US-China Clean Energy Research Center (CERC) Joint Work Plan for Research Projects on Water Energy Technologies

中美清洁能源联合研究中心(CERC)

能源与水技术项目联合研究方案

1. **Introduction**

In November 2009, the President of the United States of America, Barak Obama, and the President of the People's Republic of China, HU Jintao, jointly announced the establishment of the bilateral Clean Energy Research Center (CERC), the primary purpose of which is to facilitate joint research and development on clean energy technology by teams of scientists and engineers from both countries. U.S. Secretary of Energy, Steven Chu, Chinese Minister of Science and Technology, WAN Gang, and the Chinese National Energy Administrator, ZHANG Guobao, signed the agreement, known as the U.S.-China CERC Protocol, on November 17, 2009, which established the CERC. In November 2014, and again in September 2015, the Presidents of the United States (Obama) and China (XI Jinping) reaffirmed their country's commitment to joint cooperation on clean energy research, extended the CERC for an additional 5-year term from 2016 to 2020, and expanded the Center's scope to include water-related aspects of energy production and use. The expanded scope was codified by amending the Protocol on September 14, 2015. The United States and Chinese Governments are currently implementing four programs under the CERC, one of which is CERC-Water Energy Technologies (CERC-WET).

1.引言

2009 年 11 月，中国国家主席胡锦涛和美国总统奥巴马发表了建立中美清洁能源联合研究中心(CERC) 的通告，11 月 17 日美国能源部部长朱棣文、中国科技

部部长万钢和国家能源局局长张国宝签署协议启动建设中美清洁能源联合研究中心。中美清洁能源联合研究中心的主要目标是由两国科学家和工程师合作促进两国清洁能源技术的研发。2014 年 11 月和 2015 年 9 月，美国总统奥巴马和中国国家主席习近平重申，将继续致力于清洁能源研究方面的合作，并将中美清洁能源联合研究中心合作期限延长五年(2016 年-2020 年)，将能源生产和利用中涉及到水的研究纳入合作范围。2015 年 9 月 14 日，扩展后的研究内容正式纳入修改后的协议中。中美政府在中美清洁能源联合研究中心框架下，目前正在实施四个项目，其中一个即是“中美清洁能源联合研究中心能源与水联盟”（英文缩写 CERC-WET）。

Vision and Goals

The vision for CERC-WET is to build a foundation of knowledge, technologies, human capabilities, and relationships that position the Unite States and China to continue to thrive in a future with constrained energy and water resources in a changing global climate. For both countries, there is a need to improve technologies, strategies and paradigms for resource management that address the interdependencies of water and energy systems. Accordingly, the research goal for CERC-WET is to make significant contributions to the advancement of technologies, data and analyses that will enable: (a) reduced water use; (b) increased water availability and utility; (c) and more resilient and environmentally sustainable energy-water systems. In addition, CERC-WET will foster the development and adoption of novel technical and policy solutions that meet both energy and water goals.

宗旨和目标

中美清洁能源研究中心能源与水联盟的宗旨是，建立知识、技术、人类能力和关系的基础，在全球气候变化条件和有限的能源和水资源下，使中美两国未来能够继续繁荣发展。两国有必要改进资源管理技术、战略和范例，以解决水与能源系统的相互依赖性。所以，中美清洁能源研究中心能源与水联盟相应的研究目标应当为促进技术、数据和分析的进步做出贡献，从而：（1）减少水资源的使用；（2）提高水资源的获取和利用；（3）建立更加灵活和使环境可持续发展的能源与水系统。另外，中美清洁能源研究中心能源与水联盟将开发采用最新的技术和政策解决方案以满足双方能源和水目标。

2. Organizational Structure of the CERC-Water Energy Technologies

This complex multi-dimensional challenge will be addressed through a project portfolio that brings together and builds upon state-of-the-art research in both countries. Work in the United States will be carried out on selected campuses of the University of California (UC) system and other partnering organizations, led by UC Berkeley. Work in China will be carried out across numerous Chinese partnering institutes, universities and companies, led by the Research Institute of Petroleum Exploration and Development (RIPED) and its partners. RIPED is the R&D center of China National Petroleum Corporation (CNPC). The Chinese and the U.S. organizations for clean energy research and water energy solutions areas are shown in the tables below. Overseeing and guiding the collaborative work of CERC-WET will be a joint Steering Committee, composed of principals representing the parties to the CERC Protocol, and supported by the U.S. Department of Energy and China Ministry of Science and Technology.

2.中美清洁能源研究中心能源与水联盟的组织架构

这项复杂的多重挑战将通过整合两国最先进技术的项目组合来解决。美方将在加州大学伯克利分校的领导下，由加州大学系统遴选出的分校和其他合作伙伴来实施，中方由中石油勘探开发研究院及其合作伙伴牵头，由中国多个研究机构、大学和公司进行合作来实现。中石油勘探开发研究院是中国石油天然气集团公司的研发中心。中美双方清洁能源研究团队和能源与水研究议题如下表。联合指导委员会将负责监督和指导中美清洁能源研究中心能源与水联盟的合作工作，委员会包括美国能源部和中国科技部代表中美清洁能源联合研究中心协议中各方负责人。

Table 1: The U.S. CERC-WET Team

Consortium Director/Principle Investigator: Ashok Gadgil, UC Berkeley			
Deputy Director: Soroosh Sorooshian, UC Irvine			
Deputy Director: Scott Samuelsen, UC Irvine			
Universities	**National Labs**	**US Companies**	**Other Organizations**
University of California Berkeley	Lawrence Berkeley National Laboratory	General Electric Company	Department of Energy
University of California Davis		SoCalGas	University of California Office of the President
University of California Irvine		Southern California Edison	California Energy Commission
University of California Los Angeles		Glacier Technologies	Stockholm Environment Institute (SEI-US, Massachusetts)
University of California, Merced		Walt Disney Imagineering R&D	Energy Foundation
		Duke Energy	

表 1: 中美清洁能源研究中心能源与水联盟美方团队

联盟主任/项目负责人: 阿肖克·卡吉尔, 加州大学伯克利分校			
副主任: 瑟鲁士·瑟鲁森, 加州大学欧文分校			
副主任: 斯科特·萨穆埃尔森, 加州大学欧文分校			
大学	**国家实验室**	**美国公司**	**其他组织**
加州大学 伯克利分校	劳伦斯伯克利 国家实验室	通用电气公司	能源部
加州大学 戴维斯分校		美国南加州 煤气公司	加州大学校长办公室
加州大学 欧文分校		南加州 艾迪森公司	加州能源委员会
加州大学 洛杉矶分校		冰川技术公司	斯德哥尔摩能源研究院 (美国马萨诸塞分部)
加州大学 默塞德分校		华特迪士尼幻想 工程研发公司	能源基金会
		杜克大学	

Table 2: The China CERC-WET Team

Consortium Director/Principle Investigator: LIU He, RIPED		
Executive Deputy Director: WANG Jianhua, IWHR		
Universities	**Research Institutes**	**Companies**
Tsinghua University	Research Institute of Petroleum Exploration and Development(RIPED)	China National Petroleum Corporation (CNPC)
Beijing Normal University	China Institute of Water Resources and Hydropower Research (IWHR)	China Guodian Corporation
Northeast Petroleum University	Guodian New Energy Technology Research Institute(GNETI)	Yalong River Hydropower Development Company, Ltd.
Peking University	Institute of Engineering Thermophysics, Chinese Academy of Sciences(CAS)	Jilin Oilfield, CNPC
	Institute of Seawater Desalination and Multipurpose Utilization, State Oceanic	Dano (Beijing) Oilfield Services Co.,Ltd

	Administration(SOA)	
	National Climate Centre (NCC), China Meteorological Administration(CMA)	China Three Gorges Corporation
	Energy Research Institute, National Development and Reform Commission (NDRC)	
	Institute of Atmospheric Physics, CAS	
	Chinese Academy of Meteorological Sciences (CAMS)	
	Wuhan Regional Climate Center(WRCC), CMA	
	International Applied Energy Technology Innovation Institute	

表 2: 中美清洁能源研究中心能源与水联盟中方团队

联盟主任/项目负责人: 刘合, 中国石油勘探开发研究院		
执行副主任: 王建华，中国水利水电科学研究院		
大学	**研究机构**	**公司**
清华大学	中国石油勘探开发研究院	中国石油天然气集团公司
北京师范大学	中国水利水电科学研究院	中国国电集团
东北石油大学	国电新能源技术研究院	雅砻江流域水电开发公司
北京大学	中国科学院工程热物理研究所	中国石油吉林油田分公司
	国家海洋局天津海水淡化研究所	丹诺（北京）石油技术服务有限公司

	中国气象局国家气候中心	中国长江三峡集团公司
	国家发改委能源研究所	
	中国科学院大气物理研究所	
	中国气象科学研究院	
	武汉区域气候中心	
	国际应用能源创新研究院	

Criteria for Project Selection

Joint research projects must meet the following criteria, mutually agreed by the Parties to the U.S.-China CERC Protocol. The research must be designed to produce outcomes that would benefit both countries, not just one country. The proposed research plan must evidence bilateral collaboration, such as through division of tasks among researchers in both countries on a single project, or leveraging of complementarities and/or interdependencies on multiple related projects. The research must evidence strong scientific and technical merit, emphasize innovation and/or novel approaches, and be relevant to advancing higher level CERC, Consortium, and Theme Area goals and technical objectives. Additional criteria for selection of projects are the quality of the research team--including leadership, key personnel, and expertise--and the contribution of identified resources, equipment and facilities in delivering the expected outcomes. Expected outcomes must have potential for the creation of intellectual property (IP) and with potential path to commercialization and/or implementation of resulting knowledge or technology advancements.

项目遴选标准

联合研究项目必须符合中美清洁能源联合研究中心协议中各方相互达成的如下共识标准：研究必须旨在产出有利于两国而非一国的成果。所提议的研究方案

必须体现双方的合作，可以是两国就同一个项目在各自研究人员之间进行不同的分工，或者是对多个相关项目的相互补充性和/或依赖性的平衡。研究内容必须体现强有力的科学技术优势，强调创新和/或新方法，并且能够将中美清洁能源联合研究中心、联盟以及议题研究的宗旨和技术目标推向更高的层次。其他的项目遴选标准还有研究团队的质量，包括领导力，核心人员和经验，以及对已有的资源、仪器设备和设施取得预期成果的贡献。预期成果必须具有创造知识产权（IP）的潜力，具备商业化和/或知识或技术进步的实施的潜在路径。

3. Research

The United States and China will conduct research jointly in the topic areas identified in the Table 3. Descriptions of a group of research topics from which specific projects will be chosen are as follows, with further details to be developed after the initiation of projects. Under the CERC's U.S.-China Protocol and its Intellectual Property Annex, no work on any cooperative activity between the two countries can begin without a mutually agreed upon Technology Management Plan.

3. 研究内容

中国和美国将按照表 3 的议题开展联合研究，具体的项目研究内容将从中选择，细节将在项目启动后确定。根据中美清洁联合能源中心协议及其知识产权附约，双方在就技术管理方案达成共识后方可启动合作活动。

Table 3 CERC-WET Topic Area Leads

Topic Area No.	Topic Area Name	US Leads	China Leads

1	Water Use Reduction at Thermoelectric Plants	Per Peterson Yanbao Ma	GUO Hua ZHAO Lifeng
2	Treatment and Management of Non-Traditional Waters	David Sedlak Robert Kostecki	YANG Qinghai ZHANG Yushan
3	Improving Sustainable Hydropower Design and Operation	Soroosh Sorooshian Jay Lund	WANG Dongsheng WU Shiyong
4	Climate Impact Modeling, Methods, and Scenarios to Support Improved Energy and Water Systems Understanding	Alan Di Vittorio Soroosh Sorooshian	XIAO Chan XIAO Weihua
5	Data Analysis to inform Planning, Policy, and Other Decisions	Nan Zhou Arpad Horvath	WANG Jianhua YANG Yufeng

表 3：中美清洁能源研究中心能源与水联盟研究议题及负责人

议题编号	议题名称	美方负责人	中方负责人
1	火电厂水资源减量利用	柏·彼得森 马砚保	郭桦 赵丽凤
2	非传统水资源处理与管理	戴维德·塞德拉克 罗伯特·科特基	杨清海 张雨山
3	可持续水电设计和运行的改进	瑟鲁士·瑟鲁森 杰恩·朗德	王东胜 吴世勇
4	通过气候影响建模、分析与情景设计，加深对能源与水系统的认知	阿兰·迪·维托利奥 瑟鲁士·瑟鲁森	肖潺 肖伟华
5	规划、政策及其它决策的支撑数据与分析技术	周南 阿帕德·霍瓦特	王建华 杨玉峰

3.1 Water Use Reduction at Thermoelectric Plants

Conventional approaches to reducing water consumption by thermoelectric plants generally result in reduced efficiency and increased carbon dioxide emissions. The overarching objectives of our work in Topic Area 1 are to address electricity needs, particularly in regions where water is scarce, by creating technological breakthroughs in the areas of water recovery system, dry cooling, non-conventional power conversion, dry carbon-capture methods, and reduced fuel consumption. The research projects will be aimed at developing new approaches to reduce water consumption and carbon dioxide emissions from thermoelectric plants.

3.1 火电厂水资源减量利用

热电厂减少耗水的传统方法通常会造成效率低下和二氧化碳排放的增加。议题1 研究的总体目标是通过在水回收系统、干冷、非传统能量转化、干式碳捕捉方法和减少燃料消耗领域取得技术突破来解决电力需求问题，特别是在水资源稀缺地区。研究项目旨在开发新方法减少热电厂的耗水和二氧化碳排放。

3.2 Treatment and Management of Non-Traditional Waters

Stresses on available water resources make the use of non-traditional waters (e.g., oil and gas produced wastewaters, water from carbon sequestration, municipal wastewater, brackish groundwater) essential for the solution of many current water-energy problems. Non-traditional waters are available in abundant quantities, but they cannot be used for industrial, agricultural, and municipal applications without treatment to remove impurities, including: (i) high salinity; (ii) divalent cations (e.g., Ca2+, Mg2+) that cause scaling when water is heated; (iii) anions (e.g. F-, NO3-) that can damage health through drinking water supply (iv) organic contaminates (e.g., hydrocarbons, synthetic organic chemicals) that can damage equipment or compromise public health; and (v) inorganic compounds (e.g., borate, sodium) that enhance corrosion and damage on plants. In addition, developing advanced energy technologies is also an important way to reduce the tension between energy development and water shortage. The objective of this topic is to develop new treatment approaches for the contaminants in non-traditional waters, waterless fracturing techniques and operating optimization techniques of water system during energy development, to reduce water consumption and improve water utilization efficiency.

3.2 非传统水资源处理与管理

水资源短缺压力使得非传统水资源(如油气生产废水、来自碳汇的水、城市废水、苦咸地下水等)的开发利用成为解决当前能源与水相关问题的关键。非传统水资源丰富，但其中含有的杂质使其难以直接用作工业、农业和市政用水，必须去除其中杂质后才能得以利用。这些杂质包括：(1)高盐度；(2)水加热后造成结垢的二价阳离子(如钙离子、镁离子)；(3)饮用水中影响健康的阴离子(如氟离子、硝酸根离子)；(4)对设备或公共卫生造成破坏的有机污染物(如烃类化合物、合成有机化学品)；以及(5)可腐蚀和损伤植被的无机化合物(如硼酸盐、钠)。此外，开发先进的能源应用技术亦是解决能源开发与水资源短缺之间矛盾的重要途径。本议题旨在开发新方法以管控非传统水资源中的污染物，并开发不使用淡水资源的无水压裂技术以及能源开发中水系统运行优化技术，从而降低水资源消耗，提高水资源利用效率。

3.3 Improving Sustainable Hydropower Design and Operation

The overall objectives of Topic Area 3 are getting progress and breakthrough in the temperature control of the drainage of water in the reservoir, reservoir ecological operation, river habitat protection theory and the technical measures, short-term reservoir inflow forecast based on rainfall forecast, optimal operation of reservoir under climate change scenarios, and to improve the sustainable hydropower design and operation in China through the cooperation. Specific objectives are:(i) to build up the prediction model of effects of stratified water releases of the reservoir, put forward the ecological protection measures evaluation method, and set up hydropower station optimal operation mode under changing conditions; (ii) to monitor water temperature in typical reservoir and its downstream river in Yalong River or Jinsha River basin; (iii) to carry out the habitat protection demonstration research in Yalong River or Jinsha River Basin; (iv) to obtain high precision of short term (3 to 7 days) precipitation forecast information based on multi-source data fusion technology of precipitation forecast, set up model coupling precipitation forecast and hydrological forecast , and improve flow forecast accuracy of the hydropower station reservoir; (v) to estimate the reservoir flow changes based on downscaling data under different climate change scenarios generated by Topic Area 4, and carry out research on optimal operation of reservoir under climate change.

3.3 可持续水电设计和运行的改进

议题 3 的总目标是通过中美合作，在水库下泄水的温度控制、水库生态调度、河流栖息地保护理论和技术措施、短期降水预报和基于降水预报的水电站水库来流预报、气候变化情景下的水库来流与水温变化预估以及气候变化情景下的水库优化调度研究等方面取得进展和突破，改进中国可持续水电的设计与运行。具体目标为：（1）构建水库分层取水效果预测模型，提出水电站生态环保措施评估方法，建立变化条件下水电站优化运行模式；（2）选择雅砻江或金沙江流域典型水电站，开展水库水温监测及其分层取水设施效果评估；（3）选择雅砻江或金沙江流域开展栖息地保护示范研究；（4）融合降水数值预报产品、地面观测数据、雷达测雨数据，获取高精度的短期（3-7 天）降水预报信息，建立耦合降水预报与水文预报模型，改进水电站水库来流预报精度；（5）利用课题四生成的降尺度后的不同气候变化情景资料来预估水库来流变化，并研究气候变化情景下水库调度方案的优化方法。

3.4 Climate Impact Modeling, Methods, and Scenarios to Support Improved Energy & Water Systems Understanding

The overall objectives of Topic Area 4 are to project future changes in the hydrological cycle of the American West and China, to evaluate these projections against the historical record, and utilize the validated projections to quantify the impacts of the changing hydrological cycle on power plants, electric grid operations, hydropower generation, and power requirements for the reliable provision of water supplies.

Water is a critical resource for sustaining society and the environment and for producing energy. Due to the effects of climate change, reliable supplies of water for these vital sectors may be increasingly at risk. Climate change is altering historical patterns of rain and snowfall and displacing inputs from infrastructure designed to provide water to communities, industries, and agriculture. Simultaneously, global warming is elevating water temperatures, compromising its use as a coolant in thermoelectric energy production, and elevating the risk of extreme weather damage to critical energy and water- treatment facilities. The breadth of these potential impacts, combined with the large uncertainties inherent in current projections, raises the importance of actionable predictions of near- and medium-term changes in the Earth's hydrological cycle that affect China and the U.S., together with our international partners. Such predictions require the development of a tightly integrated suite of simulations and diagnostics coupling Earth system, hydrological, and operational water and energy resource models.

Understanding the effects of climate change requires joint projections of climate change interacting with the energy and water resource sectors. Such joined projections require three capabilities: (i) Observations of the state of the current inputs to and outputs from the regional hydrological cycle relevant the provision of energy and water resources; (ii) Validated models to project the future changes in these inputs and outputs due to global climate change; and (iii) Methods for converting these projections into impacts on power generation, consumption, and transmission connected to the state of the water system. The primary goal of Topic Area 4 is to improve our understanding of the resiliency and risks associated with critical energy and water resources.

3.4 通过气候影响建模、分析与情景设计，加深对能源与水系统的认知

议题 4 的总体目标是预测美国西部和中国水文循环的未来变化，评估针对历史纪录的预测，利用校验预测结果来量化变化中的水循环对电厂、电网运行、水电发电和具有可靠供水的电力需求的影响。

水是维持社会、环境和能源生产的关键资源。由于气候变化的影响，关键部门的可靠供水可能面临越来越多的风险，气候变化正在改变降雨和降雪的模式，改变基础设施对于城市、工业和农业的投入。同时，全球变暖对水温的抬升使其作为热电能源生产冷却剂的功能有所弱化，从而增加了极端天气对重要的能源和水设施造成破坏的风险。对全球水循环中短期变化进行可操作性的预测会对中国、美国和其他国际伙伴造成影响，而这些潜在的影响范围和目前预测所固有的不确定性，增加了预测的重要性。这些预测要求进行一整套严谨的综合性地球系统耦合模拟与诊断、开发水文模型和可操作的水与能源模型。

理解气候变化带来的影响要求对气候变化和能源与水部门互动关系进行联合预测，这种联合预测要求三种能力：(1)与能源和水资源供给相关的区域水循环的输入输出观测；(2)在全球气候变化条件下，对输入输出的未来变化进行预测的验证模型；以及(3) 将这些预测转化为产生影响的方法，去影响和水系统相关联的发电、耗电和输电过程。议题 4 的主要目标是改进对于关键的能源和水资源相关的弹性和风险的理解。

3.5 Data Analysis to Inform Policy and Planning Decisions

The work in Topic Area 5 will provide insights for future energy-water nexus management decisions in the United States and China. The research team will identify technology and energy development pathways to maximize water/energy efficiency and greenhouse gas (GHG) reduction. The approach will highlight climate impacts on energy development paths and water limits to future energy development in key regions of China and the U.S. This topic will also include conducting policy analysis and providing recommendations for optimal co- control of energy and water.

3.5 规划、政策及其它决策的支撑数据与分析技术

议题 5 的研究将为中国和美国未来的能源与水纽带关系管理提供见解。研究团队将识别能够最大化提高水/能源效率和减少温室气体的技术和能源发展路径。研究方法将突出中国和美国关键区域中，气候变化对能源开发路径的影响，以及未来能源开发中的水资源限制。该议题还包括为优化能源和水协同控制进行政策分析和提供建议。

Metrics

Progress of CERC-WET towards its goals will be assessed through the tracking of a number of high-level indicators of progress and metrics for performance. These will include the following:

- Significant research outcomes that shape future technology development
- Advancements that improve technology performance
- Advancements that reduce technology costs
- IP disclosures filed in US; in China; and jointly; patents issued
- Business engagement (e.g., partners, cost-share, integrated research planning)
- Application of CERC-WET research by OEMs, suppliers, start-ups, and policymakers
- U.S.-China collaboration (e.g., joint projects, joint publications)

- Joint conferences, workshops and symposia
- Awards received (individual, team, technology)
- Prestigious lectureships/keynotes given at national and international conferences
- Journal and conference papers published
- Post-doctoral fellows and students trained
- Number, frequency, duration of personnel exchanged/collocated among organizations

衡量标准

中美清洁能源研究中心能源与水联盟通过跟踪一些项目进展的高级指标和绩效标准对目标进行评估，包括以下几点：

- 形成能够促进未来技术发展的重大研究成果
- 推动技术性能的进步
- 推动技术成本的降低
- 在中国或在美国或双方联合的知识产权披露或专利发布
- 商业管理（比如：合作伙伴，成本分担，综合研究规划）
- 定牌生产合作、供应商、新成立的企业和政策制定者对于中美清洁能源研究中心能源与水联盟研究成果的应用
- 中美合作（比如：联合项目，联合出版物）
- 共同举办的会议、研讨会和座谈会
- 所获奖励（个人、团队、技术）
- 国内国际会议上知名报告或主旨报告
- 发表的期刊论文或会议论文
- 培养的博士后和学生
- 组织机构间人员交流/合作的人数、频率和时间

4. Approvals

The above Joint Work Plan has been jointly developed and reviewed and is hereby approved by the respective authorities in each country, as indicated by the signatures of the appointed CERC-WET Directors below, made this date _________, 2016.

4.批准签署

以上联合研究方案已经中美双方联合编制和达成一致，并经双方主管部门批准，由中美清洁能源研究中心能源与水联盟中美双方主任于 2016 年__月__日签署。

For the CERC Water Energy Technologies Consortium for the United States

能源与水联盟美方

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