Nebraska Department of Natural Resources, INSIGHT: Integrated Water Resource Tools

Nathan Morris presented on Nebraska's new INSIGHT program, which is short for Integrated Network of Scientific Information and Geo-Hydrologic Tools. He described the purview of the Nebraska Department of Natural Resources as overseeing surface water rights, while the natural resource districts that cover the state administer groundwater. INSIGHT will integrate a variety of data and provide a centralized comprehensive set of records to support management decisions for Nebraska and broader efforts. The final product will use a mapping format, which will make the information easy to access by the public and other stakeholders. These will benefit by having access to data about water uses, demands and available supply. INSIGHT information is integrated and published used three primary mechanisms: the data management framework, the web-mapping framework and a web interface for data viewing and retrieval. The viewing interface will be a combination of looking at information for each basin of interest, including pictures and a summary of the water supply sources and uses, as well as a timeline of that supply and use over many years for a longer perspective. INSIGHT is undergoing testing, and will likely be complete in July of 2013.

Breakout Session Summaries

After the presentations, the attendees were subdivided into groups for a breakout/discussion section to be held in an adjacent room. Each group had a moderator assigned to them and was given four questions to get their discussion going. If none of the questions were of interest to the group, they could propose a question and answer that instead.

Yellow Group – Questions and Answers

Yellow group was moderated by Tom Iseman of the WGA. His group selected three questions to answer. Question One: What data are still needed for energy and/or water planning? The group expressed the need for water availability data that is inter-seasonal, spatial and for a variety of water supply sources, including definitions of water availability related to physical, legal, political, social and environmental factors. It was suggested that some of this data is available, but that they need to be more timely and comparable between areas or regions. This may include cost information about the water, and could encompass a life-cycle analysis of different sources and their impacts on other sectors. Some regions have more pressing issues related to water availability than others. Question Two: How does energy development planning in your region impact the water sector? For some group members, a concern is the movement of water from the agricultural sector to the energy sector. There is a need to consider feedback loops, and the local economic and demographic changes caused by this transfer of use. There is a need to determine the amount of water used for new technologies of energy extraction and if there is a trend toward increasing use. Question Three: How is lack of data (for either energy or water activities) a constraint to good planning? This depends on the state doing the planning. A question was posed about what the drivers are for starting to include certain types of data into a planning process. This could be either a crisis or a proactive approach to a perceived emerging issue. Sometimes it’s not a lack of data that is the problem but a lack of being able to find the data. They need to be centralized, comparable, and easily accessed.

Green Group – Questions and Answers

Green group was moderated by Vince Tidwell of Sandia National Lab. His group selected three questions to answer. Question One: Is there (enough) interaction between energy and water planners? The group used examples of water and energy groups working jointly on projects to demonstrate some instances of cooperative planning (i.e. Colorado Water Resources and Xcel Energy, Pacificorp, Manitoba Water Works and hydropower operations). The group looked for more opportunities for collaboration between the two resource groups, noting that many of these instances for cooperation were a result of environmental or endangered species concerns. Question Two: What are some of the most important energy/water models and data that are being used by energy/water resource planners? The group cited several instances where models were used to answer water/energy related questions, such as watershed models to prove up water rights, or decision support systems for evaluating new developments. Forecasts for streamflow and climate models are being incorporated into hydropower operations and environmental regulation for use on different time frames. The group noted some gaps in modeling tools include a linkage between hydropower with broad power dispatch modeling, and with more variable renewable energy sources. There is also a lack of incorporation between each resource group (i.e. water only recently being integrated as a parameter or constraint to planning, energy use planned into water development, etc.). Question Three: What are some of the main issues with energy used for the water supply and consumption cycle? In many cases, a lack of good data is a primary constraint to identifying issues with energy used for water provision, despite energy cost being a significant factor in overall operating budgets. Using renewables to power water provision provides an outlet from the negative feedback loop created by increasing energy use for water provision.

Blue Group – Questions and Answers

Blue group was moderated by Tony Willardson of the WSWC. His group worked to address two their possible questions. Question One: Concerning water/energy efficiency and conservation, what are some of your strategies? The group specified several options for both energy and water demand side management strategies. Education and outreach were seen as very important to establishing more of a conservation ethic related to both resources. Some regions facing scarcity may need to mandate some level of water conservation, or simply adopt new water-related regulations (i.e., watering lawns only at night). It was suggested that pricing water in such a manner that encourages conservation was a very effective strategy. Question Two: What is your organization’s vulnerability to extended drought? Energy providers are vulnerable to drought in terms of their water available for withdrawal for cooling at the facility, as well as by regulation of effluent temperatures. Energy producers do have options during a drought, which include paying agricultural irrigators to fallow their fields, or purchasing/leasing senior water rights. In this manner the agricultural sector acts as a buffer during extreme drought years. States also have the right to exert emergency measures for either sector in extreme cases of drought.

Red Group – Questions and Answers

Red group was moderated by Nathan Bracken of the WSWC. His group focused on one question that was of import to the group. How can energy planners take long-term drought or climate change into their planning? The group felt that energy planners needed to be proactive about addressing this issue. They would need to consider cross-boundary impacts, and the drivers of the drought/extreme weather. Group members desired to see agencies plan for the extremes of their forecasts instead of averages. This could include new approaches for determining what those extremes are. FERC relicensing processes could include and work to address climate change impacts. Increasing energy portfolios to include more drought resilient sources of energy (such wind, photo-voltaic solar, and small-hydro) was also an option. Multi-scale planning would be needed – working from local to regional to national levels. New technologies that conserve water should be fostered, while other cooling technologies that have more intensive water use could possibly be limited. Establishing a framework and encouraging the use of water markets could also provide additional flexibility in the face of a prolonged drought or climate change.

Conclusion

After the breakout/discussion session, the groups' moderators and the participants met back in the conference room to report on the answers to the questions they had discussed. Each moderator explained their questions and answers to all other participants. Tony Willardson also discussed the "next steps" to be taken by the WSWC with regard to publishing the results of the current workshop, and the need for continuing a dialogue about energy and water in the future, with the possibility of conducting more workshops that built on the information gathered that day. He commented on the breadth and depth of the topics and research that had been presented by the speakers that day. He also noted that the breakouts had provided much needed insight and some excellent suggestions for further inquiry.

APPENDIX H

WSWC and WGA Contract 30-230-60 and Modification #1 30-230-70
Related WSWC Activities and Deliverables

The following items correspond to the specific tasks for the "Resource Assessment and Interconnection-Level Transmission Analysis and Planning" grant project as set forth in the WSWC's Scope of Work which is found in Exhibit A of WGA Contract Number 30-230-60 and Modification #1 30-230-60.

Task 1(a)

- 2009 – WECC and WGA initiated the RTEP project.
- 9/2009 – WSWC and its Water-Energy Subcommittee identified first pilot states for participation in the project and began data gathering with Sandia[ii].
- 10/2010 – WSWC staff prepare a matrix of available state data available.
- 11/2010 – Contract 30-230-60 is signed by WSWC and WGA.
- 1/2011 – WSWC, WGA and Sandia began update/briefing meetings every third Wednesday of each month to coordinate efforts and ensure good communication between all parties.
- 4/2011 – WSWC hosts the Sandia research team at the 2011 Spring Council meeting to present their study proposal to members and discuss a schedule for data-gathering.
- 4/2011 – WSWC surveyed its members regarding state policies, data, and analysis of the impacts of electricity development on water availability.
- 4/2011 – With the help of its WestFAST liaison, WSWC completed a report on water availability studies and began to coordinate with USGS and other federal agencies on how water availability estimates from the states could inform federal efforts[iii].
- 7/2011 – WSWC initiated a water data exchange project that would ensure the sustainability and repeatability of the RTEP project by allowing real-time access to state water data.
- 7/2011 – WSWC began efforts to inventory and characterize what data the states collect, how they collect them, how they are stored, etc[iv].
- 7/2011 – WSWC initiated and coordinated workgroups for analysis of state data capabilities and methodologies, as well as the data schema (format) and technical approach for a data exchange project that would support the Sandia water availability assessment and other related studies[v].
- 7/2011 – WSWC approved the creation of a new position to work with WGA and Sandia on the water availability assessment project, and oversee the development of the data exchange project.
- 12/2011 – Contract 30-230-60 Modification #1 Signed.
- 12/2011 – WSWC hired Sara Larsen to be the water data exchange project manager. (See Mod#1, Pg. 1, Para. 3)
- 1/2012 – present – Based on information provided by the states, WSWC began working and continued updating the data schema (WaDE schema v0.1) allowing for perpetual sharing of the more common elements of state-generated data[vi]. (See Mod#1, Pg. 2, Para. 6&7)
- 1/2012 – 7/2013 – WSWC conducted outreach visits with states' water agencies and federal agencies to inform and encourage participation in the Sandia water availability assessment study and the WSWC data exchange project, and to review the proposed data schema. (See Mod#1, Pg. 2, Para. 2&5)

- 1/2012 - Attended WECC/WGA/WSWC/Sandia RTEP study kickoff meeting. All parties discussed project details, roles, and refinements to deliverables to WECC for their bi-annual long-term planning tool (LTPT) deadlines. As per WGA request, Sandia agreed to step up their data acquisition from the states for a new deadline of June 2012. WSWC agreed to provide Sandia team members with state agency contacts for their analyses, and to help convene a team of experts to review Sandia's proposed methodology for water availability and demand metric development. (See Mod #1, Pg. 1, Para. 5&6)
- 2/2012 – WSWC and Sandia held a coordination meeting in Albuquerque, NM on the RTEP study[46].
- 2/2012 – WSWC provided contacts to Sandia research team for state agency participation from Nevada and South Dakota.
- 2/2012 – WSWC held an Executive Committee call to propose that state agency experts be assigned to the existing WSWC Methods Workgroup to hold bi-weekly conference calls with Sandia to "[provide] advice on development and evaluation of the water availability metric, together with WGA"[47].
- 3/2012 – WSWC conducts a webinar for all council members to discuss the RTEP study. Vince Tidwell presented on Sandia's data collection and analysis and how they would provide the data to WECC for their LTPT models. WSWC staff also presented on the WaDE concept and how that would be used to support future studies and analyses similar to Sandia's.
- 3/2012 – Tom Iseman, Vince Tidwell, Dwane Young and Sara Larsen attended the 2012 Spring Council meeting in Washington, DC to present the RTEP study to council members[48].
- 4/2012 – WSWC coordinates the first water/energy metric webinar that will inform Sandia's efforts. WSWC and Sandia coordinate metric group meetings weekly and biweekly as needed through May 2012. Participants include the following: Sara Larsen, Dwane Young, Tony Willardson, WSWC; Tom Iseman, WGA; Todd Stonely, Utah Division of Water Resources; Barry Roberts, VinceTidwell, Barbie Moreland, Barry Norris, Katie Zemlick, Sandia National Lab; Andy Moore, Colorado Water Resources Board; Ken Stahr, Oregon Water Resources Division; Dan Hardin, David Mitamura, Texas Water Development Board; Bret Bruce, US Geological Survey; Steve Wolff, Wyoming State Engineer's Office. (See Mod #1, Pg. 1, Para. 5&6)
- 4/2012 – WSWC provides state agency contacts to Sandia for Washington, New Mexico and South Dakota, and Montana
- 6/2012 – WSWC presents a detailed overview of Sandia's methods, metrics and preliminary results at the 2012 Summer Council meeting. WSWC also presents on the work being performed for the (then named) WaDE project, which is intended to support and improve long-term data accessibility. (See Mod #1, Pg. 1, Para. 5&6) and (See Mod#1, Pg. 2, Para. 6&7)
- 6/2012 – Sandia gave preliminary results to WECC for incorporation into their LTPT models.
- 7/2012 – present – WSWC began infrastructure component development for WaDE[vii]. (See Mod#1, Pg. 2, Para. 6&7)
- 7/2012 – WSWC hosted a Water Information Data Subcommittee (WIDS) call to discuss temporal/spatial/methodological scale issues and whether WSWC could seek additional funding for

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[46] Western States Water Council, Sandia National Laboratory. RTEP In-Person Meeting Agenda – January 2012. Webpage: (http://www.westernstateswater.org/wp-content/uploads/2015/03/a1_20120210_MeetingAgenda_Sandia.pdf).

[47] Western States Water Council. Executive Committee Conference Call Notes, held on February 2, 2012. Webpage: (http://www.westernstateswater.org/wp-content/uploads/2015/03/a2_0224-2012-Executive-Committee-Conference-Call.pdf).

[48] Western States Water Council. 2012 Spring Council Meeting, Washington DC – Powerpoint Presentation by Tom Iseman. (http://www.westernstateswater.org/wp-content/uploads/2015/03/a3_Iseman-WSWC-energy-water-March-2012.pdf).

longer term viability of the data exchange project. WSWC also discussed doing a WaDE demonstration during the 2012 Fall Council Meeting. (See Mod#1, Pg. 2, Para. 6&7)

- 9/2012 – WSWC and Sandia conducted a user interface development webinar to discuss interface options and determine how Sandia results/data will be integrated into WaDE, and how Sandia and others will access WaDE data in the future for repeat studies. (See Mod #1, Pg. 1, Para. 5&6)
- 10/2012 – WSWC staff presented on their ongoing QA/QC work with Sandia, and on the WaDE infrastructure development at the 2012 Fall Council meetings. Council members express a desire to review the data in a mapped format instead of using spreadsheets. (See Mod #1, Pg. 1, Para. 5&6)
- 10/2012 – 12/2012 – WSWC worked with Sandia to create the Sandia Data Review online map application by which the states can review the metrics spatially and provide feedback to the Sandia team. (See Mod #1, Pg. 1, Para. 5&6)
- 11/2012 – WSWC and WGA held online meetings with ESRI and Sandia on Water Availability Assessment and WaDE hosting on ESRI's ArcGIS Online cloud solution. (See Mod #1, Pg. 1, Para. 5&6)
- 11/2012 – WSWC submitted application for Exchange Network funding for WSWC to continue coordination of the WaDE program and to help the five partner states (TX, OR, WA, OK, and ID) with costs. (Mod#1, Pg. 2, Para. 2&5)
- 1/2013 – WSWC staff prepared strawman agenda and began preparations to host a water/energy nexus planning agency workshop in Denver, CO. (See Mod #1, Pg. 1, Para. 5&6)
- 1/2013 – WSWC coordinated the reassembly of the original water metric development team to work on an "environmental" water metric that addressed energy development water impacts on riparian and environmentally sensitive species and environments[viii]. (See Mod #1, Pg. 1, Para. 5&6)
- 2/2013 – WSWC and WGA coordinated with Stanford on potential dashboards/applications to be built using data from Sandia's water metric data and/or WaDE data. (See Mod #1, Pg. 1, Para. 5&6)
- 2/2013 – WSWC participated in environmental metric development calls. (See Mod #1, Pg. 1, Para. 5&6)
- 3/2013 – WSWC began first round of data review teams to vet the Sandia water availability and demand estimates. Data reviews continued through the winter of 2013. (See Mod #1, Pg. 1, Para. 5&6)
- 3/2013 – WSWC assisted with editing and contributed to peer-reviewed publications on the Sandia water availability assessment metrics and related studies[ix]. (See Mod #1, Pg. 1, Para. 5&6)
- 4/2013 – WSWC hosts energy/water workshop in Denver, CO. The workshop assembled 13 speakers from a wide-range of agencies and perspectives, and a diverse group of attendees (about 75 including webinar participants), to discuss ideas for more strategic joint management of water/energy resources. Breakout sessions were also conducted facilitate a dialogue among participants. WSWC published a summary report of this event[x]. (See Mod #1, Pg. 1, Para. 5&6)
- 5/2013 – WSWC attended the University Council On Water Resources (UCOWR) conference for increased visibility and participation, and also submitted a related peer-reviewed journal article on Landsat and the WaDE data program to the UCOWR Journal on Water Resources[xi,xii]. (Mod#1, Pg. 2, Para. 2&5)
- 6/2013 – WSWC updated the Council on the Sandia data review progress and on infrastructure development for WaDE at its summer meetings in Casper, WY.
- 7/2013 – WSWC attended the Consortium of Universities for Advanced Hydrologic Sciences Inc. (CUASHI) Hydroinformatics Conference for outreach. (Mod#1, Pg. 2, Para. 2&5)

- 7/2013 – WSWC and partner states are awarded requested grant funding from the Exchange Network to assist with WaDE deployment. (Mod#1, Pg. 2, Para. 2&5)
- 7/2013 – WSWC, Sandia, Argonne National Lab members and Stanford's Water in the West representatives met to discuss what a water availability DSS dashboard might look like, how it would be implemented and how it would integrate with WaDE. (See Mod #1, Pg. 1, Para. 5&6)
- 7/2013 – WSWC publishes the WaDE v0.2 of its data schema document, and a Flow Configuration Document (FCD)[xiii], which is a guide for both installers and users of the WaDE web services, and an "Issues and Recommendations" report[xiv]. (See Mod#1, Pg. 2, Para. 6&7)
- 7/2013 – As per recommendation of Technology Workgroup, WSWC reconfigured WaDE web services programming code to match the Exchange Networks' Representational State Transfer (REST) service standard specifications. (See Mod#1, Pg. 2, Para. 6&7)
- 8/2013 – WSWC coordinated the final review of Sandia data. All metrics and related publications were updated. Final results were given to WECC for incorporation into the next round of LTPT modeling. (See Mod #1, Pg. 1, Para. 5&6)
- 10/2013 – WSWC presented updated Sandia metric data results at the 2013 Fall Council meeting. Members were concerned about confusion over whether state generated data would be mixed up with Sandia metric results, and asked that the Sandia metric data not be included as part of the WaDE datasets, but otherwise made accessible. (See Mod #1, Pg. 1, Para. 5&6)
- 10/2013 – 5/2014 – WSWC assisted Sandia with both training and the initial set up of their own map application depicting the results of the water availability assessment metrics. (See Mod #1, Pg. 1, Para. 5&6)
- 11/2013 – WSWC assisted with editing a book chapter related to the RTEP study authored by Iseman and Tidwell[xv]. (See Mod #1, Pg. 1, Para. 5&6)
- 1/2014 – WSWC provided linking information and graphics so that Sandia can link back to the WaDE central portal. (See Mod #1, Pg. 1, Para. 5&6)
- 1/2014 – WSWC established a steering committee to oversee and coordinate the FY2013 EN grant work[xvi]. (Mod#1, Pg. 2, Para. 2&5)
- 1/2014 – WSWC assisted Utah and Wyoming state water agencies with initial deployment steps.
- 2/2014 – WSWC attended the 2014 Exchange Network Annual Conference to engage with the EN governance and introduce the WaDE project to the EN community. (Mod#1, Pg. 2, Para. 2&5)
- 5/2014 – With WSWC assistance, Sandia publishes the water availability assessment maps and all results[1]. (See Mod #1, Pg. 1, Para. 5&6)
- 5/2014 – WSWC attended the National Water Quality Monitoring (NWQM) Conference and the AWRA GIS Specialty conference for outreach, increased visibility and participation. (Mod#1, Pg. 2, Para. 2&5)
- 6/2014 – WSWC published the State Capabilities Assessment Survey and Report Document that provides a comprehensive analysis of western state water planning program data gather, storage and IT capabilities. The report also includes and links to a series of maps that provide the status of western data gathering and acquisition in a spatial format by state[3]. (See Mod#1, Pg. 2, Para. 6&7)
- 7/2014 – WSWC presented the final products from the Sandia water demand and availability analysis to council members and provided an update on WaDE infrastructure component development. (See Mod #1, Pg. 1, Para. 5&6)
- 7/2014 – As per recommendation of the State Capabilities and Methods Workgroup, WSWC developed an additional web service call for accessing just the methodology information provided by WaDE partners by making a GetMethods web service request. (See Mod#1, Pg. 2, Para. 6&7)

- 7/2014 – At the request of the Technology Workgroup, WSWC incorporated the ability to access GIS spatial data from the WaDE portal and query results. This allows the user access to all GIS-related materials to their query results. (See Mod#1, Pg. 2, Para. 6&7)
- 8/2014 – WSWC provided feedback and guidance to the USBOR Lower Colorado Region Office pilot for sharing reservoir and streamgage data using openly-published interoperable formats. (Mod#1, Pg. 2, Para. 2&5)
- 8/2014 – Due to concerns from several states about implementing web services on-site, WSWC developed a proof of concept WaDE application using "cloud" infrastructure to host data remotely and securely, while increasing the ability of the application to respond to increased network traffic[xvii]. (See Mod#1, Pg. 2, Para. 6&7)
- 9/2014 – WSWC participated in the DOI-based and ACWI-led discussions surrounding an "Open Water Data Initiative (OWDI)," and are added as a member to ACWI's Subcommittee on Spatial Water Data. (Mod#1, Pg. 2, Para. 2&5)
- 10/2014 – WSWC gave a briefing on the status of the WaDE project deployment options (including cloud deployments and "assisted" deployments) to the full council meeting. (See Mod#1, Pg. 2, Para. 6&7)
- 10/2014 – Legal contract between WSWC and Texas Commission of Environmental Quality (TCEQ) (FY2013 EN Grant Lead State Agency) is signed to continue WaDE funding through 2016. (Mod#1, Pg. 2, Para. 2&5)
- 11/2014 – WSWC attended and participated in the 2014 National American Water Resources Association (AWRA) Annual Conference for increased outreach, visibility and participation. (Mod#1, Pg. 2, Para. 2&5)
- 11/2014 – WSWC partnered with the states of CO, SD and NV to submit a FY2015 Exchange Network Grant application. (Mod#1, Pg. 2, Para. 2&5)
- 12/2014 – WSWC updated the original Flow Configuration Document (FCD) to include changes to methodology reporting schema, and GIS data provision[xviii]. (See Mod#1, Pg. 2, Para. 6&7)

Task 1(b) – Completed. Note: the water demand and availability assessment listed in Tasks 3 and 4 of the national labs scopes of work accomplish these objectives. As discussed above, the WSWC assisted Sandia with the development of these models and case studies.

Task 1(c) – Completed.

- 1/2011 – WSWC and WGA worked to develop a drought study request to propose to WECC.
- 3/2011 – WSWC reviewed and commented on draft versions of the drought study proposal and attended several meetings with RTEP partners. WSWC and WGA's drought study proposal was accepted by WECC.
- 7/2011 – WSWC assisted Sandia with an analysis of the potential impact of drought on electricity generation for WECC and ERCOT modeling. Support for the study was made available by Argonne and Pacific Northwest National Labs and the National Renewable Energy Lab[xix].

Task 1 (d) – Note: See Task 3 below.

Task 2

- 11/2010 - 5/2014 – WSWC worked with Sandia to develop a water demand and availability assessment, which incorporated information related to state institutions, laws, regulations and policies that govern water withdrawals and transfers for energy development. (See Mod #1, Pg. 1, Para. 5&6)

- 4/2011 – WSWC and Sandia addressed the best way to present such information, e.g. in a GIS or a numerical format that is similar to work being done by the EDTF.
- 4/2011 – WSWC issued a survey (see Task 1(a) also) that gathered information from states with respect to legal and institutional issues associated with new permits or transfers of water for energy development[49].
- 6/2012 – WSWC began analysis of legal and institutional constraints that impact the allocation of available waters within the states.
- 6/2012 – WSWC developed a proposal with WGA to prepare an analysis of the legal and administrative issues associated with new permits or transfers of water for solar energy development, which is intended to contribute to WGA's broader efforts as it examines the water-energy nexus.
- 4/2014 – WSWC distributed draft of the legal and institutional issues report for state review.
- 3/2015 – WSWC provided final draft of the legal and institution issues report for review[xx].

Task 3 (a&b Ongoing, c Completed)

- 4/2011 – WSWC began policy development tasks listed in Task 1(d) and Task 3.
- 4/2011 – WSWC continued its work with ACWI and USGS as part of Task 3(b).
- 7/2012 – WSWC completed a report initiated by WGA and NREL describing water-related impacts of concentrated solar energy development in the West. Although separate from the RTEP grant, the report contributed to the identification of policies that promote water-efficient energy technologies[50].
- 7/2012 – WSWC worked with the WGA to complete a report on water transfers, again separate from the RTEP grant, but it identified many policy options and tools that the states and other stakeholder could use to avoid impacts from transfers, including ways to facilitate water banking and water conservation.
- 4/2/2013 – WSWC hosts energy/water workshop in Denver, CO. The workshop assembled thirteen speakers from a wide-range of agencies and interests, and there was a diverse group of attendees (about 75 including webinar participants). Ideas for more strategic joint management of water/energy resources were discussed. Breakout sessions were also conducted to facilitate a dialogue among participants. WSWC published a summary report of this event.
- 6/2013 – WSWC members adopted Position No. 355 in support of water research and development programs at DOE national labs.

Task 4(a)

- 1/2011 – WSWC member Alex Davis (CO) served as the liaison to WECC's State Provincial Steering Committee (SPSC), with Tony Willardson serving as an alternate member, and as a liaison to WECC's Environmental Data Taskforce (EDTF).

Task 4(b)

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[49] Western Governors' Association, Western States Water Council. "Water Transfers in the West," published December 2012. Webpage: (http://www.westernstateswater.org/wp-content/uploads/2012/12/Water_Transfers_in_the_West_2012.pdf)

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- 1/2011 – WSWC's Water-Energy Subcommittee assisted WGA and the national labs to develop the water demand and availability models discussed in preceding tasks. Alex Davis served as the subcommittee Chair. Other members include representatives from AZ, CA, ND, NM, ND, TX, UT and WY.
- 4/2011 – WSWC members discussed the initial data and information presented by Sandia and whether more detailed state data may be available to refine Sandia's initial work/results.
- 7/2012 – WSWC's Water-Energy Subcommittee continued to support the work of the national labs to create water demand and availability models under the direction of Jennifer Gimbel (CO). Other members included AZ, CA, ID, ND, TX, UT and WY.
- 6/2013 – WSWC's Water-Energy Subcommittee continued to assist the national labs to create water demand and availability models under the direction Dennis Strong (UT). Other members included AZ, CA, ID, ND, TX, and WY.
- 6/2013 – WSWC adopted Position No. 355 in support of water research and development programs at the DOE national labs.

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