U.S. and China - Clean Energy Research Center

Joint Work Plan for Research Projects under the Clean Vehicles Consortium

（CERC-CVC2.0 2016-2020）

中美清洁能源研究中心

清洁汽车联盟研究项目联合工作计划

（CERC-CVC2.0 2016-2020）

Introduction 介绍

In November 2009, the President of the United States of America, Barak Obama, and the former President of the Peoples 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.

2009 年 11 月，中国前国家主席胡锦涛和美国总统奥巴马共同宣布要成立旨在促进中美两国科学家和工程技术人员开展清洁能源技术联合研究和开发的"中美清洁能源联合研究中心"（英文名为 Clean Energy Research Center，简称 CERC)。

Former U.S. Secretary of Energy Steven Chu, Chinese Minister of Science and Technology Wan Gang, and former the Chinese National Energy Administrator Zhang Guobao signed the CERC Protocol on November 17, 2009, launching the Center. In November 2014, and again in September 2015, the Presidents of the United States and China renewed and reaffirmed their joint commitment to an extended and expanded U.S.-China CERC program.

2009 年 11 月 17 日，美国能源部前部长朱棣文与中国科技部万钢部长，及中国国家能源局前局长张国宝，共同签署了中美清洁能源研究中心合作协议，正式启动了中心运行。2014 年 9 月及 2015 年的 11 月，美中两国首脑续签协议，重申其共同承诺，继续和扩大中美清洁能源研究中心项目。

As the world's top energy consumers, energy producers and greenhouse gas emitters, the U.S. and China will play leading roles in the world's transition to a clean energy economy in the years ahead. Because China and the United States are the Number 1 and Number 2 motor vehicle markets in the world, one country alone cannot achieve global goals for the reduction of petroleum consumption and greenhouse gas emissions. Working together gives the best chance of success. Over the long-term, it is significant to note that much of the energy-consuming infrastructure of the 21st century, including its future vehicle fleets, has yet to be built and therefore will benefit from the results of this work.

根据议定书达成的共识，作为全球最主要的 能源消耗和生产以及温室气体排放大国，中美两国必将在近期将要发生的全球向清洁能源 经济过渡的过程中起到引领作用。作为机动车市场在全球排名前两位的国家，仅靠一个国家的努力不可能实现石油能源消耗

和温室气体排放的全球性目标，只有两国合作才有机会成功。而从长远利益来看，本世纪（21 世纪）与能源消费相关的基础设施以及相应的车队，都尚未完全建立起来，因此该项合作研究将对建立面向二十一世 纪能源基础设施起到深远而有益的影响。

Recognizing that energy use in vehicles represents both challenges and opportunities for our two countries, the United States and the People's Republic of China have chosen Argonne National Laboratory and Tsinghua University to lead a consortium of experts to collaborate in the field of clean vehicles research for phase two of the CERC's Clean Vehicle Consortium (CERC-CVC) beginning in 2016. This second 5-year program of research, from 2016 through 2020, will build on the outstanding accomplishments of the first 5-year program, from 2011 through 2015.

正是认识到汽车能源的使用代表着两国的挑战与机遇，中美两国选择阿岗国家实验室和清华大学领导一个专家联盟，开展清洁汽车领域的合作研究，作为 2016 年开始的中美清洁能源研究中心清洁汽车联盟(清洁汽车联盟)的第二阶段。从 2016 年到 2020 年，第二个五年研究项目将会在第一个五年项目（2011-2015 年）所取得的杰出成就的基础上开展。

Vision 愿景

The vision for the CERC-CVC is to contribute to dramatic improvements in technologies with the potential to reduce the dependence of vehicles on oil and reduce emissions of greenhouse gases (GHGs). The CERC-CVC will build a foundation of knowledge, technologies, human capabilities, and relationships in mutually beneficial areas that will position the United States and China for a future with highly efficient clean vehicles that have very low environmental impacts. The collaboration will leverage the complementary strengths of each country's intellectual and research capacities and accelerate the advancement of technologies for clean vehicles through joint research and development. Outcomes will create new market opportunities for business and speed technology commercialization and deployment in both countries.

清洁汽车合作联盟的愿景是促进相关技术的大幅度进步，降低汽车对石油的依赖和减少温室气体排放。中美清洁汽车合作联盟 CCERC-CVC) 将在互惠互利的基础上，建立包括知识、技术、研发能力、研发人员等 在内的合作机制，共同致力于中美两国车用能源的高效、低污染化合作。中美合作将充分利用每个国家在知识和研究能力方面的互补优势，通过联合研发加快清洁汽车技术的进步。合作成果将为企业创造新的市场机会，加速技术在两个国家的商业化和推广应用。

The Teams 团队

The CERC-CVC will bring together academia, national laboratories, and industry into a consortium of exceptional intellectual strength and expertise in key engineering, natural science, and social science areas. The U.S.-China teams in each of the major research thrust areas will focus on maximizing collaborative efforts and leveraging the respective strengths of the research partners in order to both accelerate invention and commercial success through close ties with industry partners in both countries. CERC-CVC aims to be the leading US- China effort in the clean vehicle arena by performing both long-range transformational and translational research to

bring discoveries and technologies to market. Successful demonstration of the proposed CVC technologies will involve strategic partners from industry in the U.S. and China, including leading OEMs in the transportation and energy sectors, suppliers and innovation companies.

清洁汽车合作联盟将汇集学术机构、国家实验室、以及产业界的力量，形成在工程技 术、自然科学和社会科学等领域内具有智慧及经验优势的合作团队。在每个主要研究方向 的团队，都将专注于最大化的合作和充分发挥各自优势，其目的是在两国工业伙伴的 密切配合下，促进创新和商业化成功进程。清洁汽车合作联盟旨在致力于前沿研究及技术、发明的商业化，成为中美清洁汽车领域的引领者。清洁汽车技术的成功示范将会涉及 到来自中美两国的战略合作伙伴，他们包括交通和能源领域的设备制造商、供应商和创新 型企业。

In the US, Argonne National Laboratory leads an academic-national laboratory team, examples among key members include the University of Michigan, Ohio State University, M.I.T., University of California at Davis, The International Council on Clean Transportation, Calstart, Oak Ridge National Laboratory, Pacific Northwest National Laboratory and Brookhaven National Laboratory.

In China, Tsinghua University leads an academic-national lab team, examples among key members include Beijing Institute of Technology, Shanghai Jiaotong University, Institute of Electrical Engineering of China Academy of Sciences, Technical Institute of Physics and Chemistry of China Academy of Sciences, Beihang University, State Grid Corporation, Hunan University, China Automotive Technology Research Center.

美方以阿岗国家实验室为首的学术-国家实验室团队，主要成员包括密歇根大学，俄亥俄州立大学，麻省理工学院，加州大学戴维斯分校，国际清洁能源理事会，加州清洁交通组织，橡树岭国家实验室，西北太平洋国家实验室和布鲁克海文国家实验室。

中方以清华大学为首的学术-国家实验室团队，主要成员包括北京理工大学、上海交通大学、中国科学院电工所、中科院理化所、北京航空航天大学、国家电网公司、湖南大学、中国汽车技术研究中心。

Criteria for Project Selection 项目遴选原则

Joint research projects must meet the following criteria, mutually agreed by the Parties to the U.S.-China CERC Protocol. The research must promise outcomes that, if successful, would benefit both countries, not just one country. The proposed research plan must evidence bilateral collaboration, such as a foreign partner, division of tasks, leveraging of complementarities, and/or interdependencies. 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 Thrust or Theme Area goals and technical objectives. The selection of projects will weigh the quality of the research team, including leadership, key personnel, expertise, and identify contributing resources, equipment and facilities. 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.

联合研究项目必须符合以下原则，且当事人双方遵守中美清洁能源联合研究中心的协议。研究必须承诺，如果成功，研究成果将有利于两国而不只是一个国家。研究计划必须证明是双边合作，包括外国合作伙伴、任务分工、双方互补性、和/或相关性。研究必须证明具有较强的科学和技术水平、主要创新点和方法的新颖性、与推进更高层次的中心合作、本联盟、研究任务或主题等领域目标和技术目标的相关程度。项目的选择将权衡研究团队的质量，包括领导力、关键人员、专家，并评估其资源、设备和设施。预期成果必须具有产生知识产权（IP）的潜力和知识或技术成果的商业化和/或实施的潜在途径。

Research Areas 研究领域

The CERC-CVC aims to have an impact on society's grand challenges, such as climate change, energy security and sustainability, while spurring innovations to enhance market growth, economic development and jobs creation in vehicle manufacturing, clean energy industries and their associated supply chains. A dramatic reduction of petroleum-based fuel consumption and vehicle greenhouse gas emissions for both nations can be accomplished through the synergy of optimized low-carbon energy carriers. Highly-efficient electrified propulsion technologies that incorporate novel energy conversion, electrified powertrains, vehicle optimization, battery storage and connectivity will be integrated into vehicle platforms based on advanced, low-carbon footprint lightweight materials and components. An integrative life cycle design framework will guide the research and development (R&D) of advanced systems and will enable us to establish greenhouse gas reduction targets, pathways, and policies for translating research results into clean vehicles. Our pioneering research and innovative testbeds will provide unique opportunities to translate laboratory research to industry applications.

清洁汽车合作联盟会对当今社会面临的气候变化、能源安全和环境可持续性发展等挑战产生积极的影响，同时也会通过推动创新促进汽车制造业、清洁能源产业、以及 相关的供应链产业等的经济发展和创造就业机会。通过优化包括电力和生物燃料等在内的低碳能源 载体，中美两国的车用石油燃料消耗和汽车温室气体排放都将显著减少。其次，高效的电 驱动车辆平台不仅囊括了新型能源转换、余热回收、高能储存电池、车网融合等前端技 术，还将采用先进的低碳排放轻质材料和部件。尤为重要的是，本联盟所开展的先进系统 的研究和开发都将在全生命周期设计框架的指导下进行，这使我们在面对将研究成果应用 于竞争性清洁汽车领域时，能够确立明确的温室气体减排目标、途径和相关政策。我们的 前沿性研究和开拓创新的展示平台将为把实验室研究成果转化为产业上的应用提供独一无二的机 会。

Transformation of such a complex scientific and technological nature will depend on the availability of a work force with the appropriate skills and abilities to attain clean vehicle mobility. The US-China CERC-CVC team has a strong representation of scientists, engineers, faculty and students with diverse backgrounds, spanning the key areas of engineering and science needed to attack these grand challenges. The research accomplishments of the CERC-CVC will be leveraged to attract new talent in innovation, global transportation energy research and education. We will capitalize on the multi-disciplinary nature of the CERC-CVC to produce a rich set of academic and hands-on experiences for the scholars and university students in the program, who will work on CVC projects for career development and degree credit. The by-products of the CERC-CVC

are to create a pipeline of new engineers and scientists that are focused on the critical energy and environmental problems in transportation,

这样一个复杂的科学和技术性质的转换，取决于参与人员是否具有实现清洁汽车的技能和能力。中美清洁能源研究中心清洁汽车联盟团队拥有科学家、工程师、教师和学生的综合团队，他们拥有不同的背景，横跨攻破这些重大挑战的关键工程和科学领域。中美清洁能源研究中心清洁汽车联盟的研究成就将用来吸引在创新、全球交通能源研究和教育领域的人才。我们将利用中美清洁能源研究中心清洁汽车联盟多学科的性质，为项目中的研究人员和大学生提供丰富的学术和实践经验，他们将通过 CVC 项目而取得学位和为未来职业发展做准备。中美清洁能源研究中心清洁汽车联盟另一个成果则是建立一个关注交通领域重要的能源和环境问题的工程师和科学家的后备军。

To realize our shared vision, the CERC-CVC has developed a highly collaborative joint research agenda that has been organized in four thrusts, as described below. Under the CERC's U.S. China Protocol and its Intellectual Property Annex, no work on any collaborative activity between the two countries can begin without a mutually agreed upon Technology Management Plan. The four thrusts areas are:

为了实现我们的共同愿景，清洁汽车联盟已经开发了一个高度协作的联合研究计划，包括如下四个领域。在中美清洁能源研究中心的中美协议及其知识产权附属条款下，只有在双方都同意的技术管理计划的框架下，才能开展两国之间的协作活动。

Thrust Area 1: Advanced Batteries 研究方向 1：先进电池

Transformational changes in battery technologies are critically needed to enable the effective use of renewable energy sources, such as solar and wind, to allow for the expansion of the electrification of vehicles. For these applications, batteries must store more energy per unit volume and weight, and they must be capable of undergoing many thousands of charge-discharge cycles. Developing high-performance batteries, which relies on material breakthroughs, is critical to meeting these requirements. For instance, to enhance the performance and lifetime of batteries (specifically, lithium-ion batteries), the formation of the solid-electrolyte interphase (SEI) layer, and the degradation mechanisms in battery electrodes, oftentimes at the nanometer scale, must be better understood. Advanced state-of-the-art in-situ techniques and operando spectroscopic characterization tools will be critical to understanding battery behavior and could help address all the major issues of lithium batteries and beyond. Especially with the development of the third generation synchrotron source, the in-situ study of the cell during discharge and charge using X-ray techniques could provide insight into the structural changes at the atomic level. This thrust area will conduct the research on rechargeable Li-ion battery and energy storage systems to help develop the next generation of advanced batteries, which are needed to expand the electrification of vehicles and grids.

电池的革命性发展是太阳能、风能以及电动汽车应用的关键技术。为应对这些应用的需求，单位重量与单位体积的电池必须能储存更多的能量、耐受数千次的充放电循环。发展高性能的电池 依赖电池材料与技术的突破。例如，要发展长寿命的电池（特别是锂离子电池），必须在纳米尺度内更好地理解 SEI 膜以及电极衰减机。目前最先进的原位技

术和 operando 光谱等表征工具对理解电池行为、更好地说明锂离子电池、锂电池内所发生过程的均非常重要。特别利用第三代同步幅射光源的发展，我们将可以在原子尺度上现场研究电池充放电过程中材料结构的变化过程。在本课题中，我们重点研究锂离子电池以及储能系统，并在此基础上发展下一代先进电池技术，从而推动电动车与电网技术的发展。

Thrust Area 2: Vehicle Technologies 研究方向 2：车辆技术

Market shares of Plug-In Electric Vehicles (PEVs) which include Plug-in Hybrid Electric Vehicles (PHEVs), Extended Range Electric Vehicles (EREVs) and Battery Electric Vehicles (BEVs) continue to grow rapidly with global sales for 2016 expected to exceed 700,000 units largely due to strong growth in China, Europe and the U.S. Three main topical areas were identified, covering Electrified Powertrains, Energy Conversion Devices and Vehicle Optimization. At the onset of the project, the impact of powertrain options, component sizes and technology alternatives on energy, cost and GHG will be evaluated for specific driving patterns both in the U.S. and China based on consistent vehicle technical specifications. High-efficiency engine combustion system options including advanced spark-ignition engine concepts as well as low temperature combustion systems will be evaluated accounting for regional usage patterns while adhering to market-specific constraints such as available fuel options and blending practices. Vehicle light-weighting research will be focused on design methods as well as the coupling of battery crash protection and vehicle lightweight requirements. Benchmarking of Chinese as well as U.S. selected advancing electrified options forms the basis for the definition of powertrain requirements, serving to validate sizing results and providing critical input into design and development of a high-efficiency evaluation platform ultimately also helping to inform vehicle electrification policies.

由于电动车产销在中国、欧洲和美国等市场的持续强劲增长，预计 2016 年电动车在全球的产销量会超过 70 万辆，包括插电式混合动力、增程式和纯电池驱动的电动车。在车辆技术方面，本方向将主要进行以下三个方面的研究：电驱动、能量转换装置和轻量化。在基于中国和美国统一的车辆技术指标和规定的驾驶方式下，项目初期将评估动力系统选择、车辆尺寸及相关技术选项在能源、成本和温室气体排放等方面的影响。在评估高效发动机燃烧系统时，拟包括先进点燃和压燃发动机以及低温燃烧系统等技术，还要考虑不同地区燃油供给和混合燃料应用的可行性。车身轻量化方面的研究重点是，电池的碰撞保护要求与车身轻量化要求的相互影响及设计方法。项目将为高效电驱动车辆评估示范平台的动力系统、电驱动方式和车身轻量化结构提供技术选项和支撑，同时需对标中美不同的电驱动车辆架构的相关指标。

Thrust Area 3: Connected and Automated Vehicles 研究方向 3：网联车

By 2050, 70% of the world population is likely to be urban, with many living in megacities of more than 10 million people. Monstrous traffic jams are already normal in many metropolitan areas in both U.S. and China. Combined with the population density increase, at the current rate, the number of vehicles is expected to rise from 800 million to 2.5 billion by 2050. Such a growth is unsustainable both from a mobility point of view and an energy point of view. Connection and automation are destined to change the transportation system as we know it, connected and automated vehicles will make the car sharing possible. To address this challenge, some researchers estimated (1) that 30% of the trips will leverage car sharing, 25% public transportation, 20% with

personal cars, 15% with bikes and 10% with motorized two-wheelers. Understanding the safety and energy impact of connected and automated vehicles is critical. Research on integration of CAV and advanced vehicle technologies (i.e. electric vehicles) is also needed.

The project will focus on these topical areas: Assessing the energy impact of connected and automated vehicles through transportation system, infrastructure and shared mobility. On-road vehicle test data will be used to understand the impact on driver behavior. The energy impact of shared mobility will be assessed for multiple market penetration levels and powertrain technologies. The impact of transit (i.e., dedicated bus lanes, automated buses etc.) will be considered. Due to the expected increase in electric vehicles, technologies that enable connected and automated electric vehicles and connection with infrastructure (i.e. Wireless Charging and V2G) will be developed and assessed. The charging infrastructure will be assessed through multiple charging technology options.

到2050年，世界上70%的人口将居住在城市，其中很多人会居住在超过1000万人口的超大城市，对中美而言，大都市严重的交通拥堵问题已经司空见惯。结合当前人口增长速度估计，到2050年，当前的汽车保有量将从8亿辆增长到25亿，从交通和能源的角度考虑，这样的增长是不可持续的。车联网和智能驾驶技术的出现将改变这一切，使整个交通运输发生革命性的变化，智能网联汽车将大大促进车辆共享技术的发展，有学者估计未来30%的出行将通过车辆共享，25%的出行将依赖于公共交通，20%依赖于私人汽车，15%使用自行车，10%使用两轮摩托，因此智能网联汽车技术对能源和安全的影响是非常重要的，进一步结合电动车和智能车及车联网技术，开展智能网联电动车的研究也是非常有意义和重要的。

本领域研究将重点集中在以下方面：通过交通系统、基础设施和移动共享评估智能车和车联网技术对能源消耗的影响，通过实验数据研究智能化、网联化技术对驾驶行为的影响，研究共享车辆不同渗透率条件下和使用不同动力总成对能源消耗的影响，公交运输的因素如公交专用车道和智能公交车等也将被考虑在内。考虑电动车未来的快速发展趋势，开展电动车智能化、网联化技术的研究，开发智能网联电动车及自动驾驶技术并通过无线充电等技术实现与电网和基础设施的互联互通，开展相应测试工作，研究采用不同充电技术的充电网络基础设施的评测和优化。

Thrust Area 4: Systems Assessment 研究方向 4：系统评估

This thrust area will assess CERC-CVC technology impacts in terms of energy and environmental benefits of deploying technologies such as PEVs in the U.S. and China, study consumer driving behavior and advanced vehicle market potential, and examine enabling mechanisms such as policies, standards/protocols, and demonstration to help technologies move from lab to the market.

The thrust area will cover 4 topical areas. Topic 1 will characterize technologies such as PEVs under investigation by CERC-CVC; develop supply chains for technologies; conduct lifecycle analysis (LCA) modeling with the GREET model for PEVs, Internal Combustion Engine Vehicles (ICEVs), and batteries; and conduct impact analysis in both countries with technology penetration scenarios. Topic 2 will address consumer driving and purchasing behavior and PEV

market prediction by conducting consumer surveys with instrumented vehicles and by developing detailed vehicle market modeling based on vehicle attributes and macro- and micro-economics. Topic 3 will be on vehicle policy research. It will study PEV fiscal and non-fiscal policies/incentives in both the U.S. and China; compile information on battery improvements and cost reductions and explore how these can influence future PEV markets; and study the influence of US and Chinese fuel economy/GHG standards on efficient technologies such as PEVs, light-weighting, and new engines. Topic 4 will be on best practices to move technologies from lab to market. It will identify the most successful processes that have occurred in the U.S. and China and in particular localities; study on-going PEV demonstration programs in both countries for experiences and lessons; and identify, develop, and implement new high-impact clean, low carbon transportation market development programs.

本部分将对其他三个方向的相关技术成果在中美应用的影响进行评估，评估主要开展电动车的能源和环境效益。包括研究消费者的驾驶习惯与先进技术汽车的市场潜力、评价技术从实验室走向市场的普适性政策与标准法规机制和示范工程。

研究集中在以下 4 个课题。课题 1 是表征车辆技术，建立技术链， 使用 GREET 模型进行对电动车，传统内燃机车和电池生命周期的分析，并评估相关技术在两国推进所带来的能源及环境影响；课题 2 是汽车技术市场研究，建立市场预测模型。通过使用安装数据记录装置的车辆调查两国消费者在驾驶和购买车辆方面的行为习惯，开展电动汽车市场预测，并基于车辆属性和宏观/微观经济学建立细分市场模型；课题 3 主要开展政策研究，构建政策工具箱。首先研究两国针对电动汽车的财政/非财政政策激励机制，其次研究并探索电池性能提升和成本降低对于未来市场的影响，最后研究中美两国在传统燃料经济和温室气体排放方面的政策对节能技术，如电动汽车、轻量化汽车和新型发动机等的影响；课题 4 研究示范工程进展，总结实验室技术向市场转移的经验。从中美两国及其他地区已成功运行的实例中开展最优化筛选，针对中美在运行的电动车示范工程的经验进行总结，实施新的清洁、低碳交通运行市场化项目。

Metrics 评价指标

Progress of the CERC-CVC towards its objectives will be assessed through the tracking of a number of high-level metrics, which 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-CVC research by OEMs, suppliers and start-ups
- 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

为达到 CERC-CVC 预期目标，项目将通过跟踪一系列高水平的指标进行评估。其中包括：

- 重构未来技术的重大突破性研究成果
- 提高现有技术性能的重要进步
- 降低现有技术成本的重要进步
- 在美国、中国登记和批准的知识产权、专利；
- 商业协定（如合作伙伴、成本分摊、综合研究计划）
- CERC-CVC 研究成果在生产厂商、供应商和初创企业的应用
- 中美合作（如合作项目、联合出版物）
- 联合会议、研讨会和座谈会
- 所获奖项（个人、团队、技术）
- 国家和国际会议上的著名演讲/主题报告
- 期刊和会议论文发表
- 博士后研究人员和学生的培养
- 研究人员互派、交换的数量、次数和持续时间

Signed（签署）

D Hillebrand

Date 07 April 2016

Date March 29, 2016

Dr. Donald Hillebrand	**Prof. Ouyang Minggao**
Director，U S CERC-CVC	**Director，China CERC-CVC**
Argonne National Laboratory	**Tsinghua University**
唐纳德 希勒布兰德　博士	**欧阳明高 教授**
美方主任	**中方主任**
阿岗国家实验室	**清华大学**