Research Area 5-1. Complete the design, testing and commercial viability assessment of fish friendly turbines.	
Statement of Need	Hydropower facilities are an important component of the nation's energy mix, but hydropower's potential is not fully realized and significant lost opportunities exist as a result of water being committed to traditional fish bypass structures. R&D on fish-friendly turbines has been initiated, but the work is not complete. If the design, testing and commercial/ecological viability assessment of fish-friendly turbines is left incomplete, the ability to fully realize the nation's hydropower potential, capture lost generation opportunities, offer additional fish passage options in FERC relicensings, and increase renewable energy generation will be compromised.
Research Objective	Today's fish friendly turbine concepts are either partially designed and tested with no commercial implementation evaluated/attempted (Alden/Concepts NREC turbine), or have been initially designed and implemented but subject to limited in-situ testing/evaluation (Voith-Siemens design at Wanapum Power Plant, Grant County PUD, Washington state). Primary research objectives include; (1) Continue and complete design, testing, feasibility and technology transfer work associated with the Alden/Concepts NREC turbine, and (2) Continue in-situ testing of the Voith-Siemens turbine at Wanapum.
Impact/Benefits	The result this program will increase clean renewable hydropower generation via the capture of lost generation opportunities by allowing industry to consider fish-friendly turbines during FERC relicensings, when replacing existing turbines or expanding capacity, and when exploring feasibility of adding hydro generation at dams where no hydro presently exists. A significant fraction of the nation's turbines and lost water could be positively affected by this program.
Priority	High
Summary Scope of Work	**<u>Alden/Concepts NREC Turbine</u>** • Build upon and continue modeling and prototype model testing performed to date and refine and complete the turbine design • Perform power efficiency testing (none has been done to date) • Perform additional fish survivability testing • Evaluate materials and manufacturing techniques and develop cost opinions **<u>Voith-Siemens Kaplan (Wanapum)</u>** • One year of in-situ testing has been performed at Wanapum, this testing should continue for at least 1 more year • Use results to refine/improve turbine design
Technical Approach	A variety of approaches including traditional engineering design/feasibility/testing techniques, CFD modeling, physical modeling, biological performance/monitoring methods, and construction methods/techniques will be employed.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Partnership between industry and governmental entities (prior funding partnerships relative to existing program can be used as guide). These would likely include Alden/Concepts NREC, Voith-Siemens, EPRI, and National Labs
Potential Collaborative Government Agencies	DOE, Nat'l Labs, state research agencies (e.g., New York State Energy Research and Development Authority), resource agencies and NGO's
Leverage Opportunities with Existing Programs	Alden/Concepts NREC and Voith-Siemens have each led development of their respective concepts through DOE research programs; need to expand, leverage and partner with these programs to continue and build upon body of work completed to date.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Need to overcome mindset that on-going fish friendly turbine programs are somehow mature/complete; they are not and there exists a significant amount of unfinished design and testing work. Until recently, state and federal resource agencies and NGO's would not even consider allowing fish to pass through a turbine. In New York, this view has changed in that agencies and NGO's are willing to examine the Alden/Concepts NREC turbine as a primary means of downstream movement (subject to in-situ testing).
Estimated Cost	$4 million per year for 6 years.
Execution Horizon (early, mid, late)	Essentially this scope is the continuation of an existing program so the execution is now (early) so continuity with existing program maintained.
Schedule/Duration	Six years
Level of Development/ Level of Maturity at completion	It should be the expectation that the design, testing and commercial/ecological viability of fish-friendly turbine technology is known/mature at completion.

Research Areas 5-2 and 5-3. Bioengineering for fish passage and entrainment mitigation.	
Statement of Need	Fish movements upstream and downstream are blocked by hydropower structures and fish are entrained into hydropower turbines and water intakes, resulting in unacceptable mortality. Technology solutions to reduce this mortality and entrainment are expensive and ineffective in many cases. New, more cost-effective solutions are needed.
Research Objective	Develop and field-test new technology to reduce fish mortalities in/around hydropower facilities and improve fish movements upstream and downstream. Focus on improving the scientific understanding of fish behavior related to hydraulic conditions and using fish behavior in designing new engineering solutions.
Impact/Benefits	Demonstration of cost-effective technologies for fish protection will reduce public and regulatory resistance to new hydropower development (conventional and unconventional). Development costs and cost-of-energy can be substantially reduced with innovative technology solutions. More water will become available for energy production if less is required in fish passage mitigation, such as spill. New technical information will assist the FERC decision-making process associated with EPAct changes in mandatory conditions in licenses.
Priority	High
Summary Scope of Work	1. Conduct basic research into fish movement queues (both positive and negative) and produce biocriteria for multiple species. Study lessons-learned from existing designs and synthesize knowledge about what works and what doesn't. 2. Incorporate new biocriteria into new designs. 3. Conduct cost-shared demonstrations of new technology to determine effectiveness in real-world applications.
Technical Approach	Cost-shared demonstrations coupled with rigorous performance measurement in real-world applications
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE national laboratories (e.g., ORNL, PNNL), USGS-BRD,
Potential Collaborative Govt. Agencies	US FWS for data on effectiveness of existing designs; hydraulic design expertise in Corps and Bureau of Reclamation, plus academia (e.g., U. Minn. Saint Anthony Falls Lab and others).
Leverage Opportunities with Existing Programs	Columbia River Fish and Wildlife Program; very dispersed information in FERC hydro licensing records; EPRI Environmental R&D
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Reluctance of state and federal fish management agencies to accept new technology without comprehensive testing/demonstrations; ignorance of new ways of solving old problems.
Estimated Cost	$2M/yr for 6 years
Execution Horizon (early, mid, late)	Early-Mid.
Schedule/Duration	Design and testing will require at least 2 years of monitoring after construction of new technological fixes
Level of Development/Level of Maturity at completion	Mature
Additional comments	

Research Area 5-4. Water quality mitigation technology.	
Statement of Need	Dissolved oxygen (DO) and water temperature are two water quality problems encountered often at hydropower projects, new and old. Mitigation is often expensive and/or requires water to be diverted away from hydropower turbines, resulting lost energy. New, more cost-effective and less water intensive solutions are needed.
Research Objective	Develop and demonstrate innovative technologies, including aerating turbines; study how to optimize design and operation to minimize costs, maximize energy values, and maximize environmental benefits.
Impact/Benefits	Water use for energy production could increase if less is used in water quality mitigation.
Priority	Medium
Summary Scope of Work	1. Review state of the art, document, and identify gaps/opportunities for improvement, including quantification of lost power – cover issues including selective withdrawal for temperature management, aerating turbines, etc. 2. Develop new designs/technology to target sites with high lost power; 3. Conduct cost-shared demonstrations of new technology to determine performance and O&M costs
Technical Approach	Define current/available technologies and opportunities for improvement, design new solutions, test/demonstrate; all in terms for DO mitigation and temperature mitigation.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE national laboratories (ORNL, PNNL), academia
Potential Collaborative Govt. Agencies	TVA, Bureau of Reclamation
Leverage Opportunities with Existing Programs	EPRI is conducting limited criteria development for thermal discharges that could be transferred to hydropower settings
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Knowledge and acceptance of available technology, such as environmental optimization of operations and aerating weirs, is no wide-spread – regulatory agencies resist innovative solutions without assurance of performance; as with other hydro areas, new technology does not penetrate the federal-nonfederal dichotomy of hydro sector.
Estimated Cost	$1M/yr for 5 years
Execution Horizon (early, mid, late)	Early (designs are ready and available for testing now)
Schedule/Duration	
Level of Development/Level of Maturity at completion	Mature
Additional comments	

Research Areas 5-5 and 5-6. Develop decision support models for hydropower facility operation and planning schedules including analysis and determination of sources of generating variability that are spatially and temporally dependant.	
Statement of Need	Need to understand the hydropower generation sensitivity to variability in 1) climatic/meteorological/hydrologic processes 2) variability in operational constraints imposed by environmental regulations, other multiple water use objectives (e.g., flood control, recreation, etc), 3) power demand, etc.
Research Objectives	Develop decision support models for hydropower facility operation and planning schedules including analysis and determination of sources of generating variability that are spatially and temporally dependant.
Impact/Benefits	Increased overall energy system efficiency plus enhanced value of water resources utilization. Also, will reduce uncertainties in system operations resulting leading to less conservatism in operating practices.
Priority	High, since this development will result in a tool that allows use of a presumably high and valuable energy margin that is not now captured.
Summary Scope of Work	1. Analyze and determine sources of hydropower generating variability across spatial (local to regional) and temporal (hours to seasons to years) scales 2. Develop improved climate/meteorological/streamflow forecast models 3. Incorporate improved understanding and forecast models into optimization and decision support models 4. Demonstrate benefits of deploying improved decision support models to optimize the value of limited water resources for hydropower operations and energy production. For example, a pilot project that demonstrates the ability to increase overall system efficiency resulting in increased power production while meeting other water use objectives.
Technical Approach	1. Identify representative study areas that encompass the range of climatic/hydrologic/regulatory conditions for the U.S. Develop and implement necessary statistical analytical methods and models to assess key sources of variability. Assess value of information associated with existing data and need for additional data. 2. Develop/improve/implement variability and forecast models for each of the study areas 3. Integrate results from the above into decision support modeling framework. 4. Conduct detailed demonstration case studies to evaluate potential benefits of alternative operation scenarios and approaches.
Lead Investigators (academia, natl. lab, industry, international, partnership)	For each of the elements in the technical approach: 1. National laboratories and academia 2. National laboratories and academia 3. National laboratories and academia in collaboration with the utility industry/EPRI 4. Utility industry/EPRI with support from national laboratories and academia
Potential Collaborative Govt. Agencies	USGS, NOAA/NCDC, USBR, USCOE, NCAR
Leverage Opportunities with Existing Programs	Links to research areas 1-33 thru 1-40.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Reluctance of utilities to change practices; interagency relationships; similar challenges noted in 1-33 through 1-40
Estimated Cost	$3 to 5 M per year
Execution Horizon (early, mid, late)	Early. Could start sensitivity analyses immediately.
Schedule/Duration	5 to 7 year
Level of Development/Level of Maturity at completion	End result of this development is a product that could be used by utilities in operations; result of this development is a useable end product not an intermediate research result.
Additional comments	

Research Area 5-7. Pilot testing of advanced systems to reduce implementation risks.	
Statement of Need	Advanced technologies on the threshold of implementation often are stalled because prospective users cannot justify implementation risks. Specific hydropower-related technologies where the facilitation of technology transfer could yield significant benefits are: • Installation of variable/adjustable speed turbines • Installation of Kaplan-type advanced hydro turbines (AHTs) • Installation of hydro plants at existing (non-hydro) dams and reservoirs Other advanced technologies will also likely need pilot testing support to achieve beneficial implementation
Research Objective	Foster implementation of available advanced technologies that can positive influence energy supply and water conservation from existing and new hydropower installations
Impact/Benefits	Advanced technologies have high potential for adding to national supplies of hydroelectric power (without diminishing water supplies)
Priority	High
Summary Scope of Work	• Identify key advanced technologies ripe for implementation • Support pilot testing to provide implementation experience
Technical Approach	For each candidate technology, assess potential of technology for beneficial additions to energy supply.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Partner with project owners/developers as appropriate, e.g. • Variable/adjustable speed turbine – owner & EPRI • Installation of Kaplan-type AHTs – owner • Installation of hydro plants @ non-hydro dams and reservoirs – developer and equipment manufacturers
Potential Collaborative Government Agencies	COE, BoR, BPA
Leverage Opportunities with Existing Programs	DOE's Fossil Energy Technology Transfer program may provide useful model
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Minimal
Estimated Cost	$5M per year for 5 years
Execution Horizon (early, mid, late)	Early
Schedule/Duration	5 years
Level of Development/ Level of Maturity at completion	Outlined program should result in meaningful increases in MW and MWh in early time-frame

Research Area 5-9. Conduct/fund proof of concept and demonstrations of kinetic hydropower systems (including such technologies as horizontal and vertical axis turbines, paddle wheels, lift or flutter vanes, and venturi devices).	
Statement of Need	Kinetic hydropower systems (i.e., systems requiring minimal civil works, dams, or tidal barrages) offer great generating potential. These systems, which operate in the "free-flowing" water currents of rivers and tidal straits, also are referred to as "instream" energy systems (note: these are not "run-of-river" turbine systems). Instream or kinetic hydropower systems require test support and demonstration funding to facilitate adoption.
Research Objective	To determine proof of concepts with working single prototype units and to demonstrate kinetic hydropower systems' operational viability and environmental impacts with pre-commercial multiple unit projects.
Impact/Benefits	Given the reliability and predictability of water flows and how close to "load pockets" these systems can be sited, the impacts and benefits are significant: an estimated 20,000 MW of undeveloped US potential; an excellent source for distributed generation; base power for integrated and hybrid renewable energy systems; co-location for water purification systems, irrigation pumping, and aeration of anoxic waters; and a new clean indigenous resource to help states meet their renewable portfolio standards (RPS) and energy mandates.
Priority	High-priority activity
Summary Scope of Work	Identify universities, labs, and other entities where proof of concepts might be conducted. Help establish, or collaborate with, testing centers such as the UK's European Marine Energy Centre (EMEC) and National and Renewable Energy Centre (NaREC), and Canada's Cornwall Ontario River Energy (CORE) Project, where operational tests can be conducted and environmental impacts can be assessed.
Technical Approach	Assessment studies of universities, labs, and entities of their capabilities for conducting such work to help determine what is needed in order to conduct the work.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National labs, universities, industry research institutes, including private labs, international (UK & Canada), supplier and vendor partnerships
Potential Collaborative Government Agencies	DOE, DOI, DoD, DHS, FERC, ACE, NOAA, USGS
Leverage Opportunities with Existing Programs	Roosevelt Island Tidal Energy Project, EMEC, NaREC, CORE Project, EPRI,
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Funding support, regulatory and licensing processes, lack of coordination and collaboration between agencies
Estimated Cost	$500K
Schedule/Duration	6 months
Level of Development/ Level of Maturity at completion	Building block for a funding process to help take ideas from concepts to pre-commercial development

Research Area 5-9b. Conduct/fund proof of concept and demonstrations of wave power systems (including such technologies as oscillating water columns [OWC] and wave energy devices [WED]).	
Statement of Need	Wave power systems offer great generating potential. These systems, which operate by the motion of waves or by the air pushed by waves, require test support and demonstration funding to facilitate adoption.
Research Objective	To determine proof of concepts with working single prototype units and to demonstrate kinetic hydropower systems' operational viability and environmental impacts with pre-commercial multiple unit projects.
Impact/Benefits	Given the reliability and predictability of wave actions the impacts and benefits are significant: an estimated 75,000 MW of undeveloped US potential; an excellent source for base power and for desalination systems, and a new clean indigenous resource to help states meet their renewable portfolio standards (RPS) and energy mandates.
Priority	High-priority activity
Summary Scope of Work	Identify universities, labs, and other entities where proof of concepts might be conducted. Help establish, or collaborate with, testing centers such as the UK's European Marine Energy Centre (EMEC) and National and Renewable Energy Centre (NaREC), and Oregon State University's wave center, where operational tests can be conducted and environmental impacts can be assessed.
Technical Approach	Assessment studies of universities, labs, and entities of their capabilities for conducting such work to help determine what is needed in order to conduct the work.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National labs, universities, industry research institutes, including private labs, international (UK & Canada), supplier and vendor partnerships
Potential Collaborative Government Agencies	DOE, DOI, DoD, DHS, FERC, ACE, NOAA, USGS
Leverage Opportunities with Existing Programs	AquaEnergy's Puget Sound Project, EMEC, NaREC, Oregon State University, EPRI
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Funding support, regulatory and licensing processes, lack of coordination and collaboration between agencies
Estimated Cost	$2 million
Schedule/Duration	1 year
Level of Development/ Level of Maturity at completion	Building block for a funding process to help take ideas from concepts to pre-commercial development

Research Area 5-10. Advanced weirs for flow reregulation and aeration.	
Statement of Need	Variable flows below hydropower projects can have adverse environmental impacts on fish habitat and sediment transport during peaking operations. Reregulating weirs can be used to stabilize river flows and also aerate waters with low DO.
Research Objective	Optimize the engineering designs of weirs and demonstrate how they can be used to improve the efficiency of existing projects and reduce environmental impacts.
Impact/Benefits	New technologies that enable more hydropower peaking will increase values and allow for greater use of hydropower to complement intermittent energy from other renewables (e.g., wind and solar). Wind-Hydro integration, where feasible, will have a net increase in energy system use of water.
Priority	High
Summary Scope of Work	Hydraulic design studies, coupled with model tests and prototype demonstrations.
Technical Approach	Review, synthesize and publish past work; identify range of sites where peaking operations are currently happening; design appropriate solutions; build and field test; document innovative solutions that match the full range of sites.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE national laboratories plus engineers at Corps, Bureau of Reclamation, and/or TVA
Potential Collaborative Govt. Agencies	Water development agencies (Corps, Bureau, TVA); possibly USGS-Water
Leverage Opportunities with Existing Programs	Very little work is being done in this area today; EPRI has done some work in the past (~10 years old)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Funding
Estimated Cost	$2 M total
Execution Horizon (early, mid, late)	Early (i.e., could be started and completed immediately)
Schedule/Duration	One year for design studies, plus two years for construction and demonstrations
Level of Development/Level of Maturity at completion	Mature
Additional comments	

Research Area 5-11. Develop and test kinetic hydropower and pressure systems for manmade conduits (open and closed systems).	
Statement of Need	The nation's irrigation and water conveyance systems are a potential source of electricity generation, if technologies can be developed to harness the energy in these systems. Kinetic hydropower systems (i.e., systems requiring minimal civil works, dams, or tidal barrages) offer great generating potential. These systems also can operate in the "accelerated-flow" waters of manmade open conduits such as canals and aqueducts. Pressure systems can operate in closed systems such as pipes. Kinetic hydropower and pressure systems require test support and demonstration funding to facilitate adoption.
Research Objective	To determine proof of concepts with working single prototype units and to demonstrate kinetic hydropower systems' operational viability and environmental impacts with pre-commercial multiple unit projects.
Impact/Benefits	Given the reliability and predictability of water flows and how close to "load pockets" these systems can be sited, the impacts and benefits are significant: a new clean indigenous resource to help states meet their renewable portfolio standards (RPS) and energy mandates.
Priority	High-priority activity
Summary Scope of Work	Identify universities, labs, and other entities where proof of concepts might be conducted. Help establish, or collaborate with, testing centers where operational tests can be conducted and environmental impacts can be assessed.
Technical Approach	Assessment studies of universities, labs, and entities of their capabilities for conducting such work to help determine what is needed in order to conduct the work.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National labs, universities, industry research institutes, including private labs, international, supplier and vendor partnerships
Potential Collaborative Government Agencies	DOE, DOI, DoD, DHS, FERC, ACE, NOAA, USGS
Leverage Opportunities with Existing Programs	California's Aqueduct and Canal Energy (ACE) Project, Connecticut Project with Rentricity
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Funding support, regulatory and licensing processes, lack of coordination and collaboration between agencies
Estimated Cost	$500K
Schedule/Duration	6 months
Level of Development/ Level of Maturity at completion	Building block for a funding process to help take ideas from concepts to pre-commercial development

Research Area 5-12. Advanced Integration and control of renewable energy technologies.	
Statement of Need	Wide-spread adoption of renewable energy technologies and their integration with water-resource management and treatment requires the development of advanced integration and control mechanisms.
Research Objective	Develop and commercialize the technologies, methodologies, and system applications that maximizes the value of renewable energy and water resources
Impact/Benefits	The realization of resource sustainability through increased renewable energy utilization, water efficiency, security, and economic viability and associated reduction in negative environmental impacts.
Priority	High
Summary Scope of Work	Develop a cooperative program that achieves the stated objective for both utility-scale and distributed applications: 1. R&D Phase a. Needs assessment, solution identification, and development of decision methodologies, tools and systems. b. Develop and prototype algorithms and integrated system solutions 2. Demo & validate Phase (Field Demo) 3. Commercialization (Including elimination of institutional and market barriers and establishment of effective market mechanisms)
Technical Approach	Develop and demonstrate hybrid control systems to include real time pricing, resource optimization and optimal economic value methodologies. Develop control methods and mechanisms for renewable energy technologies, including: • Algorithm development • Scalable/modular control mechanisms • Off-grid hybrid electric/water systems • Integrate peripheral technologies including wind, PV, geothermal, storage, thermal, hydro, desalination, purification, pumping, etc
Lead Investigators (academia, natl. lab, industry, international, partnership)	Lead investigators could be a combination of Government, National Labs, utilities, technology companies, and NGOs
Potential Collaborative Govt. Agencies	DOE, Power Authorities, BoR, USGS, US State
Leverage Opportunities with Existing Programs	DOE OEDER, EERE, DOI (desal)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Policy, regulatory, environmental management
Estimated Cost	$5m per year for 5 years
Execution Horizon (early, mid, late)	Early
Schedule/Duration	5 years
Level of Development/Level of Maturity at completion	Ready for market
Additional comments	

Research Area 5-13. Develop short, intermediate, and long-term forecasts and projections of regional meteorological conditions and integrate with optimal dispatch of energy and water systems.	
Statement of Need	1. For wind and other intermittent renewable energy resources, integration with hydro and pumped storage hold significant promise, but accurate forecasting tools are not fully developed and need further R&D to provide accurate forecasts of next-hour and next-day and longer generation with adequate lead times. 2. Over the longer term (decades to centuries), decadal cycles and global climate change create considerable uncertainty for future regional patterns of precipitation and other conditions that affect water availability and renewable generation. 3. Opportunities exist to integrate forecasts with optimal dispatch of energy and water systems to reduce water consumption and maximize renewable energy generation.
Research Objective	1. Develop improved near-term (hours to days) forecasts of meteorological conditions that affect aquifer, river, and other sources of water flow forecasts and renewable energy generation. 2. Develop long-term (decades to centuries) projections of meteorological conditions that determine aquifer, river, and other sources of water flow forecasts and renewable energy generation. 3. Develop strategies for integrating forecasts of wind and other intermittent generation and load with scheduling and operation of electricity generation and transmission grid and river and aquifer management systems.
Impact/Benefits	Forecast impact of long-term variability of meteorological conditions and precipitation on regional water availability from river and aquifer sources. Reduce consumption of fresh water for power generation. Optimize use of river and aquifer water resources. Increases amount of wind and other intermittent renewable generation that can be connected to grid and further reduces water consumption for power generation
Priority	High
Summary Scope of Work	1. Near-term forecasting of meteorological conditions: Complete R&D on short- and intermediate-term meteorological forecast algorithms used by wind and solar energy forecasting services to provide more accurate forecasts of same day and longer term hourly forecasts of energy generation. Demonstrate forecast algorithms via application by utility and/or regional system operators, including integration with hydro and river system models, such as Tennessee Valley Authority, Bonneville Power Administration, and others. This research activity will identify needs for improved meteorological data and instrumentation. 2. Long-term projections of (1) impacts of decadal and other cycles, global climate change, and other factors on regional meteorological conditions (2) future regional electricity and water demand, energy and electricity supply mix, fuel costs, etc.: Assemble existing scientific knowledge and data related to decadal cycles and global climate change impacts on regional meteorological conditions. Assess the information for completeness and applicability, and develop additional information or models as needed. Use river and aquifer models to forecast impacts on river and aquifer resources based on forecasts of meteorological conditions, water consumption, and other factors. Forecast regional seasonal temperature, precipitation, wind, and other conditions. Develop regional projections of wind, solar, and hydro generation by season vs. decade. A challenge here will be the requirement for regional climate projections that can be couple with resource models,

	particularly hydrologic. Develop resource maps for potential energy generation via wind, solar, and hydro. 3. Integration of meteorological and load, energy price, and other forecasts with energy and water system operations: Develop strategy and define metrics for optimization of energy and water systems. Develop optimal control algorithms to dispatch renewable energy, energy storage, and other electricity generation and transmission grid resources in coordination with operation of the river and aquifer systems. Hydroelectric generation is part of both the electricity grid and the river system. Evaluate performance of alternate strategies and algorithms using regional electricity system and river and aquifer models. Identify promising strategies and algorithms that best meet the objectives of reducing fresh water consumption and maximize alternative energy use.
Technical Approach	Same
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories, NREL, CEC, EPRI, NCAR, utilities, independent system operators,
Potential Collaborative Govt. Agencies	DOE, USBR, USGS, DOI/USFWS, TVA, BPA
Leverage Opportunities with Existing Programs	Existing CEC-EPRI, Xcel Energy RDF Project, SCE, Ca ISO, BPA. This Research Area ties to Research Areas 1-33 through 1-40.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Accurately forecasting rapid ramp rates of large wind developments with adequate lead time same-day and next-day. Uncertainty of long-term climate change impacts, population, load, water consumption, fuel prices, etc.
Estimated Cost	R&D: $10M over 5 years
Execution Horizon (early, mid, late)	Prior development of regional climate models is required. Three parallel R&D projects, each 1 to 3 years Two demonstrations: each 2 years
Schedule/Duration	5 years total
Level of Development/Level of Maturity at completion	Ready for commercial deployment following demonstration, 5 years.
Additional comments	

Research Area 5-14. Integration of renewable technologies for water treatment and pumping applications.	
Statement of Need	Evaluating technical, economic and policy constraints associated with integration of renewable energy sources for water treatment and pumping applications.
Research Objective	To provide guidance based on existing applications for water and waste water utilities and irrigation districts to integrate renewable energy resources.
Impact/Benefits	• Reduced water consumption based on renewable displaced power • Increased water efficiency through synergies • Increased energy security due to diverse and distributed energy sources • Increased Reliability • Protection against future price increases of conventional energy sources • Improved public relations
Priority	High
Summary Scope of Work	Survey of existing integration applications to determine problems, barriers, benefits. Determine from these existing applications what needs to be done to address the problems and propose new demonstrations for testing and evaluation.
Technical Approach	• Determine technical integration issues, operational and maintenance issues, policy constraints and economic issues for specific, existing project applications. • Identify solutions to these issues. • Propose new demonstrations that incorporate identified solutions • Additional demonstrations for new applications that require technical innovation– such as control platform hardware and algorithms for pv and/or wind driven desalination that capture the synergies of the two technologies.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories, State Energy Offices, Academia
Potential Collaborative Govt. Agencies	National laboratories, State Energy Offices, Academia, Industry
Leverage Opportunities with Existing Programs	Very large leveraging opportunities with existing projects: State energy offices, NREL, Consortium for Energy Efficiency
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	One goal of this activity is to identify constraints and challenges in this area. Additionally the issues of control of generation sources by utilities, intermittency, and economics.
Estimated Cost	$0.5 M for documentation; $2M / yr for 3 years for demonstrations
Execution Horizon (early, mid, late)	Early
Schedule/Duration	1 year, documentation, 3 years demonstrations
Level of Development/Level of Maturity at completion	Will assist in renewable integration for water applications.
Additional comments	This research topic is focused on integration of existing renewable technologies for water related applications that will reduce consumption of water from conventional generation sources, as well as take advantage of integration synergies of renewable resources for water applications. It will not require basic research into renewable technology development

Research Areas 5-14a and 5-15a. Integration of renewable technologies for water treatment and pumping applications.	
Statement of Need	Evaluating technical, economic and policy constraints associated with integration of renewable energy sources (e.g. wind, PV, fuel cells, biogas, gasification, etc…) for water treatment and pumping applications. Develop, demonstrate and commercialize appropriate technologies such as control strategies and advanced solutions to include applications (oil and gas produced water treatment).
Research Objective	To provide guidance based on existing applications for water and waste water utilities and irrigation districts to integrate renewable energy resources.
Impact/Benefits	• Reduced water consumption based on renewable displaced power • Increased water efficiency through synergies • Increased energy security due to diverse and distributed energy sources • Increased Reliability • Protection against future price increases of conventional energy sources • Improved public relations • Environmental • Water quality (Reduced ground-water contamination)
Priority	High
Summary Scope of Work	Survey of existing integration applications to determine problems, barriers, benefits. Determine from these existing applications what needs to be done to address the problems and develop, demonstrate, and commercialize appropriate advanced technologies.
Technical Approach	• Needs assessment • Determine potential resources and economic viability • Determine potential technical integration issues, operational and maintenance issues, policy constraints and economic issues for specific, existing project applications. • Identify solutions to these issues • R&D technology and processes. • Demonstrations identified solutions • Commercialize
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories, State Energy Offices, Academia, Technology Companies
Potential Collaborative Govt. Agencies	National laboratories, State Energy Offices, Academia, Industry
Leverage Opportunities with Existing Programs	Very large leveraging opportunities with existing projects: State energy offices, NREL
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	One goal of this activity is to identify constraints and challenges in this area. Additionally the issues of control of generation sources by utilities, intermittency, and economics.
Estimated Cost	$5M per year for 5 years
Execution Horizon (early, mid, late)	Early
Schedule/Duration	5 years
Level of Development/Level of Maturity at completion	Commercialization
Additional comments	This research topic is focused on development and integration of existing/new renewable technologies for water related applications that will reduce consumption of water from conventional generation sources, take advantage of integration synergies of renewable resources for water applications, and reduce potential of water contamination. It will not require basic research into renewable technology development

Research Area 5-15b. Renewable-based electric power—Renewable water use.	
Statement of Need	Adoption of emerging renewable energy technologies such as hydrogen, cultivated biomass, geothermal, etc. could be impacted by their water use. This needs to be evaluated to see water demand
Research Objective	Develop an approach that can be used to evaluate the withdrawal and consumption of water (e.g. per MWH or MMBtu) developed that provides a consistent basis for comparing water use 'n'.
Impact/Benefits	The identified process developed will provide a consistent basis for assessing emerging and renewable electric power generation technologies impact on water consumption and help drive improved energy generation technology selections.
Priority	High
Summary Scope of Work	Develop a process and model to assess water withdrawal and consumption for electric power generation technologies, especially emerging and renewable approaches such as hydrogen and biomass across the full life cycle from production to use.
Technical Approach	Develop model and tools to help support evaluation and water use and consumption in power generation. Model should include metrics to be included in assessments.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories with electric power industry as peer review to ensure appropriate metrics considered and included in assessments.
Potential Collaborative Govt. Agencies	Government agencies could include USDA, for example for biomass water consumption, as well as industry associations.
Leverage Opportunities with Existing Programs	
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Technical challenge is (a) creating a consistent approach that can be used across new technologies that can provide direct comparisons, (b) getting industry developers to support evaluations.
Estimated Cost	<$500k/year for 2 years
Execution Horizon (early, mid, late)	Early implementation will provide direction of where emerging technologies, new renewables, have the most benefit to water efficiency and where improvements are needed.
Schedule/Duration	2 years for initial effort, continuing effort at reduced level as a way to capture improvements.
Level of Development/Level of Maturity at completion	Analysis model and approach that is available for application commercially.
Additional comments	

Research Area 5-16. Continue development of less energy of less energy/water intensive in situ retorting processes and assess impacts of water quality and quantity.	
Statement of Need	Oil shale and oil sand deposits in the US are generally found in water scare regions. If these resources are to be developed, extraction and processing methods that are less water intensive than current best practices will have to be developed, or unconventional water resources utilized.
Research Objective	Continue development of less energy/water intensive in-situ retorting processes and assess impacts on water quality and quantity.
Impact/Benefits	1. Increase water availability for other uses 2. Address major environmental concern over development 3. Improve upon best management practices 4. Reduce costs for development per unit of energy recovered
Priority	High
Summary Scope of Work	Develop approaches to decrease the amount of water/energy needed to develop oil shales and oil sands, through better water management practices, use of solvents, or alternative means of delivering heat and hydrogen for shale and sand development.
Technical Approach	1. Perform state-of-the-art assessment to determine current needs 2. Perform water mass balances for proposed in situ processes 3. Understand net water demands of the currently proposed set of in-situ retorting processes. 4. Research and develop technology to make in-situ retorting processes less water and energy intensive. 5. Develop energy and water systems management tools. 6. Validate research and management tools through pilot and demonstration projects
Lead Investigators (academia, natl. lab, industry, international, partnership)	Oil industry, national laboratories, academia, USGS
Potential Collaborative Government Agencies	EPA, BLM, USGS
Leverage Opportunities with Existing Programs	Industry pilot tests
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	There is a need for a directed program or funding to pursue this work within DOE. Intellectual property; information about processes would be proprietary information Regulatory and policy issues with regards to water rights and waste handling
Estimated Cost	First 5 years, $10-15M /yr
Execution Horizon (early, mid, late)	Early = pilot Mid = production Late = continual technology support
Schedule/Duration	1-5 years coordinate with industry on pilot projects 5-20 years continual technical improvements to increase efficiency of extraction and resource development
Level of Development/ Level of Maturity at completion	1-5 years have developed new techniques to develop oil shale and sands 20 years have improved processes

Research Area 5-17. Evaluate use (including transportation) of existing or treated produced water for oil shale/oil sand production.	
Statement of Need	Utilizing produced waters in oil shale/oil sand production may facilitate the development of these resources in water scarce regions.
Research Objective	Evaluate use (including transportation) of existing or treated produced water for oil shale/oil sand production.
Impact/Benefits	• Minimize freshwater needs in oil shale developments • Reduce the cost of produced-water management • Reduce the negative impacts of produced waters
Priority	High
Summary Scope of Work	System modeling and experimental testing from the bench scale to the pilot scale of produced water utilization methods.
Technical Approach	1. Determine the magnitude and quality of produced waters 2. Assess opportunities for use of produced waters in energy extraction/processing and power generation as well as the treatment technologies required to utilize these waters. 3. Identify methods of managing excess produced water and concentrates. 4. Develop a systems-based decision-making tool (including infrastructure, transportation, regulation, economics, and social issues) for managing and controlling use of produced waters. 5. Assess water quality requirements for various water uses and conduct bench scale tests of produced water utilization. 6. Conduct field pilot tests of proposed utilization methods.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories, academia, USGS, oil industry
Potential Collaborative Government Agencies	EPA, BLM, USGS, state governments, other stakeholders (e.g., tribes, ranchers)
Leverage Opportunities with Existing Programs	Oil company pilot projects, water producer projects, NETL programs Research Areas 1-24, 5-16
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Potential regulatory constraints on water use and disposal Infrastructure constraints Physical constraints to receive produced waters Water rights issues Proprietary information issues
Estimated Cost	$25M over 5 years
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Year 1-3 years for scoping and bench scales Year 3-5 for pilot testing With potential performance monitoring during commercial production phase
Level of Development/ Level of Maturity at completion	Ready for application at end of project.