CERC-WET Topic 3 Improving Sustainable Hydropower Design and Operations

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The United States and China are the world’s largest energy producers, energy consumers and greenhouse gas emitters. The clean energy sectors in both countries are growing rapidly. The priorities of the **U.S.-China Clean Energy Research Center** reflect important areas of opportunity for both countries.
CERC-WET Topic Area overview

- **Topic Area 1: Water Use Reduction at Thermo-electric Plants**
  U.S. Lead: Per Peterson, (UC Berkeley) / China Lead: GUO Hua (CGDG Guodian)

- **Topic Area 2: Treatment & Management of Non-Traditional Waters**
  U.S. Lead: David Sedlak, (UC Berkeley) / China Lead: HE Liu (RIPED)

- **Topic Area 3: Improving Sustainable Hydropower Design & Operation**
  U.S. Lead: Soroosh Sorooshian, (UC Irvine) Co-lead: Jay Lund (UC Davis) / China Lead: WANG Dongsheng (China Institute of Water Resources and Hydropower Research [IWHR])

- **Topic Area 4: Climate Impact Modeling, Methods, Science for E-W Systems**
  U.S. Lead: Alan DiVittorio, (LBNL) Co-lead: Soroosh Sorooshian (UC Irvine) / China Lead: XIAO Chan (NMC)

- **Topic Area 5: Data/Analysis to Inform Planning, Policy, and Other Decisions**
  U.S. Lead: Nan Zhou, (LBNL) / China Lead: WANG Jianhua (IWHR)
Project Overview

**Project Title:** CERC-WET Topic Area 3: Improving Sustainable Hydropower Design and Operations

**The Challenge:**

- Large number of hydropower dams has been built globally
- Non-stationary hydroclimates are altering fundamental engineering design and operation
- A deeper understanding is required of how changing climate and varying weather condition impact on
  1. water-energy supplies,
  2. electric grid reliability,
  3. greenhouse gas implications, and
  4. ecosystem and social economic functioning.

**Partners:**

![Partners Logos]
Next Generation Hydropower (HydroNEXT)

Program Strategic Priorities

**Optimization**
- Optimize technical, environmental, and water-use efficiency of existing fleet
- Collect and disseminate data on new and existing assets
- Facilitate interagency collaboration to increase regulatory process efficiency
- Identify revenue streams for ancillary services

**Growth**
- Lower costs of hydropower components and civil works
- Increase power train efficiency for low-head, variable flow applications
- Facilitate mechanisms for testing and advancing new hydropower systems and components
- Reduce costs and deployment timelines of new PSH plants
- Prepare the incoming hydropower workforce

**Sustainability**
- Design new hydropower systems that minimize or avoid environmental impacts
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies to evaluate and address environmental impacts
- Increase resilience to climate change
Overall Objective: to improve sustainable hydropower design and operation, and to evaluate system reliability under non-stationary hydroclimates.

- **Project 3.1 (Viers, UCM & Lund, UCD):** provide the hydropower facilities short-term optimal operation strategies.
- **Project 3.2 (Sorooshian, Gao, UCI & Lund, UCD):** improve hydropower facilities life-time design and operations under non-stationary hydroclimates.
- **Project 3.3 (Sorooshian, Hsu, Gao, Aghakouchak, UCI):** develop remote-sensing precipitation monitoring and forecasts platform to support short-term hydropower scheduling and examine system resilience under extreme events.
- **Project 3.4 (Samuelsen, UCI):** assess hydropower dispatch on electric grids and social impacts.

**Hydrometeorology and Climate Forecasts (Project 3.3)**

- Improve
- Support
- Develop
- Evaluate
- Guide
- Improve

**Electric grid Reliability and Greenhouse Gas Implications (Project 3.4)**

**Optimal Operation (Project 3.1)**

**Engineering Design (Project 3.2)**
Linkage to Other CERC-WET Projects

- **Events-Based Precip. (Storm) Database (Project 4.3)**
  - Support
- **Hydrometeorology and Climate Forecasts (Project 3.3)**
  - Evaluate
  - Guide
- **Historical Climate Extremes Analysis (Project 4.4)**
  - Support
- **Electric grid and Greenhouse Gas Implication (Project 3.4)**
  - Improve
  - Predict
- **Optimal Operation (Project 3.1)**
  - Water impact of long-term energy development (Project 5.2)
- **Engineering Design (Project 3.2)**
  - Modeling complex water-energy systems (Project 5.3)
Project Outputs:

- **Optimization Software** (Project 3.1 and 3.2)
- **Weather Forecasts Platform** (Project 3.3)
- **Global Storm Database** (Project 3.3)
- **Optimal Ecosystem Planning** (Project 3.1)
- **Reservoir System Decision Making Support** (Project 3.2 and 3.3)
- **Electric Grid Reliability Analysis** (Project 3.4)
- **Hydro facility Risk Management** (Project 3.2)

Industry Partner:

- Insurance Company
- Non-Profit Organization
- Consulting/Utility Company
- Construction Company
Approach: Support Additional Hydropower System Operational Optimization from Three Elements

- Meteorology and Hydrological Data Support
  - UC Irvine / NWS / NOAA

- Decision Making Support Tools
  - Deltares USA

- Modelling Approaches
  - UC Irvine / Davis / Merced
Example: Global Multi-objective Optimization Algorithms

Significance: Hydropower production is a decision making process that involves many trade-offs, such as water vs. energy, ecosystem vs. temperature increases, spills vs. turbine flows, economic benefit vs. other benefit.

Uniqueness: Advanced global evolutionary-based search algorithm to identify optimal solutions in a multi-objective context.

Source: Yang et al 2015. Environmental Modelling and Software
Progress in 2015-2016:
Many research papers have been published and a number of manuscripts are submitted for review:

Published:

- many more as listed in review report…

In review:

- Yang et al. An Enhanced Artificial Neural Network with A Shuffled Complex Evolutionary Global Optimization with Principal Component Analysis Information Sciences
- Yang et al. Developing Reservoir Monthly Inflow Forecasts Using Artificial Intelligence and Climate Phenomenon Information Water Resources Research
- Liu et al. Evaluating the streamflow simulation capability of PERSIANN-CDR daily rainfall products in two river basins on the Tibetan Plateau Hydrological and Earth System and Science
Project Budget

Topic Area 3 Budget:

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- Project awarded in mid-2015 but received by University of California in mid-2016
- Year 1 expenses have been reported
- Year 2 allocation have landed in all participating campuses of Topic 3
- Deltares USA Inc. provides in-kind supports for a number of projects.

Overall CERC-WET Budget:

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Partners, Subcontractors, and Collaborators: We will continue to work with the industry partners within the CERC-WET consortium from both the United States and China, as well as any potential partners from academia, government agencies, and industry.

Communications and Technology Transfer:
- Annual CERC-WET meeting, CERC-WET stakeholder meeting, CERC-WET steering committee meeting
- American Geophysical Union Annual Meeting
- American Meteorological Society Annual Meeting
- Quarterly teleconference with DOE experts
Next Steps and Future Research

FY17/Current research: In FY17, many case studies will be jointly carried out with the China team as the following hydropower intensive areas have been identified by both U.S. and China teams:

- **U.S.**: Columbia River Basin, Tennessee Valley Area, Colorado River Basin, and Northern California
- **China**: Ya-long River Basin, Jin-Sha River Basin, and Yangtze River Basin

Proposed future research:

- Investigate the application of hydro-meteorological forecasts in support of short-term hydropower scheduling
- Enhance the optimization algorithms and decision making support tools that are currently being used by both operating agencies and industry.