U.S.–CHINA CLEAN ENERGY RESEARCH CENTER

中美清洁能源研究中心

ANNUAL REPORT 2011

English Version

Foreword

The United States and the People's Republic of China share strategic and economic interests in advancing clean energy technology. We are among the world's greatest economies and our futures depend on the efficient use and innovative production of clean fuels and power.

The technologies under development in the U.S.-China Clean Energy Research Center—clean coal, energy-efficient buildings, and clean vehicles—are central elements of national energy strategies in both countries. These technologies can assure clean and efficient energy futures; reduce vulnerabilities to imported oil; improve air quality, especially in and around growing population centers; and strengthen economic growth by lowering energy costs. They will also mitigate the impacts of energy production and use on the global environment.

Collaborative research can spur rapid innovation in these areas. The U.S.-China Clean Energy Research Center is an ambitious, virtual collaboration, with the United States and China contributing equally to the $150 million pledged over five years. It brings together leading researchers in both countries from dozens of top-flight research institutions and business enterprises. With support from both governments, it provides an attractive, promising platform for spawning new relationships, promoting mutual respect for intellectual property, and facilitating private engagement. It presents previously untapped opportunities that arise from the complementary strengths and research capabilities of each country.

In November 2009, President Obama directed the U.S. Department of Energy and President Hu directed China's Ministry of Science and Technology and National Energy Administration to explore a new model for bilateral cooperation in clean energy research. The collaboration was later joined by China's Ministry of Housing and Urban and Rural Development. Since then, both countries have selected leaders and participants, formulated joint work plans for research, codified frameworks for strengthening protection of intellectual property, and engaged business partners to lead critical research efforts.

This report provides an account of joint progress and illuminates plans for the future. It is the first in a series of annual reports.

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Executive Summary

For more than 30 years, the United States and China have collaborated on science and technology development. Emerging global challenges, including energy security and growing environmental concerns, have spurred a new phase of mutually beneficial cooperation between the two countries.

A new and promising component of this new phase of cooperation is the U.S.-China Clean Energy Research Center (CERC). Established in 2009 by U.S. President Barack Obama and China President Hu Jintao, CERC strives to accelerate clean energy innovation and help both countries improve quality of life and meet energy and environmental goals.

CERC facilitates joint research, development, and commercialization of clean energy technologies. It brings together leading scientists, engineers and prominent business leaders from both countries. With complementary strengths in science and technology development, CERC leverages these strengths to help position both countries for a prosperous, clean, and energy efficient future.

CERC is built on a new, collaborative model for bilateral cooperation that encourages interaction and ensures that partners benefit from collective research. CERC includes a novel framework for protecting intellectual property (IP) that provides a strong foundation for U.S.-China clean energy cooperation. The framework provides research partners with important tools for protecting sensitive information and ensures that partners retain appropriate rights for new technologies they create. It also has features that facilitate access to markets in the other's territory.

Supported by this IP framework, CERC conducts joint, collaborative research and development (R&D) in three consortia:

1. Advanced coal technologies, including carbon capture, storage, and utilization
2. Building energy efficiency
3. Clean vehicles, including electric and alternative fuels

The signing of Joint Work Plans in January 2011 officially launched CERC's first year of programmatic and technical activities.

Key Achievements

CERC's first-year activities laid a solid foundation for advancing collaborative research, development, and commercialization of new clean energy technologies in the United States and China through 2015. Key achievements include the following:

Governance

Establishing formal leadership and oversight. Key positions in the CERC governance structure were filled in both countries. The CERC governance structure includes a Cabinet-level Steering Committee, a Secretariat headed by executives from the United States and China, U.S. and China CERC Directors, and an Executive Committee of distinguished technical leaders for each of the three research consortia.

Planning

Developing joint work plans that enhance coordination. The countries selected and made awards to their CERC-leading research institutions, who led the development of five-year Joint Work Plans (JWPs), which outline mutually agreed upon areas for CERC research. Following the signing of the JWPs in January 2011, teams collaborated to develop detailed Ten-Point Plans for each CERC research project. These plans, which were completed in December 2011 and jointly signed by the lead researchers for each project, constitute clear commitments for future work and form the basis for mutual accountability for CERC research and progress.

Committing private sector and government funding. Leading U.S. and China businesses and research institutions are investing at least $75 million toward CERC collaborative research over five years. Governments in both countries have demonstrated their commitment by each securing approximately $15 million in funding to support activities through 2012, and each committing $37.5 million over five years. Altogether, these private sector and government investments in both countries total $150 million in planned funds through 2015.

Intellectual Property

Creating a groundbreaking framework for protecting intellectual property. Teams negotiated Technology Management Plans (TMPs) over the course of 2011 that create a framework for protecting intellectual property throughout the CERC collaboration. Teams negotiated a separate TMP for each CERC consortium in both English and Chinese to ensure maximum clarity, which were subsequently given weight by government endorsements. Both nations launched an education and training program to help CERC researchers understand the IP framework outlined in the TMPs, and other pertinent IP laws and policies in each country.

Partnerships

Fostering long-term research partnerships. The teams of U.S. and Chinese scientists and engineers collaborated through R&D planning workshops, research team visits, joint appointments of faculty, student and staff exchanges, joint meetings, and information exchanges. These relationship-building efforts are essential to information sharing and encourage productive collaboration.

Technology

Developing significant technological advancements. Researchers shared findings at conferences, through invention disclosures, and in publications. Key technological achievements are described throughout this document and detailed in Appendix D, which provides summaries of each CERC research project.

Introduction

For more than 30 years, the United States and China have collaborated on science and technology development. Emerging global challenges, including energy security and growing environmental concerns, have spurred a new phase of mutually beneficial cooperation between the two countries.

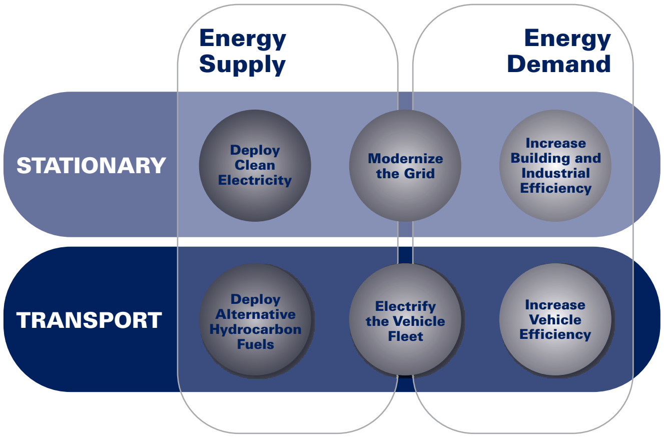
Shared Challenges; Common Goals

The United States and China are the world's two largest economies, the two greatest producers of energy, and the two greatest consumers of energy. Recognizing the vital importance of secure, affordable, and clean energy, China and the United States face common challenges. Both countries generate the majority of their electricity using domestic supplies of coal, and both rely heavily on foreign sources of oil. Together, the two nations account for 40 percent of annual global greenhouse gas emissions.

In addressing these challenges, the United States and China are each pursuing forward-looking energy strategies predicated on efforts to unleash technological innovation. In the United States, multiple energy technologies are bound together in a multiyear framework for planning and coordinated among federal agencies, state and local governments, and the private sector, who are the major owners, operators, and investors of the energy system (Figure 1).[1] Similarly, China's strategy for developing and deploying energy technologies emphasizes strengthening energy supply, mainly through use of domestic resources, and addressing energy demand by improving efficiency.

The clean energy sectors in both countries are growing rapidly. Expansion creates opportunities for both testing new ideas and gaining footholds for innovative products in new markets. Strong research institutions inspire technical and economic competitiveness. Pioneering businesses have the production knowledge and market insight needed to successfully transition innovations to the marketplace. The combination of opportunity and innovation will improve quality of life. Both nations understand that strengthening cooperative scientific discovery, under an effective protocol for protecting intellectual property, is a means to build a foundation of knowledge, technologies, human capabilities, and relationships that will position both countries for a prosperous, clean, and energy efficient future.

Figure 1: Framework for Strategies of the U.S. Department of Energy



China's Energy Strategy: A Foundation for Development

The aim of China's energy strategy is to establish an economic, stable, clean and safe energy supply system to sustain socio-economic development. The strategy:

- Prioritizes conservation
- Relies on domestic resources
- Develops diversified energy sources
- Pursues technological innovation
- Protects the environment
- Strengthens international cooperation for mutual benefit

[1] U.S. Department of Energy, Report on the First Quadrennial Technology Review, September 2011.

A Groundbreaking Collaboration

U.S.-China Clean Energy Research Center (CERC) facilitates joint research, development, and commercialization of clean energy technologies between leading scientists and engineers from the United States and China. Leveraging both nations' strengths in science and technology development, CERC is accelerating innovation to improve quality of life and meet tomorrow's challenges.

This flagship initiative is driven by leadership from businesses, universities, governments, and research institutions. It is funded in equal parts by both countries. U.S. funds are used exclusively to support work conducted by U.S. institutions and individuals, and Chinese funds support work conducted by Chinese institutions and researchers.

The United States and China have a rich history conducting cooperative research in diverse fields, including basic research in physics and chemistry, earth and atmospheric sciences, a variety of energy-related areas, and environmental management.[2] Prior cooperative research partnerships between the two nations centered

[2] Research was conducted, and continues to be conducted in areas not covered by the CERC Protocol, under The Science and Technology Cooperation Agreement of 1979, as amended in 1991.

Cooperation on Clean Energy Technologies Benefits Both Countries

As the world's two largest energy markets, the United States and China both benefit from clean energy innovations. Collaborative partnerships produce synergies in research that strengthen domestic industries, ensuring that our nations remain at the forefront of clean energy technologies. This creates jobs in both countries, generates exciting new products for consumers, and boosts exports. CERC is helping to create an improved energy future through:

- Innovative building technologies that save energy and improve comfort
- Cleaner and more efficient power generated with fewer emissions
- Advanced vehicles that are safe, save money, and reduced dependence on foreign oil
- Access to new markets for businesses, strengthening the economy, and creating new jobs

China is the world's fastest-growing market for aviation, energy, transportation and healthcare. GE's initiatives on clean energy in China, including the U.S.-China Clean Energy Research Center, advanced coal technologies, high-speed rail and others will apply GE's technology and innovation strengths to these growth challenges. These initiatives will support jobs in both China and the United States.

Jeff Immelt, Chairman and CEO, General Electric

Figure 2: U.S. President Barack Obama and China President Hu Jintao announced the establishment of the $150 million U.S.China Clean Energy Research Center in November 2009

on academic teams of researchers conducting similar projects and sharing this knowledge through technical papers and reports. In this traditional partnership model, relationships were collegial, projects were coordinated, and work was carried out largely independently. Intellectual property (IP) provisions were not flexible.

Protecting intellectual property is a vital part of promoting innovation. CERC operates on a new model that encourages interaction and ensures that both partners benefit from collective research. Researchers collaborate through jointly developed work plans, work on joint tasks, and maintain interdependent relationships that build on complementary R&D strengths. This enables teams to divide their labor, leverage resources, and accelerate joint R&D breakthroughs. The benefits of these breakthroughs can then be shared among partners, according to IP agreements established before work began, and can be extended by commercialization interests.

The CERC IP framework is outlined in two key documents, the CERC Protocol and the IP Annex. This framework protects U.S. and Chinese researchers, scientists, and engineers by assuring IP rights for the technologies they create. It also defines how intellectual property may be shared or licensed in each country. IP rights are guaranteed in each territory, and IP terms and conditions may be negotiated. Where IP is created in a jointly funded research project, the project's participants in both countries have the right to obtain a non-exclusive license to the IP.

More information about the development of the IP framework is presented on page 8.

Industry Partners Drive Innovation

Businesses and government research teams in both countries work together to accelerate invention and commercial success. Compared to traditional frameworks for collaboration, the CERC collaborative model delivers several key benefits that empower industry partners to assume a central role, including:

- Enhanced intellectual property protection
- Embedding of partners in the innovative process
- Partners gaining insights into research processes underway
- Ownership or licensing of IP for commercial purposes
- Exposing new technologies to potentially large markets

These benefits have successfully attracted active industry participation and support for CERC research efforts. Leading manufacturing and technology development firms are co-leading selected research projects, spearheading planning efforts and information exchanges, and providing essential funding that redoubles the research investments made by the U.S. and Chinese governments.

The U.S.-China Clean Energy Research Center Vision

CERC will accelerate development and rapid deployment of critical technologies for cleaner use of coal, including carbon capture, storage, and utilization; energy efficiency, especially in the built environment; clean vehicles, including electric and alternative fuels; and other areas of clean and renewable energy. These efforts are executed with the aspiration to generate a diversified energy supply and accelerate the transition to a low-carbon economy while avoiding the worst consequences of climate change.

CERC aims to help both countries meet energy and environmental goals by facilitating research, development, and commercialization of clean energy technologies by teams of scientists and engineers in both countries. It also serves as a platform for the exchange of knowledge and bilateral experts in terms of clean energy affairs.

Cooperative activities through CERC are conducted on the basis of five principles:

- Equality, mutual benefit, and reciprocity
- Timely exchange of information relevant to cooperative activities
- Effective protection of intellectual property rights
- Peaceful, non-military uses of the results of collaborative activities
- Respect for the applicable legislation of each country

CERC Research and Development Consortia

The United States and China will each benefit from accelerated deployment of clean energy technologies within each of the three consortia: advanced coal technologies, building energy efficiency, and clean vehicles.

Advanced Coal Technology Consortium

The United States and China both have abundant coal resources and are dependent on coal for electricity—about 50 percent in the United States and 80 percent in China. This presents challenges and opportunities in environmental performance and commercial development. Within CERC, the Advanced Coal Technology Consortium (ACTC) is advancing cleaner coal technologies and practices for capturing, storing, and utilizing carbon dioxide emissions, which will result in economic development, reduced emissions, and improved energy efficiency. Joint research is addressing coal-fired power plants using integrated gasification combined cycle technology with carbon dioxide (CO_2) capture and storage; post-combustion CO_2 capture, utilization, and storage technology; sequestration capacity and near-term opportunities; CO_2-algae biofixation and use; oxyfiring combustion; coal co-generation with CO_2 capture; and additional projects.

Building Energy Efficiency

In the United States, more than 75 percent of electricity generated is used to operate buildings. Incorporating new and developing technologies to an existing building can significantly reduce energy consumption. In China, if present trends continue, floor space will be built in the next 20 years equal to the entire U.S. building stock. Rapid and widespread development projects present prime opportunities to incorporate energy-efficient technologies and strategies into new buildings. Such measures would improve the efficiency, save energy, reduce greenhouse gas emissions, and increase indoor comfort. This in turn also reduces stress on the electric grid and avoids the need for additional transmission lines and construction of additional power plants. The CERC Building Energy Efficiency (BEE) consortium is addressing research on building energy efficiency technologies and practices. U.S. and Chinese researchers jointly conduct research on monitoring and simulation, building envelope, building equipment, whole building integration, and commercialization.

Clean Vehicles

The United States and China are the world's two largest automobile markets and oil consumers, both importing more than half the oil they consume. The CERC Clean Vehicles Consortium (CVC) seeks to improve technologies to reduce the dependence of vehicles on oil and improve vehicle fuel efficiency. Joint research is addressing advanced batteries and energy conversion, advanced biofuels, clean combustion and auxiliary powertrain units (APUs), vehicle electrification, advanced lightweight materials and structures, vehicle-grid integration, energy systems analysis, technology roadmaps and policy.

Funding from Public and Private Sectors of Both Countries

This flagship initiative is funded in equal parts by the private and public sectors in both countries, with broad participation from industry, government, universities, and research institutions. Contributions from the private sector in each country are at least $37.5 million. As of December 2011, governments of both nations had demonstrated their commitment to the success of CERC research and development by providing funding for the first two operating years. The United States (through the Department of Energy [DOE]) awarded $15 million dollars, and China (through the Ministry of Science and Technology [MOST]) committed 80 million Yuan (¥), or about $12.7 million dollars to three Chinese teams. The total investments exceed $150 million through 2015, according to the funding plan (Table 1).

While U.S. funds are applied to U.S. researchers and Chinese funds are applied to Chinese researchers, the collective impact of the funding is amplified because of CERC's collaborative efforts. CERC avoids cross-border duplication and leverages shared knowledge, accelerating development of breakthroughs and technological solutions as the world confronts the global challenge of shifting to a low-carbon future.

Table 1. Five Year CERC Funding Plan (Million U.S. Dollars)

		United States		China	Consortium
		DOE	Partners	MOST & Partners	Totals
5-Yr Totals	Advanced Coal	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	Buildings	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	Clean Vehicles	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	TOTAL	$37.5	≥ $37.5	≥ $75.0	≥ $150.0

More information about CERC funding, including year-by-year breakdown of government and industry contributions, is presented in Appendix C.

CERC Accomplishments in 2011

The first-year activities of CERC have laid a solid foundation for maximizing collaborative research and have achieved significant technological advancements toward development and deployment of new clean energy technologies.

Key accomplishments in 2011 include the following:

Governance	**Establishing formal leadership and oversight** for CERC efforts, including the placement of experts to participate in governance structures in both countries
Planning	**Developing joint work plans that enhance coordination** for each of the three consortia
Intellectual Property	**Creating a framework for protecting intellectual property** to enable closer cross-border collaboration
Partnerships	**Fostering long-term research partnerships** between teams of U.S. and Chinese scientists and engineers through R&D planning workshops, research team visits, student and staff exchanges, joint meetings, and information exchanges
Technology	**Developing technological advancements** and sharing findings at conferences, through invention disclosures, and in publications

Together, these efforts accelerate progress in technology development, demonstration, and enhancement to help both countries meet energy and environmental goals.

Establishing Formal Leadership and Oversight

Program governance structures provide management, oversight, and accountability for CERC efforts.

Both countries established governance structures that will provide key leadership and oversight. This included recruiting or appointing positions on the CERC steering committee, CERC secretariat, and appropriate executive committees, along with CERC country directors and staff.

The CERC governance structure is composed of a Steering Committee and Secretariat headed by executives from the United States and China, and Executive Committees for each of the three consortia. The Steering Committee members provide high-level direction and authority to guide and ensure lasting commitments and overall successes of the program. The Secretariat and country directors work to facilitate inter- and intra-governmental coordination between and within the respective countries, providing leadership, technical support, and diplomatic and legal guidance as required to advance CERC goals. The Executive Committee for each consortium, reporting to the CERC Secretariat, provides oversight and review of CERC progress, advises on the CERC portfolio and projects, and identifies opportunities for synergies with other related R&D programs. The structure, shown in Figure 3 and with more detail in Appendix B, is provided equally by both countries.

Figure 3: Structured governance supports strong bilateral program management

Steering Committee

U.S.
Secretary Steven Chu, DOE

China
Minister WAN Gang, MOST
Administrator LIU Tienan, NEA
Vice Minister QIU Baoxing, MOHURD

Secretariat

U.S.
Assistant Secretary David Sandalow, DOE

China
Vice Minister CAO Jianlin, MOST
Members: Deputy Director General MA Linying, MOST
Director General LI Ye, NEA
Deputy Director General HAN Aixing, MOHURD

Executive Committee for Clean Coal Consortium | Executive Committee for Buildings Consortium | Executive Committee for Clean Vehicles Consortium

MOST: Ministry of Science & Technology; NEA: National Energy Administration; MOHURD; Ministry of Housing and Urban-Rural Development

Developing Joint Work Plans that Enhance Coordination

Unique Joint Work Plans and supporting Ten-Point Plans focus efforts and ensure mutual accountability in meeting research goals.

Joint Work Plans, Ten-Point Plans Identify Common Research Priorities

In 2011, both countries worked together to develop formal plans for CERC research and development. The countries established five-year Joint Work Plans (JWPs), which outline the high-level, mutually agreed upon thrusts for CERC collaborative research. The JWPs were signed in January 2011 in conjunction with the State visit of President Hu and President Obama in Washington, DC.

Figure 4: Teams of scientists and engineers from academia, national laboratories, and industry in the United States and China are now conducting joint research projects in these areas

Following the signing of the JWPs, teams collaborated to begin developing Ten-Point Plans for each CERC research project. These detailed research project plans are the key to mutual accountability for CERC research efforts.

Ten-Point Plans Ensure Mutual Accountability

Ten-Point Plans for each research project are jointly signed by the principal investigators who lead each project. The plans explain how the project differentiates itself from other government-sponsored research in this area, addressing the following ten components:

- Research objective
- Background and technical approach
- Task statements
- Roles and responsibilities of leads, performers, and partners
- Equipment, resources, sites, facilities, and materials to be supplied
- Work schedule, with interim milestones (or decision points)
- Deliverables and dates
- Estimated costs (indicating level of effort, or person-hours equivalents)
- Reporting requirements (interim reports, final)
- Technical Management Plan (TMP)

This innovative and enhanced framework for protecting intellectual property is an important step for the Clean Energy Research Center and collaborative research.

Dr. Steven Chu,
U.S. Secretary of Energy

Creating a Framework for Protecting and Sharing Intellectual Property

Technology Management Plans ensure protection of intellectual property and ease sharing information to accelerate innovation. Education and training efforts increase awareness and understanding of intellectual property issues and paths forward.

Technology Management Plans Provide Framework to Protect Intellectual Property

Early in the development of CERC, negotiators agreed that an overarching framework of Technology Management Plans (TMPs) for each consortium would guide development of CERC project- or IP-specific contracts. These TMPs were negotiated and endorsed over the course of 2011 (see sidebar). Although each of the consortia has unique characteristics for the TMP to address, common elements are shared in the plan framework. Key provisions of the TMPs include the following:

- A clear understanding of IP principles and administrative procedures before work begins
- Enhanced protection for IP rights with endorsements by both governments
- A requirement to share the benefits of joint research
- Means for negotiating terms and conditions
- Pathways for dispute resolution

The framework outlined in the TMPs, negotiated by industry participants and other stakeholders from both nations, provides a strong foundation for U.S.-China clean energy cooperation. It protects intellectual property for both existing and newly developed technologies. It provides businesses and other research partners with important tools for protecting sensitive information. It also ensures that partners retain appropriate rights for new technologies they create, allowing CERC project participants to enter traditional commercial contracts to set the terms and to allocate their rights to—and royalties from—their creations.

Countries Provide IP Education and Training

To help business and academic researchers understand the IP framework outlined in the TMPs, as well as other pertinent IP laws and practices in each county, the U.S. DOE and China's MOST agreed to carry out a continuing program of IP education and training. The program will increase mutual awareness and understanding of the intellectual property laws and practices of each country, how they intersect, and how they pertain to the formation of IP-protected research collaborations under CERC. Both countries will also offer guidance and technical assistance to CERC participants to ensure that CERC-related contracts comport with the TMP and controlling documents.

To improve CERC participants' understanding of each country's laws and practices impacting intellectual property rights, the CERC Forum designed an IP Workshop in which Chinese and American experts would discuss with ACTC participants applicable laws and the TMP and government contracting requirements that impact IP rights. The first IP Workshop, held at the Huazhong University of Science and Technology (HUST) in Wuhan, China in May 2011, was attended by U.S. and Chinese ACTC participants. Planning for two subsequent workshops that will include all CERC participants is underway for 2012. The first will be held in China in March and the second in the United States later in the year.

Figure 5: High-level ceremony held in Beijing on September 23, 2011, when documents agreeing to support the three TMPs was signed by representatives of the U.S. Department of Energy and the China Ministry of Science and Technology

Construction of the Technology Management Plans: Laying the Foundation for Collaboration

Technology Management Plans (TMPs) Negotiated

In May 2011, U.S. and Chinese officials presented their proposed ACTC TMP. The U.S. negotiators drafted the first joint document, based on contributions from both the first U.S. proposal and that of the Chinese. The document was negotiated simultaneously in English and Chinese to ensure that both countries had a complete understanding of the intent of the language. The U.S. negotiators worked with bilingual experts and the law firm of Wilson-Sonsini to ensure the Chinese and English language was faithful in meaning. The Chinese negotiators were fluent in English, a fact that enhanced the process immeasurably. The U.S. negotiators produced a document that interleaved the English and Chinese language into a single document and it was agreed that this would be the format for the final documents.

- ACTC TMP: Negotiations proceeded through July. China's Ministry of Science and Technology and the U.S. Department of Energy formally reviewed the document. The final ACTC TMP was signed on August 19, 2011, by ACTC Directors Professor Dr. Zheng Chuguang for the Chinese and Dr. Jerald J. Fletcher for the United States.
- BEE TMP: CEF and the Ministry of Housing and Urban Rural Development's Mr. Liang Junqiang, Director for the BEE Chinese consortium, negotiated the BEE TMP. It was signed on September 22, 2011 by Director Liang and Michaela Martin on behalf of the U.S. BEE consortium.
- CVC TMP: Further negotiations between CEF on behalf of the United States and MOST for the Chinese resulted in the CVC TMP being signed by its Directors, Dr. Minggao Ouyang (China) and Dr. Dennis Assanis (United States) on September 20, 2011.

Letters of Endorsement Signed

To ensure legal enforceability, the corresponding government ministries must also agree to the TMPs. To this end, DOE and MOST signed a separate Agreement on the TMPs for the U.S.-China Clean Energy Research Center for each of the three consortia. This served as an agreement to and endorsement of the three consortia TMPs.

On September 23, 2011, U.S. Energy Secretary Steven Chu and Minister Wan Gang, of the Chinese Ministry of Science and Technology, witnessed the signing of the letters of endorsement recognizing intellectual property guidelines agreed upon by each of the three consortia. David Sandalow, Assistant Secretary for Policy and International Affairs signed for the United States. Linying Ma, Deputy Director General for International Affairs, Ministry of Science and Technology, signed for China.

Figure 6: Signing of the Technology Management Plans

Both China and the United States are large energy producers as well as large energy consumers, having complementarity in the area of energy studies. CERC will become a platform and support for the bilateral cooperation in the area of energy studies, playing a positive role in strengthening S&T cooperation between China and the United States.

Dr. Wan Gang, Minister,
Ministry of Science and Technology

Figure 7: Special signing ceremony for the CERC Advanced Coal Technology Consortium (ACTC) held in Morgantown, West Virginia, on August 19, 2011, when the TMP was approved by the ACTC Directors

Fostering Long-Term Research Partnerships

CERC has facilitated close partnerships between U.S. and Chinese researchers.

Staff and Student Exchanges Improve Information Sharing

Staff and student exchanges and co-location between organizations are improving the research and information sharing that can help make dramatic improvements in technologies.

In ACTC, cooperative research teams led by West Virginia University (WVU), HUST, and China Huaneng Group Clean Energy Research Institute are developing the networks and foundations for long-term research alliances. In addition, ACTC members hosted counterpart delegations and facilitated partnership building and exchange of data and ideas.

Exchanges like these are improving collaboration channels and bringing together foremost world experts from industry, academia, and government to work side-by-side on some of the most difficult clean energy challenges.

Joint Meetings Provide a Structured Forum for Discussion

Joint meetings and virtual information exchanges have provided pathways for researchers to collaborate and share ideas, stimulating further advancements. Several joint conferences, workshops, and symposia were held in 2011. These in-person working sessions between U.S. and Chinese researchers and committed partners established a structured forum for sharing ideas and stimulating further advancements.

At an October workshop in Beijing hosted by Tsinghua University and the University of Michigan, representatives from U.S. and Chinese governments, national laboratories, universities, and representatives from General Motors, Ford, Chrysler, Cummins, and Delphi exchanged information on high-priority research topics. Discussions included current vehicle design activities and emerging developments, research breakthroughs that are needed, and mutually beneficial work areas for future projects.

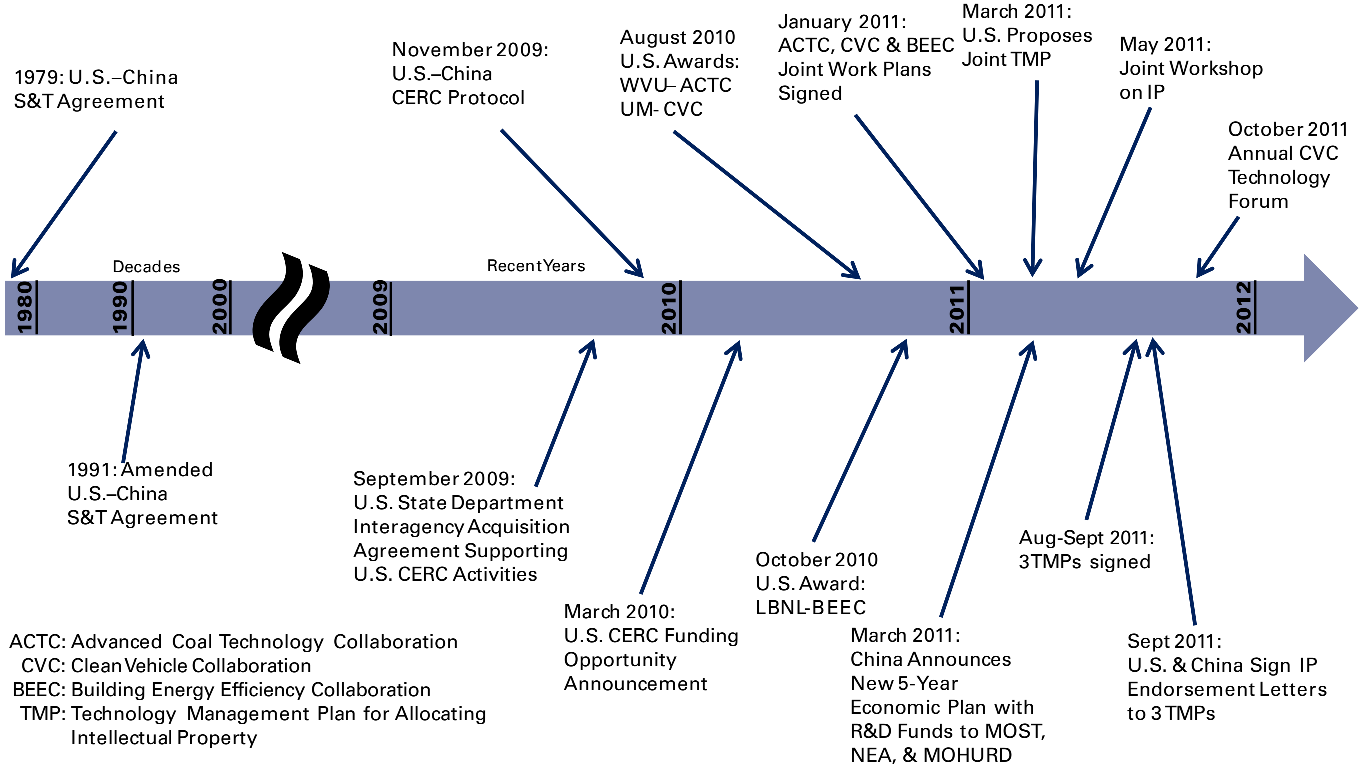
Developing Technological Advancements

The first year of CERC research efforts saw great strides in collaborative and technological development, and the teams promoted these achievements at conferences, in relevant journals and publications, and through intellectual property filings.

Among the impressive list of significant advancements, researchers developed CO_2 storage models, synthesized catalysts for CO_2 capture at power plants, conducted behavioral research and surveyed energy use in buildings, developed a comparative building standards tool, identified components that may help improve the cycle life of Li-ion batteries in vehicles, and developed low-cost design and production methods for lightweighting vehicle materials. Notable technological developments are described for each of the consortia in the following section, and in more detail in Appendix D.

Teams also communicated research developments through interactive media such as web applications. Joint research efforts also yielded important intellectual property that is being protected and shared under the IP framework established in the TMPs.

Figure 8: Milestones and Achievements in U.S.-China Clean Energy Research Partnership



2011 Achievements of the Research Consortia

The following sections examine the three research consortia for advanced coal technologies, building energy efficiency, and clean vehicles—ACTC, BEE, and CVC, respectively—and their achievements over the last year. Achievements with the construction and design in the first full year of this novel partnership have set the stage for years of promising technological innovations. Establishing the administrative structure for collaboration between countries, research institutions, and industry partners involved significant effort and strong leadership at all levels. In addition to these organizational milestones, selected technical accomplishments are highlighted in the following sections, with a more comprehensive representation shown separately in Appendix D.

Advanced Coal Technology Consortium

Jointly planned research in advanced coal technology is addressing new challenges associated with clean coal power generation and transformation, the development of low-cost CO_2 capture and utilization technologies, and the development of geological sequestration practices.

CERC Vision: Advanced Coal Technologies

Advance the coal technology needed to safely, effectively, and efficiently utilize coal resources including the ability to capture, store, and utilize emissions from coal use in both countries.

Examples of Benefits from ACTC Research

Advanced coal technology research supports the development of innovations that will bring cleaner, more efficient, and affordable electric power to consumers. It will help deliver essential technologies:

- Cleaner processes for combusting coal to generate electricity
- More efficient power plants
- Technologies that can capture carbon dioxide (CO_2) emissions and store them permanently
- Processes that capture CO_2 and convert it to usable products, such as feedstocks for renewable biofuels
- Catalysts that facilitate the permanent underground storage of CO_2 emissions

ACTC Research Topics

The ACTC is focusing on the most critical research needs, categorized by the following nine research topics (see Appendix D for more detailed discussion of ACTC research activities):

1. *Advanced Power Generation:* Develop breakthrough technologies in clean coal power generation and the application of advanced technology.

2. *Clean Coal Conversion Technology:* Conduct research, development, and demonstration of new coal co-generation systems with CO_2 capture, including new coal-to-chemical co-generation; new CO_2 capture processes; and co-generation systems with combined pyrolysis, gasification, and combustion. Projects in this area will pursue high-conversion efficiency.

3. *Pre-Combustion Capture:* Conduct major demonstrations of integrated gasification combined cycle power generation with carbon capture and sequestration.

4. *Post-Combustion Capture:* Investigate various technologies for post-combustion capture and conduct demonstrations of CO_2 capture, utilization, and storage in cooperation with large power generation companies.

5. *Oxy-Combustion Capture:* Study the fundamental and pilot-scale combustion and emission characteristics of indigenous Chinese and U.S. coals of different ranks under oxyfuel conditions, create a model for oxy-fired burner design, evaluate and optimize pilot-scale oxy-combustion, and conduct a commercial-scale engineering feasibility study for an oxyfuel–combustion reference plant, with the goal of achieving cost and performance breakthroughs in the laboratory and the field that help overcome the challenges to oxyfiring with both U.S. and Chinese coals.

6. *CO_2 Sequestration:* Develop research work focused on CO_2 geological sequestration (CGS) in China's Ordos Basin to better understand and verify key technologies for CO_2 storage in saline formations, to provide the scientific evidence to implement large-scale carbon capture and storage in China, and to provide support for carbon capture and storage (CCS) development in the United States.

7. *CO_2 Utilization:* Support the industrial demonstration of carbon biofixation using microalgae to absorb CO_2 and turn the biomass produced into a rich source of renewable energy, including biodiesel.

8. *Simulation and Assessment:* Apply modeling techniques to a wide variety of issues associated with pre- and post-combustion CO_2 capture and oxy-combustion in order to assess the economic and operability potential of existing capture technologies in conjunction with removal of criteria pollutants, assess the technical feasibility and potential economic benefit and operability of new, novel carbon capture technologies, and optimize the economics of different carbon capture technologies.

9. *Communication and Integration:* Provide effective management of intellectual property and information sharing, including platforms for knowledge and data sharing.

ACTC Partners

The U.S. Advanced Coal Technology Consortium is led by **West Virginia University Research Corporation**. The U.S. Consortium includes the following additional partners:

- Babcock & Wilcox
- Duke Energy
- General Electric
- Great Point Energy
- Indiana Geological Survey
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- LP Amina
- National Energy Technology Laboratory
- University of Kentucky
- University of Wyoming
- U.S.-China Clean Energy Forum, China Relations Council
- World Resources Institute

China's Advanced Coal Technology Consortium is led by **Huazhong University of Science and Technology**, based in Wuhan, and includes the following additional partners:

- Center for Energy & Power, Chinese Academy of Sciences
- China Huaneng Group Clean Energy Research Institute
- China Power Engineering Consulting Group Corporation (CPECC)
- China Power Investment Corporation, Beijing
- China University of Mining and Technology
- ENN (XinAo Group)
- Huaneng Power International, Inc.
- Institute for Rock & Soil Mechanics, Chinese Academy of Science
- Jinan University, Guangzhou
- Northwest University of China
- Shaanxi Provincial Institute of Energy Resources, Xianyang
- Shanghai JiaoTong University
- Shenhua Group
- Tsinghua University
- Yanchang Petroleum
- Zhejiang University, Hangzhou

2011 Progress

Establishing the organizational structure and leadership of the research teams for the bilateral consortium is among the most notable ACTC achievements in 2011. Coordinating efforts between countries, industry partners, and research institutions poses significant administrative challenges. The CERC team has addressed these challenges by devising and instituting a coherent governance structure and instilling dedicated leadership from the two nations. For more information on the ACTC organizational structure and leadership, please see Appendix B.

In addition to the organizational and inter-governmental aspects of creating the coal CERC and establishing its governance structure, the ACTC undertook a number of programmatic and technical activities that came to fruition during this first reporting period. Highlights of ACTC accomplishments include:

Programmatic Accomplishments

The United States and China made great strides in developing and implementing mutually beneficial research plans and building partnership relationships in the ACTC. Activities focused on building cooperative working relationships among the key participants of each jointly defined work area, specifying research projects in more detail (e.g., 10-point-plans), and framing out and agreeing on intellectual property arrangements.

Notably, the ACTC led the achievement of the milestone of the joint approval of its Technology Management Plan. The TMP describes the approach for strengthening protection and managed sharing of intellectual property among U.S. and China research teams. ACTC members hosted delegations of country counterparts and facilitated partnership building and exchange of data and ideas. Specifically, ACTC:

- Recruited and matched distinguished researchers in the United States and China and brought them together to create meaningful dialogue on joint and collaborative research.
- Negotiated a first-of-a-kind IP agreement between United States and China, known as the Technology Management Plan. The provisions of the Plan have already proved useful as statements of agreed-upon principles in subsequent negotiations between U.S. and Chinese partners.
- Created the Private Sector Board (PSB) to review research activities and inform the U.S. ACTC of business interests and opportunities afforded by its industrial partners. Representatives from each founding member company signed the by-laws and accepted the terms. The PSB meets regularly to review progress and discuss future plans.
- Identified CO2 Capture Task members for both countries. The working group established guidelines, protocols, and criteria for system optimization and evaluation, membrane synthesis and evaluation, and catalyst selection, production, and evaluation. The teams developed and refined a simulation model to be used as a common platform for collaboration and researched shared information regarding the similarities and differences of coal-derived flue gas conditions, power plant operation, and environmental requirements in the United States and China.

Technical Progress

The U.S. and Chinese post-combustion capture (PCC) analysis teams worked together to exchange data about plant operation, emissions, and performance. China has one of the world's more advanced PCC processes in sustained operation at scale. The United States and China have sophisticated models for understanding overall system operation and performance. This is the first time such a transparent collaborative process has been employed. The models stabilized and reproduced results that simulate real-world observations. They have since provided insights for retrofit schemes using an array of conventional solvents.

Other 2011 technical highlights from across the ACTC teams include:

- Advanced the development of a regional CO_2 storage model for the northern Ordos Basin in China, which holds excellent potential for long-term storage. Preliminary results from model simulations suggest that nearby limestone formations could store the CO_2 currently emitted by coal-to-liquid facilities in the Shaanxi Province for hundreds of years. Particular progress has been made in determining the regional tectonic stress and fault/fracture patterns. This model is critical to prioritizing specific geological CO_2 storage sites in both the U.S. and China. The Ordos Basin in China is geologically analogous to the Powder River Basin in northeast Wyoming USA. (Refer to Appendix D: ACTC Research topic 6).
- Determined the geologic areas of greatest potential for CO_2 enhanced oil recovery (EOR) in Shaanxi Province, China. Enhanced oil recovery represents an immediate opportunity to cost effectively store CO_2 emissions.

This research is accelerating application of EOR in key regions in China that can, in turn, present incentives—through partial cost recovery—for advancing demonstrations of advanced CO_2 capture technologies. (Refer to Appendix D: ACTC Research topic 6).

- Developed several preliminary geologic maps to depict the characteristics and details of potential storage locations. Using specialized software packages, U.S. and China researchers successfully represented geologic formations and are currently converting the information into computer programs for constructing three-dimensional carbon capture and storage models. (Refer to Appendix D: ACTC Research topic 6).
- Developed new tools to understand the flow of CO_2 after underground injection. These tools screen and quickly inform models with higher resolution, once field data are available. They are valuable in prioritizing more detailed analysis of promising CO_2 injection locations, for both EOR applications and other CO_2 storage. (Refer to Appendix D: ACTC Research topic 6).
- Developed simulation of an integrated gasification combined cycle (IGCC) plant using specialized carbon capture technologies. By comparing the simulation results to other technologies, these models will form the basis of future, plant-wide dynamic simulations of IGCC plants. (Refer to Appendix D: ACTC Research topic 3).
- Continued development of a suite of system simulation models using different technologies for post-combustion carbon capture. Created a "base-case" ammonia-based carbon capture process using the Aspen Plus platform and a simple amine-based (MEA) steady state simulation of a post-combustion carbon capture process. (Refer to Appendix D: ACTC Research topic 4)
- Completed several large oxycombustion plant analyses and configurations. The research team has also completed initial lab combustion tests of three Chinese coals and will use this to update combustion models for oxycombustion processes. These data will also be correlated to U.S. coals to evaluate and process differences. (Refer to Appendix D: ACTC Research topic 5).
- Synthesized a series of catalyst candidates based on initial literature reports. Unique substances were identified for further study that could lead to breakthroughs in carbon capture performance and cost-reduction. (Refer to Appendix D: ACTC Research topic 4).
- Completed automated data acquisition and process control upgrades on the test photobioreactors (PBRs). This accomplishment enables process parameters to be adjusted manually if needed, and it also allows the team to monitor the system from remote locations and store the data. The research is working toward optimizing conditions to maximize biochemical conversion of CO_2 by the algae. (Refer to Appendix D: ACTC Research topic 7).
- Generated probability distributions for CO_2 injectivity and capacity in the Rock Springs Uplift in Wyoming, USA. The data analysis is an important step towards paving the way for commercial-scale CO_2 sequestration projects in similar geologies in both countries. (Refer to Appendix D: ACTC Research topic 6)

Building Energy Efficiency

The CERC BEE consortium is addressing research and development on building energy efficiency technologies and practices in the United States and China. BEE works to accelerate innovation leading to commercial successes in building energy consumption monitoring and simulation, building envelope, building equipment, whole building integration, and commercialization research.

CERC Vision: Building Energy Efficiency

Reduce the high-energy consumption of existing U.S. building stock; avoid rapid growth of building energy consumption in China as a result of rapid construction of new buildings, economic development, and the possible increase in indoor comfort.

The CERC BEE supports collaborative research to build a foundation of knowledge, technologies, tools, human capabilities, and relationships that position the United States and China for a future with very low energy buildings and much reduced CO_2 emissions.

Examples of Benefits from Building Energy Efficiency Research

BEE research supports the development of innovations that will enable citizens to live and work in more comfortable, energy-efficient buildings. It will help deliver essential technologies:

- New, more energy-efficient building materials and cool roofs
- Enhanced ventilation and climate control technologies that improve indoor comfort
- Buildings that integrate renewable wind, geothermal, and solar energy systems so that they generate more energy than they consume
- High-quality, energy efficient lighting
- Tools that help building operators identify opportunities to improve energy efficiency and save money

Research Topics

As agreed by the U.S. and China consortia leaders and formalized with the Joint Work Plan, BEE has developed a collaborative research agenda organized into seven topics (see Appendix D for more detailed discussion of BEE research activities):

1. *Monitoring and Simulation of Building Energy Consumption*: Provide a rich foundation to support prioritization of energy savings opportunities from buildings. New scientific methods for collecting data and modeling energy consumption will guide development of high-impact energy efficiency technologies.
2. *Key Technology Research on Building Envelope Structure System*: Develop new building materials and related control and integration systems. Research in this area will improve understanding and strategies for ventilation, comfort systems, and cool roofs.
3. *Research and Demonstration of Adaptability of Advanced Building Equipment Technologies*: Improve the performance of climate control (heating, ventilation, and cooling) technologies and increase their market penetration. Integrate building equipment with control systems and metering equipment and optimize management software.
4. *Research and Demonstration of Technological Adaptability in Applying New and Renewable Energy to Buildings*: Integrate geothermal, solar, and wind energy systems, among others, to convert a building from an energy consumer to a net energy supplier.
5. *Research and Demonstration of Integrated Building Energy Technologies*: Analyze building energy use in the United States and China to improve building integration and optimize the use of energy efficient and low-carbon energy supply technologies.
6. *New Lighting System Design and Control Research*: Develop, test, and demonstrate efficient, high-quality lighting systems. Research U.S. and China lighting markets to advance state-of-the-art of lighting controls.
7. *Building Energy Commercialization and Market Research*: Evaluate standards, certification, codes and labels, and other policy mechanisms to establish a knowledge base from which to make effective decisions.

BEE Partners

The U.S. Building Energy Efficiency Consortium is led by **Lawrence Berkeley National Laboratory**. The U.S. Consortium includes the following additional partners:

- Bentley Systems Incorporated
- ClimateMaster
- Dow Chemical Company
- The Energy Foundation, China Sustainable Energy Program
- Honeywell Corporation
- ICF International
- Massachusetts Institute of Technology
- National Association of State Energy Officials
- Natural Resources Defense Council
- Oak Ridge National Laboratory
- Saint-Gobain
- University of California, Davis

The China Building Energy Efficiency Consortium is led by the **Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development (MOHURD)**. The China Consortium includes the following additional partners:

- Advanced Glazing Materials and Systems
- Beijing University of Civil Engineering and Architecture
- China Academy of Building Research
- China Icepower Energy Technology Co., Ltd
- Chinese Society for Urban Studies
- Chongqing University
- CISDI Engineering Co., Ltd
- CNOOC and Industrial Co., Ltd
- ENN Group Co., Ltd
- Ever Source Science and Technology Development Co., Ltd
- Futian Air Conditioning Equipment Co., Ltd
- Guangdong Provincial Academy of Building Research
- Himin Solar Energy Group Co., Ltd
- Jiangsu Joint Hot and Cold Energy Saving Equipment Co., Ltd
- Landsea Group Co., Ltd
- Leye Energy
- National Center for Quality Supervision Test of Building Energy Efficiency
- Persagy
- Shanghai Qing Ying industrial shares Co., Ltd
- Shanghai Xian Dai Architectural Design Co., Ltd
- Shenzhen Institute of Building Research
- Suntech Power Holdings Co., Ltd
- Tianjin University
- Tongji University
- Tsinghua University
- Wall Insulation Committee in China Association of Building Energy Efficiency
- Zhejiang Shield Equipment Company Limited
- ZhongJi YuanXiong Energy Storage Technology Co., Ltd
- Zhuhai Singyes Green Building Technology Co., Ltd

2011 Progress

BEE researchers demonstrated significant progress in building collaborative relationships and carrying out research activities. The foremost 2011 BEE achievement is the establishment of the organizational structure and leadership for the inter-governmental consortium. Coordinating research efforts between countries, industry partners, and research institutions poses significant administrative challenges. The CERC team has established a clear organizational structure with strong leadership across industry, government, and research communities of the two countries. For more information on the organization and leadership of BEE, please see Appendix B.

In addition to organization achievements associated with setting up the BEE consortium, the team has accomplished impressive programmatic and technical milestones. BEE has actively sought to engage the research community and ensure maximum coordination and awareness of efforts by communicating these achievements through bi-monthly newsletters and special announcements for interim major achievements. The most significant achievements from 2011 are discussed below.

Programmatic Accomplishments

The U.S. BEE and China BEE established and began implementing mutually beneficial research plans and partnership coordination efforts. There has been active and increasing participation of the U.S. and China partners. Management team meetings have helped to streamline administrative processes and understanding of their counterpart management structures. The BEE held numerous productive exchange activities, such as:

- Organized the first Annual Review Workshop on CERC-BEE in Shenzhen, China. Participants at the review meeting included MOHURD officials, technical expert committee members, all BEE researcher from China, CERC management team, BEE researchers from the United States, and Industry Advisory Board members.
- Hosted research coordination workshop and technology exchange meeting at the Building Energy Efficiency Center of Qinghua University.
- Conducted guiding committee meeting in Beijing to report and track progress on work completed.
- Participated in the first US-China Clean Energy Technology Cooperation guiding committee meeting in Beijing.
- Held joint workshop in San Francisco with Lawrence Berkeley National Laboratory and Tsinghua University to discuss research results, work plans, and next steps in detail.
- Attended the International Ground Source Heat Pump (GSHP) Conference in Tulsa, Oklahoma and the analogous session in China at the GSHP Development Conference.
- Convened two workshops on data processing of BEE in Chifeng, Inner Mongolia and Nanjing. The workshops were hosted by Center of Science and Technology of Construction (CSTC), MOHURD.
- Held China-U.S. Building Energy Labeling Workshop in Shenzhen with NASEO of U.S. and CSTC of China. National and local energy officials, relevant senior researchers from the United States, and experts from China attended the workshop.

Technical Progress

Researchers have installed real-time monitoring systems for five buildings in both countries, completed an important report on the US-China Evaporative Cooling Technology Performance Comparison, published Demonstration Building Case Study Analysis Collection Report, completed a comparative analysis of building energy consumption simulation software, and produced a report on human behavior and occupant behavior in buildings. Illustrative technical achievements for each research topic include:

- *Energy use, occupant behavior explored*: Researchers analyzed impacts on energy use and comfort of occupant behavior and operating conditions in Chinese and U.S. buildings. The team also benchmarked hotel energy use in the United States and China (640 hotels) and created a platform for monitored data sharing. (Refer to Appendix D: BEE Projects A.1/2.2, A.2/2.1, and A.3/2.3).
- *Building envelope standards and tools advanced*: Researchers encouraged adoption of ISO and NFRC standards for characterization and completed a detailed comparison of insulation standards in the United States and China. In addition, they improved a tool for assessing natural ventilation in buildings for use in China and the United States. (Refer to Appendix D: BEE Projects B.4/3.4/3.5 and B.2/3.1).
- *Energy use survey completed for public buildings*: Researchers completed an on-site energy use survey of 40 public buildings in 10 Chinese cities. Results will

be applicable to technologies and practices for use in both countries. (Refer to Appendix D: BEE Project C.3/4.5).

- *Ground source heat pump reports, module completed*: Researchers prepared preliminary reports on the status of ground source heat pump applications in the United States and China. The team also created a ground source heat pump module for the Distributed Energy Resources Center Customer Adoption Model (DER-CAM) computer model, which assesses economics of renewable energy technologies on the basis of hourly energy demand. (Refer to Appendix D: BEE Projects C.2/5.2/5.3 and D-E.1/5.5).
- *Energy optimization analysis completed for a Shanghai shopping center*: Researchers completed a distributed energy optimization analysis of a shopping mall in Shanghai and identified 10 percent cost saving and 20 percent CO_2 reduction potential. The analysis findings can be applied to optimization efforts in similar facilities in both countries. (Refer to Appendix D: BEE Projects D-E.1/5.5 and D-E.2/6.2).
- *Partners identified for lighting demonstration program*: Agreements were signed with municipal partners for the demonstration program (Peking, Shanghai, Shenzhen). (Refer to Appendix D: BEE Projects C.1/7.1/7.2/7.3).
- *Building efficiency labeling policies reviewed*: Researchers completed initial research comparing U.S. and Chinese building efficiency labeling programs. (Refer to Appendix D: BEE Projects F.1/F.2/8.1/8.2/8.5/8.6).

Clean Vehicles Consortium

The CERC Clean Vehicles Consortium (CVC) has collaboratively grown basic research knowledge, technology development, and coordination between countries. These efforts are advancing the solutions necessary to reduce the dependence of vehicles on imported oil and improve vehicle fuel efficiency.

CERC Vision: Clean Vehicles

Contribute dramatic improvements in technologies with potential to reduce the dependence of vehicles on oil and improve vehicle fuel efficiency in both countries.

Perform long-range transformational and translational research to bring discoveries and technologies to market in the United States and China to advance technologies for clean vehicles.

Examples of Benefits from CVC Research

Clean vehicles research supports the development of innovations that will enable citizens to drive in safe, lightweight vehicles that use less fuel or alternative fuels such as electricity and biofuels. It will help deliver essential technologies:

- Novel, efficient, and powerful battery designs for electric vehicles
- Tools to support the rapid design of powertrains for electric vehicles
- Monitoring tools to ensure electric vehicle battery reliability, performance, and lifetime
- Tools to coordinate the charging of electric vehicles with power grid resource requirements
- Materials that recover and reuse energy lost as heat
- Advanced biofuels and new vehicle systems
- Processes for producing and joining lightweight materials that reduce vehicle weight and fuel use while ensuring strength and safety

Research Topics

As articulated in the Joint Work Plan, approved by consortia leaders in the United States and China, CVC has developed a highly collaborative research agenda organized into six thrusts (see Appendix D for more detailed discussion of CVC research efforts):

- *Advanced Batteries and Energy Conversion*: Increase application of novel battery designs that promise much higher energy densities, such as Li-air and Li-sulfur batteries; develop high efficiency thermoelectric materials to recover waste heat.
- *Advanced Biofuels, Clean Combustion, and Auxiliary Power Unit (APU)*: Accelerate development and deployment of advanced biofuels with molecular models that can be used to predict the behavior of novel fuels in various combustion environments; system controls for clean vehicles; and development, integration and control of APU systems.
- *Vehicle Electrification*: Develop electric motors and power electronics with higher conversion efficiencies and power/energy densities than are currently possible.
- *Advanced Lightweight Materials and Structures*: Develop low-cost, energy efficient, high quality processes for producing, forming, and joining of lightweight materials to increase integration of aluminum alloys, magnesium alloys, and carbon-polymer composites into vehicle structures while maintaining structural rigidity and crash safety.
- *Vehicle-Grid Integration*: Develop advanced control strategies and protocols to coordinate plug-in vehicle (PEV) charging and develop interfaces to accelerate the deployment of PEVs and minimize impact to grid quality and battery aging.
- *Energy Systems Analysis, Technology Roadmaps and Policies*: Integrate vehicle and energy infrastructure systems to address temporal and spatial variation of energy sources, petroleum demand, and CO_2 emissions impacts; diversity in consumer drive cycles and trip patterns; producer and consumer economic factors; global vehicle and fuel market factors; and future fuel efficiency and carbon policy regimes.

CVC Partners

The U.S. Clean Vehicle Consortium is led by the **University of Michigan**. The U.S. Consortium includes the following additional partners:

- A123 Systems
- American Electric Power
- Chrysler
- Dayton Power & Light
- Delphi
- Eaton
- FirstEnergy, FE Technologies
- Ford Motor Company, Research and Advanced Engineering
- Honda R&D Americas, Inc.
- Joint Bio Energy Institute
- Magnet, Distribution Research and Technology
- Massachusetts Institute of Technology
- Oak Ridge National Laboratory, Energy and Transportation Science
- The Ohio State University
- PJM Interconnection
- Sandia National Laboratories, Combustion Research Facility
- Toyota Motor Company, Toyota Motor Engineering and Manufacturing North America
- Transportation Research Center

The Chinese Clean Vehicle Consortium is led by **Tsinghua University**. The China Consortium currently includes the following additional partners:

- Beihang University
- Beijing Institute of Technology
- Beijing SinoHytec Co., Ltd.
- China Automotive Engineering Research Institute Co., Ltd
- China Automotive Technology & Research Center
- China Potevio
- Chinese Academy of Sciences
- Geely Group
- Jing-jin Electric Co., Ltd
- Microvast
- North China Electric Power University
- SAIC Motor
- Shanghai Jiao Tong University
- Tianjin Lishen Battery Joint-stock Co., Ltd
- Tianjin University
- Tongji University
- Wanxiang
- Wuhan University of Technology
- Yintong Energy

2011 Progress

The organizational and intergovernmental aspects of setting up the CVC are among the most notable accomplishments for 2011. Coordinating efforts between countries, industry partners, and research institutions creates significant administrative challenges. To overcome the challenges, the CERC team designed and implemented a clear organizational structure with active, effective leadership from the two nations. For more information on the CVC organizational structure and leadership, please see Appendix B.

In addition to organizational accomplishments, CVC achieved a number of programmatic and technical milestones in 2011. Highlights of CVC accomplishments include the following:

Programmatic Accomplishments

- Forged stronger collaboration between countries in battery degradation and new chemistries projects.
- Developed test platforms for vehicle electrification.
- Determined open-source FE-Mesh platform to use as a model for 2011 compact vehicle simulations. By using the common platform, not only can researchers from the United States and China work more closely together, it also eliminates the need for any industrial member to share or reveal confidential designs.
- Held regular technical meetings and executed student and faculty exchanges.

Technical Progress

Significant basic science discoveries have been made through each of the research topics. The work has already resulted in a number of scientific publications, and the first intellectual property disclosures are being made.

- *Advanced Batteries and Energy Conversion*: Researchers found that lithium peroxide (a possible discharge product of lithium-air batteries) is half-metallic while lithium oxide is insulating and non-magnetic. This could explain the reversibility of systems with lithium peroxide as a discharge project, versus the irreversibility of systems with lithium oxide as a discharge product. This finding can help to improve the cycle life of lithium-air batteries. (Refer to Appendix D: CVC Project 1.2).
- *Advanced Biofuels, Clean Combustion and Auxiliary Power Unit*: In this joint research area, the focus on the Chinese side is pure electric vehicles. Combustion engines, if used, serve as auxiliary power units and will be designed to have much smaller sizes and power outputs. The United States is perusing clean combustion of biofuels and identifying fuels with better chemical and physical properties. (Refer to Appendix D: CVC Projects 2.1–2.7).
- *Vehicle Electrification*: Test-platform development is well underway to meet the project demonstration requirements. Effective and rapid powertrain design and integration tools are being developed to obtain best-execution results with respect to efficiency and reliability. Methodology development (particularly in the area of high-speed simulation tools and dynamic programming optimization engines) is paving the way for the next phase project execution and deliverables. (Refer to Appendix D: CVC Projects 3.1–3.3).
- *Advanced Lightweight Materials and Structures*: Researchers are developing a new conformal method to join dissimilar materials, and an invention disclosure for the process is being developed. U.S. and Chinese researchers have agreed on pursuing focused research to reduce cost and weight without negative impact to crash performance. (Refer to Appendix D: CVC Projects 4.1–4.4).
- *Vehicle Grid Integration*: Researchers are developing scheduling schemes for vehicle charging, and the necessary battery monitoring to ensure battery reliability, performance, and cycle life. (Refer to Appendix D: CVC Projects 5.2, 5.5, and 5.6).
- *Energy Systems Analysis, Technology Roadmaps and Policies*: Research efforts are identifying optimal fueling strategies and vehicle technology configurations to meet clean vehicle targets. Efforts have focused on developing a framework to explore the effectiveness of alternative assessment methods, regulatory instruments, and labeling formats to accurately represent vehicle energy and environmental performance from a life cycle perspective. Analysis of in-use vehicle fleets has been conducted to develop a fleet model for U.S. and for Chinese partners. (Refer to Appendix D: CVC Projects 6.1–6.4).

Conclusions and Future Plans

Energy security, economic competitiveness, and environmental concerns arising from the production and use of energy are today, and are expected to become more so in the future, key challenges facing both the United States and the People's Republic of China. These challenges are attended by strong needs for clean energy and extraordinary capabilities for research and technological innovation. The nexus of common challenges and world-class capabilities has proven to be an elixir for creative and enlivened pursuit by researchers and businesses on both sides of collaborative R&D opportunities under the auspices of the U.S.-China CERC.

CERC is predicated on the concept of a more flexible and ambitious model for bilateral science and technology cooperation. Strong support and encouragement from both governments enables and encourages engagement of businesses and researchers on both sides in joint work planning and execution. In concept, CERC can leverage assets by parsing work and dividing labor; capture efficiencies by exploiting complementarities; and speed progress by taking on a more diversified portfolio. It also includes a novel framework for protecting and sharing intellectual property that is intended to attract the best ideas from business and industry and enable innovators to realize appropriate rewards through ownership or licensing of intellectual property.

> *The U.S. and China are two great nations, and clean energy is one of the great opportunities of our time. Working together, we can accomplish more than acting alone.*
>
> Dr. Steven Chu,
> U.S. Secretary of Energy

At the end of its first year of funded activity, CERC is well on the way to realizing the benefits as envisioned. The steps for standing up the CERC were not without their challenges. As evidenced in this report, these steps included establishing bilateral governance structures, appointing leaders, selecting and making awards to leading research institutions, scoping joint work plans, negotiating the intellectual property frameworks, attracting partners, identifying leading investigators who seek joint research opportunities, and starting actual research work. The overhead on start-up requires sustained commitments from both governments and commends a 5-year initial performance period, with oversight, independent reviews, and periodic evaluation.

Now well established, the CERC model is gaining momentum. Research relationships continue to expand and deepen, drawing out and combining the unique skills and insights of industry, university, and government. Empowered by the CERC collaborative model, industrial partners are assuming a central role where appropriate, bringing market knowledge and business relevance to research planning. Encouraged by the CERC model's provisions for the protected sharing of existing IP and ownership and licensing of newly developed IP, additional private partners are seeking to join. Other countries are beginning to observe CERC as model for bilateral science and technology arrangements with China, in particular, and more generally with other emerging economies. Large-scale business ventures are exploring ways to collaborate with CERC consortia on shared data and knowledge building in order to accelerate deployment. Researchers have achieved notable technical progress, which is highlighted throughout this report and described in more detail in Appendix D.

Looking ahead, the CERC technical tracks will emphasize the following efforts in the coming year.

Advanced Coal Technology Consortium

As a result of close and frequent interactions with counterparts in the joint ACTC, opportunities for joint research and productive shifts in focus for ongoing work have become clear. The technology demonstrations and first-built commercial installations upon which CERC projects rely are on track toward completion. These completions will enable certain aspects of CERC projects to advance with anticipated results. Highlights include:

- **Large-Scale IGCC Integration and Analysis.** The completion of two IGCC projects—Edwardsport (in the U.S.) and GreenGen (in China)—has created a one-of-a-kind opportunity to assess the start-up, integration, and optimization of two plants, both aimed at 1 million ton/year CO_2 sequestration. (For additional details, see Appendix D: ACTC Project 1).

- **PCC Analysis and Technology Development**. The groundwork on the Huaneng/Gibson project should be completed in the next year, presenting a unique opportunity for instrumentation, data gathering, simulation, and analysis of platforms other than IGCC, and ideally assist in the commercialization of such projects in both countries (see Appendix D: ACTC Project 2).
- **CO_2 Utilization.** Following interests of the U.S. and Chinese leadership, more emphasis will be placed on various modes of CO_2 utilization, including CO_2-algae, EOR, and residual oil zone production (see Appendix D: ACTC Projects 3 and 4).

Building Energy Efficiency Consortium

For 2012, BEE efforts will continue to build strong communications ties between U.S. and Chinese researchers, and enhance exchange of information and cooperation within activities. The BEE annual meeting will review 2011 efforts and progress, and discuss the next Joint Work Plan. The Tool Development Workshop will discuss common problems encountered in the research. Joint research teams will create 2012 calendar of communications to enhance regular dialogue between U.S. and Chinese research partners. A regular BEE newsletter and website updates will inform and expand project supervision and monitoring of research progress, and help ensure tasks results are submitted in a timely manner. Highlights include the following:

- **Building Energy Commercialization:** The team will prepare a comparative study of energy quota/energy consumption caps and carbon trading schemes in the United States, China, and internationally. In combination with carbon trading mechanisms, the study will analyze the approaches to achieving commercialization of carbon assets, analyze the prerequisites for the implementation of energy efficiency trading, review the main components of trading, analyze policy supportive mechanisms as well as the current status of the implementation and market potential of these policies, taking into account the different development phases of the building industry in China and the U.S. and respective building energy efficiency levels. The study will also propose strategies for energy trading in both countries.

We place a high priority on building long-term partnerships between U.S. and Chinese researchers in the buildings energy efficiency area—this will be a significant outcome of our work. We hope to demonstrate the unique strength of the Chinese-U.S. collaboration on energy efficiency in buildings, so that new industrial partners will be willing to contribute additional resources to strengthen the CERC research effort.

Mark Levine, Consortium Director, U.S. CERC-BEE

- **Building Energy Modeling and Analysis:** The U.S. and Chinese researchers will produce a report on case studies for the real-time energy monitoring system, and compile a database of energy use metrics for office buildings in China and the United States.
- **Building Insulation Systems:** The research team will perform moisture durability analysis of retrofit options and review China and U.S. building codes, material standards, fire safety standards, and lessons-learned, with particular emphasis on regional variations, for both low- and high-rise buildings. Researchers will then perform a market analysis to identify barriers and gaps preventing the widespread adoption of the best technologies.
- **Cool Roofs:** The team will measure energy savings attained by applying cool roofs to existing buildings in Guangdong and Chongqing, China. Researchers will then investigate existing methods used to calculate GHG emission reductions and offsets from cool roofs, and assess their applicability to selected cities, and collect input data needed to evaluate the benefits of cool roofs.
- **Ground Source Heat Pumps:** The research teams in the United States and China will develop methodologies and necessary tools for evaluating the suitability of ground source heat pump (GSHP) applications and evaluate new GSHP system design and equipment. Simulation based evaluation and/or field tests of these new design and equipment in various climates, buildings, and geological conditions will be conducted to fully understand the applicability and potential of these new equipment and technologies.
- **Research and Demonstration of Technological Adaptability in Applying New and Renewable Energy to Buildings:** LBNL will continue developing basic ground source heat pump (GSHP) capability for the Distributed Energy Resources Customer Adoption

Model (DER-CAM). Tongji University will collect data on solar thermal, BIPV, plus ground and water source heat pumps in China and the United States. Tongji will develop case studies for both countries based on the data using DER-CAM, with LBNL assistance with WebOPT.

- **Research, Development, and Demonstration of New Municipal Lighting System:** Team members will identify lighting energy use patterns for China and the United States. Leads will develop a common reporting format to ensure consistent development of the analysis.

Clean Vehicles Consortium

In the coming year, CVC efforts will continue and expand the research collaborations underway. Programmatically, workshops over the course of the year will strengthen the collaboration, ensure progress on research, improve communication throughout the CERC structure, and share notable achievements with peers. These workshops will include the all-CERC IP workshop in Haikou, China, in March; DOE Annual Review in Washington, DC, USA, in March; EVI Workshop in Hangzhou, China in April; and the CERC-CVC US/China Annual Meeting in Ann Arbor, Michigan, USA, in August. The individual CVC research thrusts are also expected to account for specific achievements during 2012. Highlights include the following:

- **Advanced Batteries and Energy Conversion:** Researchers will secure aged LiFePO4 cells/packs, establish uniform protocols for accelerated aging of cells (as needed), and extend existing degradation experiments to include this important baseline chemistry (for additional details, see Appendix D: CVC Project 1.1); launch three new industry-sponsored projects on in-situ neutron depth profiling of lithium ion battery materials for improved electrochemical performance and aging models, Li-ion battery aging and internal degradation mechanisms, and data-based techniques for battery health prediction; and forge stronger collaboration between China and U.S. CERC teams in battery degradation and new chemistries projects.
- **Advanced Biofuels, Clean Combustion and Auxiliary Power Unit (APU):** Efforts in 2012 will focus on identifying research fuels (see Appendix D: CVC Projects 2.1-2.2).
- **Vehicle Electrification:** Researchers will improve on test-platform development (see Appendix D: CVC Projects 3.1-3.2).
- **Advanced Lightweight Materials and Structures**: The common software platform will be modified for scalability to represent different vehicle models and to simulate crash performance of lightweight parts (see Appendix D: CVC Project 4.4).
- **Energy Systems Analysis, Technology Roadmaps and Policies:** In 2012, efforts will examine opportunities to improve the effectiveness of EPA/NHTSA standards using a life cycle perspective, lightweighting with high strength steel and aluminum auto bodies, and secondary mass reductions (see Appendix D: CVC Project 6.3). A new research project investigating electricity and material sourcing scenario analyses to guide vehicle technology strategies will be based on feedback from auto industry partners. Industry-sponsored research on electricity and material sourcing scenario analyses will guide vehicle technology strategies (see Appendix D: CVC Project 6.2).

2012 Outlook

The past year was one of building foundations. The coming year will be noted for joint research progress. In addition to the energized focus on research, DOE and MOST have agreed to undertake a longer-term program of education and training in the area of intellectual property, building on the framework established in 2011. This joint activity will also extend technical assistance to industry, academic, and government project participants in negotiating terms and conditions of sub-agreements, to the extent they may be needed. In this regard, a joint workshop on IP under CERC is planned for early 2012 in China, and another is planned for later 2012 in the United States.

Secretary Chu and Minister Wan have expressed high expectations for the realization of CERC benefits to both countries, meaningful research progress, if not substantive breakthroughs, and impactful outcomes evidenced by commercialization and private investment. CERC is off to a good start. Meeting such expectations will require strong and visionary leadership and continued accomplishment throughout the CERC organization.

Appendix A. Maps of Consortia Partner Locations

ACTC

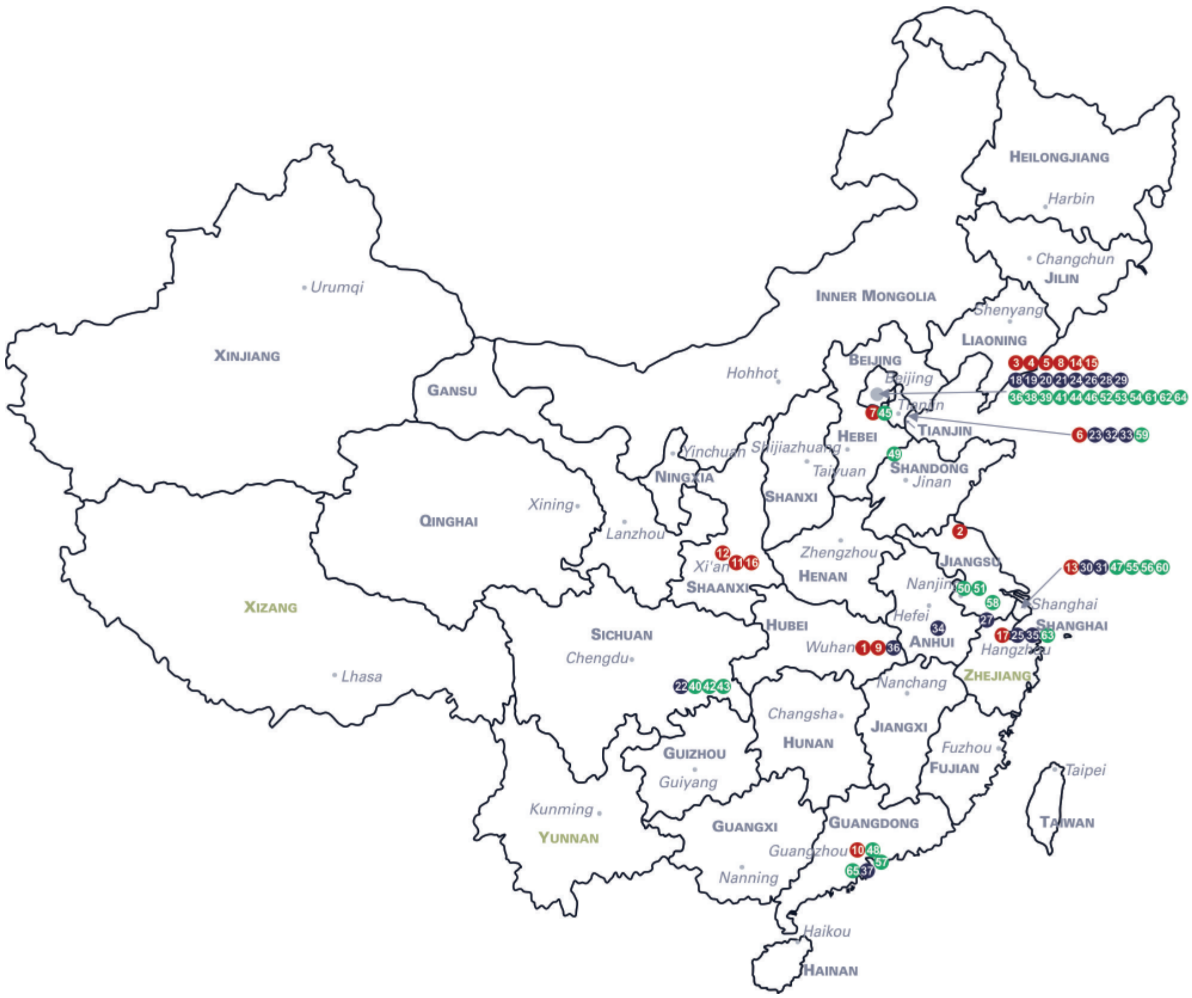
1	West Virginia University Research Corporation	Morgantown, WV
2	Babcock & Wilcox	Barberton, OH
3	Duke Energy	Charlotte, NC
4	General Electric	Houston, TX
5	General Electric	Niskayuna, NY
6	GreatPoint Energy, Inc.	Cambridge, MA
7	Indiana Geological Survey	Bloomington, IN
8	Lawrence Livermore National Laboratory	Livermore, CA
9	Los Alamos National Laboratory	Los Alamos, NM
10	LP Amina	Charlotte, NC
11	National Energy Technology Laboratory	Morgantown, WV
12	National Energy Technology Laboratory	Pittsburgh, PA
13	University of Kentucky	Lexington, KY
14	University of Wyoming	Laramie, WY
15	US-China Clean Energy Forum, Washington State China Relations Council	Seattle, WA
16	World Resources Institute	Washington, DC

CVC

17	University of Michigan	Ann Arbor, MI
18	A123 Systems	Novi, MI
19	American Electric Power	Columbus, OH
20	Chrysler	Auburn Hills, MI
21	Dayton Power & Light	Dayton, OH
22	Delphi	Troy, MI
23	Eaton	Southfield, MI
24	FirstEnergy, FE Technologies	Akron, OH
25	Ford Motor Company, Research and Advanced Engineering	Dearborn, MI
26	Honda R&D Americas, Inc.	Southfield, MI
27	Joint Bio Energy Institute	Berkeley, CA
28	Magnet, Distribution Research and Technology	Cleveland, OH
29	Massachusetts Institute of Technology	Boston, MA
30	Oak Ridge National Laboratory, Energy and Transportation Science	Oak Ridge, TN
31	The Ohio State University	Columbus, OH
32	PJM Interconnection	Norristown, PA
33	Sandia National Laboratories, Combustion Research Facility	Livermore, CA
34	Toyota Motor Company, Toyota Motor Engineering and Manufacturing North America	Ann Arbor, MI
35	Transportation Research Center	East Liberty, OH

BEE

36	Lawrence Berkeley National Laboratory	Berkeley, CA
37	Bentley Systems Incorporated	Exton, PA
38	ClimateMaster	Oklahoma City, OK
39	Dow Chemical Company	Midland, MI
40	Energy Foundation, China Sustainable Energy Program	San Francisco, CA
41	Honeywell Corporation	Washington, DC
42	ICF International	Fairfax, VA
43	Massachusetts Institute of Technology	Cambridge, MA
44	National Association of State Energy Officials	Portland, OR
45	Natural Resources Defense Council	San Francisco, CA
46	Oak Ridge National Laboratory	Oak Ridge, TN
47	Saint-Gobain	Valley Forge, PA
48	University of California, Davis	Davis, CA


HEILONGJIANG
Harbin
Changchun
JILIN
INNER MONGOLIA
Shenyang
LIAONING
BEIJING
Beijing
Tianjin
TIANJIN
HEBEI
Shijiazhuang
Taiyuan
SHANXI
SHANDONG
Jinan
Hohhot
XINJIANG
Urumqi
GANSU
Yinchuan
NINGXIA
QINGHAI
Xining
Lanzhou
XIZANG
Lhasa
Xi'an
SHAANXI
Zhengzhou
HENAN
JIANGSU
Nanjing
Shanghai
SHANGHAI
Hefei
ANHUI
HUBEI
Wuhan
SICHUAN
Chengdu
Hangzhou
ZHEJIANG
Nanchang
JIANGXI
Changsha
HUNAN
Fuzhou
FUJIAN
Taipei
TAIWAN
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13 30 31 47 55 56 60
50 51
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27
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17 25 35 63
12 11 16
1 9 36
22 40 42 43
10 48
57
65 37

ACTC

1	Huazhong University of Science and Technology	Wuhan
2	Center for Energy & Power, Chinese Academy of Sciences	Lianyungang
3	China Huaneng Group Clean Energy Research Institute	Beijing
4	China Power Engineering Consulting Group Corp.	Beijing
5	China Power Investment Corp.	Beijing
6	China University of Mining and Technology	Tianjin
7	ENN (XinAo Group)	Langfang
8	Huaneng Power International, Inc	Beijing
9	Institute for Rock & Soil Mechanics, Chinese Academy of Science	Wuhan
10	Jinan University	Guangzhou
11	Northwest University of China	Xi'an
12	Shaanxi Provincial Institute of Energy Resources	Xianyang
13	Shanghai JiaoTong University	Shanghai
14	Shenhua Group	Beijing
15	Tsinghua University	Beijing
16	Yanchang Petroleum	Xi'an
17	Zhejiang University	Hangzhou

CVC

18	Tsinghua University	Beijing
19	Beihang University	Beijing
20	Beijing Institute of Technology	Beijing
21	Beijing SinoHytec Co., Ltd.	Beijing
22	China Automotive Engineering Research Institute Co., Ltd	Chongqing
23	China Automotive Technology & Research Center	Tianjin
24	Chinese Academy of Sciences	Beijing
25	Geely Group	Hangzhou
26	Jing-jin Electric Co., Ltd	Beijing
27	Microvast	Huzhou
28	North China Electric Power University	Beijing
29	Potevio	Beijing
30	SAIC Motor	Shanghai
31	Shanghai Jiao Tong University	Shanghai
32	Tianjin Lishen Battery Joint-stock Co., Ltd.	Tianjin
33	Tianjin University	Tianjin
34	Tongji University	Tongji
35	Wanxiang Group	Hangzhou
36	Wuhan Institute of Science and Technology	Wuhan
37	Yintong Energy	Zhuhai

BEE

36	Center of Science and Technology of Construction of MOHURD	Beijing
37	Advanced Glazing Materials and Systems	
38	Beijing University of Civil Engineering and Architecture	Beijing
39	China Academy of Building Research	Beijing
40	China Icepower Energy Technology Co., Ltd.	Chongqing
41	Chinese Society for Urban Studies	Beijing
42	Chongqing University	Chongqing
43	CISDI Engineering Co., Ltd.	Chongqing
44	CNOOC and Industrial Co., Ltd.	Beijing
45	ENN Group Co., Ltd.	Langfang
46	Ever Source Science and Technology Development Co., Ltd.	Beijing
47	Futian Air Conditioning Equipment Co., Ltd.	Shanghai
48	Guangdong Provincial Academy of Building Research	Guangzhou
49	Himin Solar Energy Group Company, Ltd.	Dezhou City
50	Jiangsu Joint Hot and Cold Energy Saving Equipment Co., Ltd.	Nanjing
51	Landsea Group Co., Ltd.	Nanjing
52	Leye Energy	Beijing
53	National Center for Quality Supervision Test of Building Energy Efficiency	Beijing
54	Persagy	Beijing
55	Shanghai Qing Ying Industrial Shares Co., Ltd.	Shanghai
56	Shanghai Xian Dai Architectural Design Co., Ltd.	Shanghai
57	Shenzhen Institute of Building Research	Shenzhen
58	Suntech Power Holdings Co., Ltd.	Wuxi
59	Tianjin University	Tianjin
60	Tongji University	Shanghai
61	Tsinghua University	Beijing
62	Wall Insulation Committee in China Association of Building Energy Efficiency	Beijing
63	Zhejiang Shield Equipment Company Ltd.	Hangzhou
64	ZhongJi YuanXiong Energy Storage Technology Co., Ltd.	Beijing
65	Zhuhai Singyes Green Building Technology Co., Ltd.	Zhuhai

Appendix B. CERC Leadership and Organization Structure

The successful establishment of leadership teams and organizational frameworks are significant achievements in the first year of the inter-governmental research center. CERC is built to facilitate bilateral cooperation that encourages interaction and ensures that both countries benefit from collective research. Coordinating cross-national research efforts between institutions or across an industry frequently poses significant challenges; the CERC teams have identified and instituted the necessary structures and leadership across research communities of the two countries, for the benefit of both.

CERC Governance

The CERC governance structure is headed by a Steering Committee composed of Ministers from the United States and China. The U.S. and China Secretariats report directly to their respective country's Steering Committee members, and are headed by government officials.

Steering Committee Members

- U.S. Department of Energy Secretary, Dr. Steven Chu
- Minister of Science and Technology, Dr. Wan Gang
- National Energy Administrator, Dr. Liu Tienan
- (Ex-officio) Vice Minister of Housing and Urban-Rural Development, Dr. Qiu Baoxing

U.S. Secretariat

- U.S. Department of Energy Assistant Secretary for Policy and International Affairs, David Sandalow
- U.S. CERC Director, Dr. Robert C. Marlay
- Director of East Asian Affairs, Dr. Casey Delhotal

Chinese Secretariat

- Vice Minister, Cao Jianlin, Ministry of Science and Technology
    - Deputy Director General, Ma Linyin, Ministry of Science and Technology
    - Director General, Li Ye, National Energy Administration
    - Deputy Director General, Han Aixin, Ministry of Housing and Urban-Rural Development
- China CERC Director, Counselor Liu Zhiming, Ministry of Science and Technology
- Director, Americas and Oceania, Wang Qiang, Ministry of Science and Technology

Executive Committees for each of the three consortia report to the CERC Secretariat. These committees are composed of technical leaders and experts in the fields, and have up to five members each from the U.S. and China. The Executive Committees are tasked to provide oversight and to review CERC progress, to advise on the CERC portfolio and projects, and to identify opportunities for synergies with other related R&D programs.

ACTC Executive Committee and Research Leadership

Executive Committee for Advanced Coal Technology

- U.S. Committee Members
    - Jim Wood, Deputy Assistant Secretary, Office of Clean Coal, U.S. Department of Energy
    - Dr. Daren Mollot, Director, Office of Clean Energy Systems, U.S. Department of Energy
    - Guido DeHoratis, Director, Office of Oil & Gas Resource Conservation, U.S. Department of Energy
    - Dr. Jay Braitsch, Senior Advisor for Strategic Planning, U.S. Department of Energy
- Chinese Committee Members
    - Xiu Binglin, Director of Science & Technology Division, Department of Energy Conservation and S&T Equipment, National Energy Administration
    - Zhou Dadi, Vice Chairman, China Energy Association
    - He Jiankun, Deputy Director, State Climate Change Expert Committee

U.S. Research Team	China Research Team
Dr. Jerald J Fletcher Consortium Director West Virginia University	Dr. Chugang Zheng Consortium Director Huazhong University of Science and Technology
Dr. S. Julio Friedmann Technical Program Manager Lawrence Livermore National Laboratory	Dr. Shisen Xu Chief Engineer Huaneng Clean Energy Research Institute
Dr. Quingun Sun Collaboration Manager West Virginia University	Dr. Qiang Yao Chief Scientist Tsinghua University
Sam Taylor Operations Manager West Virginia University	

- Jiang Hongde, CAE Academician, Tsinghua University
- Huang Qili, CAE Academician, Engineer-in-chief, Northeast China Grid Company

BEE Executive Committee and Research Leadership

Executive Committee for Energy Efficient Buildings

- U.S. Committee Members
  - Roland Risser, Deputy Assistant Secretary for Building Technologies, U.S. Department of Energy
  - Patrick Hughes, Director, Building Technologies Research and Integration Center, Oak Ridge National Lab
  - Dr. Hunter Fanney, Chief, Supervisory Mechanical Engineer, Building Environment Division, National Institute of Standards and Technology
  - Richard Karney, Senior Technical Advisor, Emerging Technologies Team, Building Technologies, U.S. Department of Energy
- Chinese Committee Members
  - Tong Guichan, Deputy Director, Division of International Science & Technology Cooperation, Department of Building Energy Efficiency and Science & Technology, Ministry of Housing and Urban-Rural Development
  - Li Baizhan, Professor, Chongqing University
  - Xu Wei, Director, Institute of Building Environment and Energy Efficiency, China Academy of Building Research
  - Tan Hongwei, Professor, Tongji University
  - Zhu Neng, Professor, Tianjin University
  - Hao Bin, Director, Division of Industry Development, Center of Building Energy Efficiency, Ministry of Housing and Urban-Rural Development

U.S. Research Team	China Research Team
Dr. Mark D. Levine Consortium Director Lawrence Berkeley National Laboratory	Dr. Junqiang Liang Consortium Director Ministry of Housing and Urban-Rural Development
Dr. Nan Zhou Deputy Director Lawrence Berkeley National Laboratory	Dr. Yi Jiang Technical Program Manager Tsinghua University Ministry of Housing and Urban-Rural Development
Dr. Yuan Yao China Liaison Lawrence Berkeley National Laboratory	

CVC Executive Committee and Research Leadership

Executive Committee for Clean Vehicles

- U.S. Committee Members
  - Patrick Davis, Manager, Vehicles Technology Program, U.S. Department of Energy
  - Steve Goguen, Supervisor, Fuels, Combustion, & Deployment, U.S. Department of Energy
  - Dr. Larry Johnson, Director, Transportation Technology R&D Center, Argonne National Laboratory
  - Dave Howell, Team Leader for Hybrid and Electric Systems, U.S. Department of Energy
  - Gurpreet Singh, Team Leader for Advanced Combustion Engine Technologies, U.S. Department of Energy
- Chinese Committee Members
  - Chen Jiachang, Deputy Director General, Department of High and New Tech, Ministry of Science and Technology
  - Ren Xiaochang, Director, China Automotive Engineering Research Institute (CAERI)
  - Wu Zhixin, Deputy Director of China Automotive Technology & Research Center (CATARC)
  - Wang Binggang, China Society of Automotive Engineering
  - Wang Jiqiang, Deputy Chief Engineer, Tianjin Institute of Power

U.S. Research Team	China Research Team
Dr. Huei Peng Consortium Director University of Michigan	Dr. Minggao Ouyang Consortium Director Tsinghua University
Dr. Jun Ni Deputy Director University of Michigan	Dr Hewu Wang Deputy Director Tsinghua University
Dr. Huei Peng Dr. Jun Ni China Liaison University of Michigan	Dr Xinping Qiu Deputy Director Tsinghua University
Carrie Morton Operations Manager University of Michigan	

Figure 9. CERC Clean Vehicle Consortium Leadership Team

Appendix C. CERC Funding

The CERC is funded jointly by the United States and China, with additional funding provided by private industry in each country. Both nations demonstrated their commitment to the success of CERC research and development by providing additional funding for future activities. The United States awarded $7.5 million dollars in funding in 2011. In addition, China committed $7.5 million to three Chinese teams.

While U.S. funds are applied to U.S. researchers and Chinese funds are applied to Chinese researchers, the collective impact of the funding is amplified because of the CERC collaborative efforts. Research that avoids cross-border duplication and leverages shared knowledge, CERC is accelerating development of new breakthroughs and technological solutions as the world confronts the global challenge of shifting to a low-carbon future.

Each U. S. CERC Consortium is funded from DOE at $2.5M per year for five years, subject to annual Congressional appropriations. Likewise, each China CERC Consortium is funded at the same level from the PRC Ministry of Science and Technology (MOST). Participants from each country are expected to provide funds or services to match their country's contribution. Table 3 illustrates the five year funding plan.

Table 4. Five Year CERC Funding Plan

		United States		China	Consortium
		DOE	Partners	MOST & Partners	Totals
2011	Advanced Coal	$2.5	$2.7	$4.6	$9.8
	Buildings	$2.5	$2.5	$3.5	$8.5
	Clean Vehicles	$2.5	$1.1	$4.4	$8.0
	2011 Sub-Total	$7.5	$6.3	$12.5	$26.3
2012	Clean Coal	$2.5	$2.7	≥ $5.0	≥ $10.2
	Buildings	$2.5	$2.5	≥ $5.0	≥ $10.0
	Clean Vehicles	$2.5	$3.2	≥ $5.0	≥ $10.7
	2012 Sub-Total	$7.5	$8.4	≥ $15.0	≥ $30.9
2013	Clean Coal	$2.5	$2.7	≥ $5.0	≥ $10.2
	Buildings	$2.5	$2.5	≥ $5.0	≥ $10.0
	Clean Vehicles	$2.5	$3.0	≥ $5.0	≥ $10.5
	2013 Sub-Total	$7.5	$8.2	≥ $15.0	≥ $30.7
2014	Clean Coal	$2.5	$2.7	≥ $5.0	≥ $10.2
	Buildings	$2.5	$2.5	≥ $5.0	≥ $10.0
	Clean Vehicles	$2.5	$3.0	≥ $5.0	≥ $10.5
	2014 Sub-Total	$7.5	$8.2	≥ $15.0	≥ $30.7
2015	Clean Coal	$2.5	$2.7	≥ $5.0	≥ $10.2
	Buildings	$2.5	$2.5	≥ $5.0	≥ $10.0
	Clean Vehicles	$2.5	$3.0	≥ $5.0	≥ $10.5
	2015 Sub-Total	$7.5	$8.2	≥ $15.0	≥ $30.7
5-Yr Totals	Clean Coal	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	Buildings	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	Clean Vehicles	$12.5	≥ $12.5	≥ $25.0	≥ $50.0
	TOTAL	$37.5	≥ $37.5	≥ $75.0	≥ $150.0

Funded	Planned

Appendix D. Research Consortia Fact Sheets

Advanced Power Generation

U.S. Research Team Lead	China Research Team Lead	
• Matt Zedler, LP Amina	• Yao Qiang, Tsinghua University	
U.S. Partners	**China Partners**	
• LP Amina	• Tsinghua University • Shanghai Jiao Tong University • Harbin Institute of Technologies • Huaneng Clean Energy Research Institute	• China Power Investment Corporation • China Power Engineering Consulting Group Corporation • Shenhua Group

Research Objective

The researchers are pursuing activities that will lead to a breakthrough in clean coal generation and applications of key technologies. There are three categories within this research topic:

Integrated coal gasification combined cycle (IGCC)

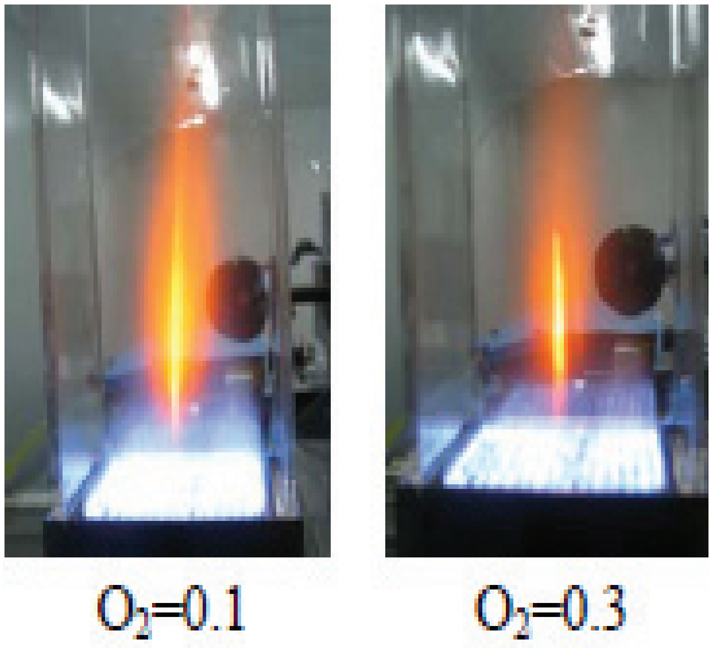
- Build a process model for the whole IGCC plant and its optimization process
- Provide an engineering design model for the whole IGCC plant
- Optimize the dynamic control system for the whole IGCC plant
- Obtain the gasification technologies for the IGCC

Advanced ultra supercritical (USC) power generation

- Conduct research on combustion and heat transfer characteristics of large-capacity and high-parameter boilers
- Study the combustion and heat transfer characteristics of super 700°C USC boilers
- Establish a prediction model for ash deposition, and provide quantitative data for fine particle removal and ash deposition prevention

Efficiency improvement and carbon reduction for in-service power plants

- Obtain detailed data related to increasing efficiency and carbon reduction for different boiler types, loads, and coal types for in-service power plants
- Evaluate the retrofitting technologies and obtain the technological roadmap for increasing efficiency and pollutant emission reduction
- Obtain the retrofitting and operation experience of key technologies



The flame shape of coal combustion in different O_2 concentrations

Technical Approach

Researchers are pursuing a variety of activities related to the IGCC. The team will conduct a coal-gasifier process simulation, integrate the gasifier and IGCC process design, conduct a study on the integrated process optimization of the IGCC system, produce a study on the dynamic control optimization of the IGCC system, and conduct a gasification technology evaluation and research for IGCC.

Advanced USC power generation activities include pursuing furnace combustion and heat transfer of a 1,000 MW USC boiler and a super 700°C USC boiler; investigating the coupling characteristics between the furnace and the pipe of the USC boiler; and evaluating combustion, fouling, and slagging issues related to USC boilers.

Regarding efficiency improvement and carbon reduction for in-service power plants, the team will conduct analysis of the potential for efficiency improvement and carbon reduction; evaluate technologies of in-service power plants; and conduct an engineering demonstration for key technologies, such as an advanced low-NO_x burner and boiler materials for USC.

Recent Progress

Researchers studied the coal combustion characteristics in the different scales of reactors, such as TGA, wire mesh, and down-fired combustors, which will help to develop the CBK char combustion model. The team also conducted a technical evaluation of pyrolytical char from lignite in the power plant.

Soot concentration around a single coal particle was measured by the laser-induced incandescent and multi-elemental diffusion flame burner under different conditions, such as variations in combustion temperature, resident time, coal types, and oxygen concentration. This data can help to develop the soot formation, oxidation model, and thermal characteristics during these processes.

The formation mechanisms of fine particle and deposition mechanisms were studied in the down-fired combustor, and researchers noted that the differences in ash deposition are due to differences in aerodynamics more so than physical or chemical differences in the ash, particularly for the practical self-sustained coal combustor. The results provide the experimental foundation for the ash deposition prediction and prevention model based on the particle aerodynamics mechanism.

Expected Outcomes

IGCC activities will lead to the generation of a complete IGCC system calculation model with sensible heat recycling, a universal IGCC power plant design method and technology, and a software copyright of the IGCC system design.

The research team's efforts in advanced USC power generation will produce a thermal calculation method of large-capacity and high-parameter boilers, a general large-capacity boiler thermal calculation program module, a calculation method of furnace combustion and heat transfer for super 700°C USC boilers, heat transfer coupling characteristics between the furnace and the pipe of USC boilers, and a prediction model of ash fouling and slagging in USC boilers.

Clean Coal Conversion Technology

U.S. Research Team Lead	China Research Team Lead
• Ismail Celik, West Virginia University	• Luo Zhongyang, Zhejiang University
U.S. Partners	**China Partners**
• West Virginia University • LP Amina • National Energy Technology Laboratory • Lawrence Livermore National Laboratory • University of Wyoming • University of Kentucky	• Zhejiang University • Shenhua Group • China University of Mining & Technology • ENN (XinAo Group) • China Academy of Sciences

Research Objective

Collaborative researcher teams from the United States and China are performing research and development of new coal co-generation systems with CO_2 capture, including new coal-to-chemical co-generation; new CO_2 capture processes; and co-generation systems with combined pyrolysis, gasification, and combustion. Specifically, the team will accomplish the following:

- Develop and deploy a new poly-generation technology to reduce waste heat, water utilization, and greenhouse gas emissions while improving thermal efficiency in utilization of coal to produce power and chemical by-products
- Design and build a demonstration coal-to-chemicals poly-generation plant in China under the leadership of LP Amina to demonstrate the stated purpose
- Conduct research and development of new coal co-generation systems with CO_2 capture, including new approaches for coal-to-chemical co-generation

Technical Approach

Researchers from both countries are working together to develop new technology to convert conventional power plants into poly-generation plants that make full use of waste heat and oxy-fuel combustion to produce chemicals and further polymers from coal. The approach leverages investments in technology development and industrial implementation aimed at reducing emissions, improving efficiency, and increasing economic benefits associated with coal power production. The technical approach includes the following:

- Build a laboratory-scale research facility
- Develop a new carbothermic reduction process to produce standard industry chemicals from limestone and coal
- Produce synthetic chemicals and fuels

Coal fired furnace

This research will result in the development of a demonstration project at a power plant in Shanxi, China, by LP Amina. In addition to standard engineering analysis, this work will require a substantial amount of basic research, especially in system analysis, reactor dynamics, chemical kinetics, emissions, and process stability and reliability.

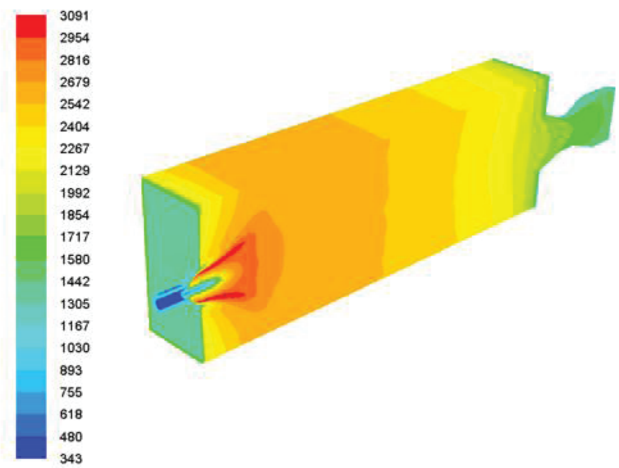
Recent Progress

The WVU research team completed preliminary equilibrium calculations for carbon oxy-combustion, carbon oxy-combustion with CO_2 dissociation, CaC_2 production, and the equilibrium of the entire system. The effect of the inlet temperature and the concentration of calcium oxide(s) on the production of CaC_2 were also investigated. The production of CaC_2 was also evaluated when the amount of CO_2 dilution was modified. The team also performed preliminary simulations of a two-dimensional axy-symmetric, swirling flow oxy-fuel combustor on the computational fluid dynamics code Ansys-Fluent 13. Temperature contours and velocity vectors were plotted across the reactor. Researchers are comparing the results to experimental data from the literature for validation purposes. Construction was also started on a high-temperature microwave furnace to study chemical kinetics of carbothermic reactions. The pyrometer and the vacuum window have been purchased and are currently being installed.

In September 2011, LP Amina signed an agreement with a Chinese power producer, GMIE, to build a poly-generation power plant using an innovative new technology development by LP Amina. The deal was developed under the U.S.-China CERC, and will enable a full-scale application of a technology that produces both chemicals and electric power. LP Amina has also completed its first demonstration project, a 100 MW unit in Shanxi, China.

Expected Outcomes

The implementation of poly-generation will reduce capital costs, greenhouse gas emissions, as well as plant maintenance costs of power generation sites. When paired with cleaner coal utilization with increased efficiency and minimal waste, poly-generation will be a cost-effective, commercially viable option for reducing CO_2 emissions in the power generation sector. It will also enable minimization of waste heat and/or materials. The LP Amina-GMIE plant would reduce greenhouse gases compared to conventional technology by more than 25%.



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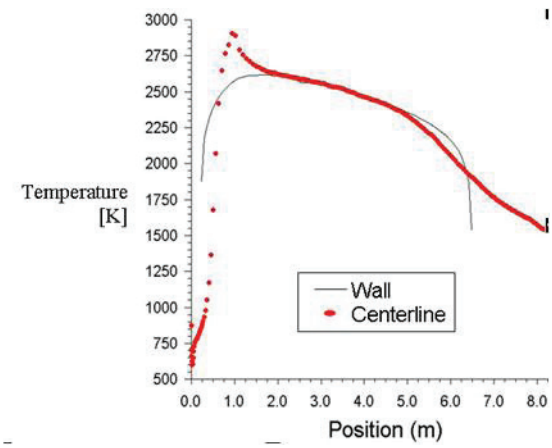
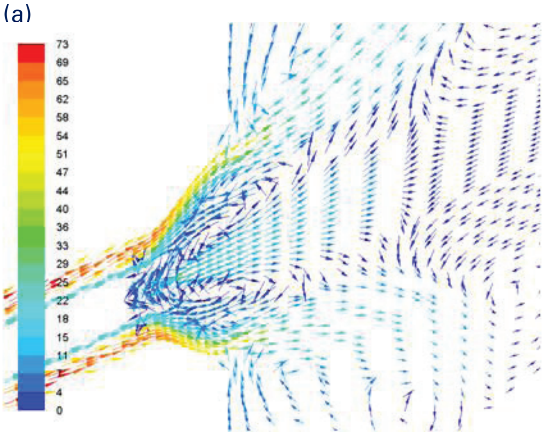


(b)



(c)

Figure. (a) Temperature contours (in Kelvin), (b) temperature profile, and (c) velocity vectors (color represents magnitude in m/s) numerically obtained in an oxy-fuel combustor. Coal is being carried by carbon dioxide stream through the inner annular inlet and hot, swirling oxygen is entering through the outer annular region. The temperature profile shows a region of around 2.5m at high temperatures for carbothermic reactions to occur.

Pre-Combustion CO_2 Capture

U.S. Research Team Lead	China Research Team Lead
• David Julius, Duke Energy	• XU Shisen, China Huaneng Group Clean Energy Research Institute
U.S. Partners	**China Partners**
• Duke Energy • General Electric • Lawrence Livermore National Laboratory • West Virginia University	• China Huaneng Group Clean Energy Research Institute • Tsinghua University

Research Objective

In this project, industrial, research, and academic leaders from both China and the United States work with industrial-scale demonstrative projects and best-in-class technologies to provide robust, transparent cost and performance estimates for IGCC power plants with CCS.

This project has one primary goal: development of techniques to aid in design and optimization of commercial-scale IGCC systems.

Specifically, the team's objectives include the following:

- Assess the economic and operability potential of existing capture technologies in conjunction with removal of criteria pollutants
- Assess the technical feasibility and potential economic benefit and operability of new, novel carbon capture technologies
- Optimize the economics of different carbon capture technologies
- Establish guidelines/protocols/criteria for system optimization and evaluation, as well as techno-economic analysis and comparison at commercial-scale application

Technical Approach

The project emphasizes system integration, optimization, key component development, and advanced CO_2 separation technology. The technical approaches for the project's two tasks are the following:

Development of Techniques for Integration and Optimization of an IGCC system

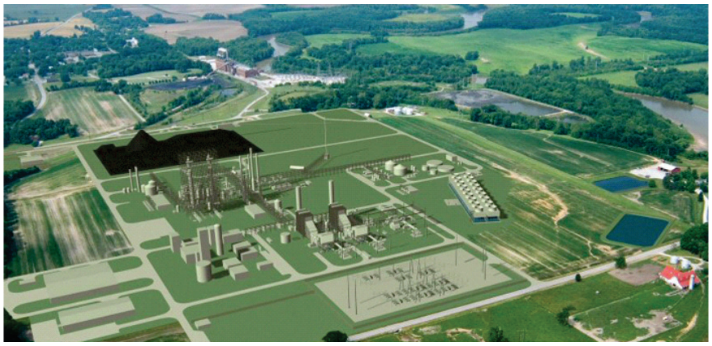
- Study the integration, optimization, and modular design of an IGCC system based on the existing research and demonstration experience of the first IGCC plant in China, as well as the experience of both existing and under construction IGCC in the United States

Development of Key Components in a Pre-Combustion CO_2 Capture Process

- Design and construct the slipstream-scale pre-combustion CO_2 capture and utilization system by extracting a slipstream syngas from an existing IGCC plant that includes water-gas shift, CO_2/H_2 separation, H_2 combustion/power generation, and CO_2 compression and utilization

To accomplish this work, researchers from U.S.-China ACTC (led by the China Huaneng Group, assisted by GE and Duke Energy in the United States) are developing the techniques for the optimization and design of a commercial-scale IGCC system based on the existing research as well as the demonstration experience of GreenGen, the first IGCC plant in China, and the experience of IGCC at Duke's Edwardsport Station.

Researchers (led by Huaneng, perhaps assisted by Los Alamos National Laboratory in the United States) are also developing the advanced key components including heat-integrated, robust, ultra-thin barriers with reasonable contamination resistance to flue gas, an advanced water-gas shift reactor, advanced separation reagents, and advanced compression technology.



An integrated gasification combined cycle power plant with carbon capture and storage

The ACTC team is also doing work in Projects 2 and 7 that supports the development of key technologies for pre-combustion capture. Specific activities that further pre-combustion CO_2 capture include the following:

- Developing and fabricating heat-integrated, robust, ultra-thin barriers with reasonable contamination resistance to flue gas for both pre- and post-combustion CO_2 removal
- Formulating new CO_2 absorbents with chemical additives for pre- and post-combustion CO_2 capture with high capacity, fast kinetics, and high stability
- Initializing models for existing pre-combustion capture technologies, chiefly physical sorbents, both as individual models and within the two reference plants (including water-gas shift and gas cleanup)

Recent Progress

Duke Energy's Edwardsport plant and Huaneng's GreenGen IGCC are under construction or in commissioning stage. Knowledge sharing of engineering data has begun; major knowledge sharing of start-up and operational lessons will occur once the plants are online and operational data are available (2013–2014).

Expected Outcomes

Key outcomes include critical data, lessons, and knowledge shared through operational experience with demonstration projects as systems are optimized and the cost of pre-combustion CO_2 capture is lowered. Such knowledge sharing contributes to accelerating the development of IGCC with CCS, a critical pathway toward low-carbon power generation with coal.

Post-Combustion CO_2 Capture

U.S. Research Team Lead	China Research Team Lead
• Kunlei Liu, University of Kentucky, Center for Applied Energy Research	• GAO Shiwang, China Huaneng Group
U.S. Partners	**China Partners**
• University of Kentucky • University of Wyoming • Los Alamos National Laboratory • Lawrence Livermore National Laboratory	• China Huaneng Group Clean Energy Research Institute • Tsinghua University • China Power Engineering Consulting Group Corporation • China Power Investment Corporation

Research Objective

The ACTC team is directly addressing the need for steep emissions reductions from the existing coal fleet by analyzing, testing, and demonstrating technologies for post-combustion capture integrated with sequestration at real power plants. Through streamlined bilateral joint cooperation, U.S. and Chinese researchers are focusing on the following:

- Research on efficiency developments for affordable post-combustion CO_2 capture technologies
- Coordinated efforts between U.S. and Chinese partners
- Development of models for post-combustion CO_2 capture, utilization, and storage technology at a commercial scale

Technical Approach

To enable commercial-scale, cost-efficient carbon capture, utilization, and storage, the ACTC team is addressing the gap between theoretical efficiency for post-combustion capture and present-day commercially available technologies.

- Researchers in the United States (led by LANL) use novel fabrication technologies to create high-permeability, high-selectivity membranes for CO_2 separation using nanotechnology
- Researchers in the United States, led by UK and assisted by Huaneng led-team in China, develop an organo-metallic enzyme that mimics catalyzed solvent to speed up the CO_2 reaction and reduce capital costs
- Researchers enrich the carbon concentration prior to solvent regenerator to minimize the stripper size and energy consumption

Piping network in an existing coal power plant

- Researchers in China, led by Huaneng and assisted by UK in the United States, develop/evaluate new capture reagents with high solute capacity and higher resistance to solvent degradation and contamination. They also conduct process heat integration/optimization and techno-economic analysis for 1 million tons/year post-combustion CO_2 capture for both U.S. and China applications
- A joint committee will be formed to accomplish the following:
    - Collect and study the similarities and differences of coals and coal-derived flue gas conditions, power plant operation, and environmental requirements between the United States and China
    - Establish guidelines/protocols/criteria for system optimization and evaluation, techno-economic analysis, and comparison for a commercial-scale application
    - Develop a research matrix beneficial to both of the previously mentioned activities

Recent Progress

A series of catalyst candidates were synthesized based on initial literature reports for carbonic anhydrase mimics. It was determined that compounds with long Zn-O yet low (< 8.5) (pKa) are needed. A longer OH-bond leads to lower Lewis acidity of metal-ligand complex, more of a "free" hydroxide (and more nucleophilic), and higher acid dissociation (pKa) for the H_2O deprotonation step.

Researchers designed, synthesized, and demonstrated a novel class of next-generation ionic liquid-based materials and membranes at LANL. LANL's ultrasonic-spray-coating-technology-based membrane fabrication platform was used to prepare the membranes of these next-generation materials in both stand-alone and supported formats. A SiF_6 salt compound that was synthesized at CAER was also tested. The testing was performed at LLNL using stopped flow kinetics measurement, and the rate constant was found to be comparable to the Zn cyclen (perchlorate salt) synthesized at LLNL. This test confirmed that the Zn-cyclen complex does have confirmed activity for catalyzing the CO_2 hydration reaction.

LLNL has worked with both Duke Energy and the HCERI to achieve several milestones for the analysis, assessing the feasibility of Huaneng's carbon capture technology. Researchers used validated Aspen models to initialize post-combustion capture simulations at Gibson-3. They acquired parametric data for Shidongkou to constrain a suite of model runs bounding different operating conditions (e.g., different circulation pressures and solution concentrations), and ran models for conventional monoethanolamine to validate PCC runs at Gibson-3, including preliminary economic analyses. Researchers also identified and repaired model mismatches and inconsistent results by identifying gaps in Huaneng data needed to finalize model runs with proprietary Huaneng solution, and a Chinese patent with relevant chemical thermodynamic and kinetic information.

Expected Outcomes

The project will produce optimized design options of competing technology pathways (e.g., amines and advanced solvent) for post-combustion CCUS cost, retrofitability, engineering, and environmental performance. The results from this work will lay the groundwork for decision makers in both nations to understand the potential role of post-combustion retrofits in achieving steep reductions, and provide new operational insights to the integration of capture and storage while developing new low-cost, post-combustion capture options.

Oxy-Combustion CO_2 Capture

U.S. Research Team Lead	China Research Team Lead
• Kevin McCauley, Babcock & Wilcox Power Generation Group, Inc.	• Liu Zhaohui, Huazhong University of Science and Technology
U.S. Partners	**China Partners**
• Babcock & Wilcox Power Generation Group, Inc. • West Virginia University • Lawrence Livermore National Laboratory • National Energy Technology Laboratory	• Huazhong University of Science and Technology • Tsinghua University • Research Center for Clean Energy and Power, Chinese Academy of Sciences

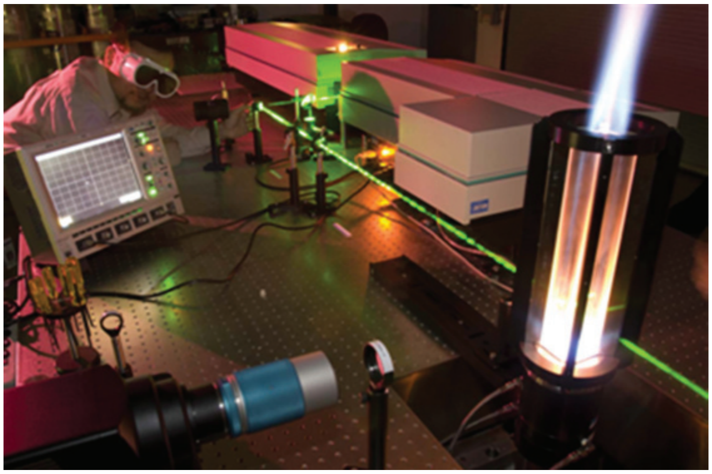
Research Objective

This project brings together flagship projects in the United States with centers of excellence in both China and the United States, with the goal of achieving cost and performance improvements through small pilot and large at-scale validation projects. For example, strategic introduction of oxygen into proper flame zones can enable low-volatile pulverized coal to burn in a wall-firing configuration and avoid the complexities associated with the down-shot boiler design. All work is expected to continually feed and update robust simulation programs. The work examines opportunities for oxyfiring with both U.S. and Chinese coals (solid fuels) by accomplishing the following:

- Understand the fundamental and pilot-scale combustion and emission characteristics of indigenous Chinese and U.S. coals (solid fuels) of different ranks under oxy-fuel conditions
- Create a model for oxy-fired burner design, pilot-scale oxy-combustion evaluation and optimization, and full system modeling
- Conduct a commercial-scale engineering feasibility study for an oxy-fuel-combustion reference plant as a new build, retrofit, or repowering
- Develop the plant simulation and modeling to accelerate further design improvements, applications, and performance. This is key in order to quickly measure the value of the costs and benefits of proposed improvements discovered in the laboratory.

Technical Approach

Both China and the United States have large coal reserves including lignite, bituminous, and anthracite coal. With the existing experience from previous U.S. work, along with the development of new research pilots in China, an opportunity exists to accelerate the path to commercialization and broaden the application across



Combustion laser diagnostics for fuel characterization and oxy-combustion

regions and fuel types. The primary approach focuses on expanding the experience of oxy-combustion into broader applications in the United States and China. The technical approach comprises four main activities:

Fuel Characterization and Hazardous Air Pollution Emission Study under Oxy-fuel Conditions

- Conduct analysis of representative samples of different ranks of Chinese and U.S. coals
- Conduct experiments on characteristics of coal pyrolysis, ignition, combustion, burn off, dust stratification, slagging, and deposition in bench-scale facilities. Also, conduct tests on NOx formation and destruction, PM2.5 emission and control.
- Develop and implement reaction chemistry sub-models on combustion and NOx formation under oxy-combustion conditions to provide a tool for burner design and oxygen injection optimization (FURN, HUST, COMO, B&W)

Pilot-Scale Oxy-fuel Combustion Evaluation and Optimization

- Carry out pilot-scale tests in research facilities at B&W and HUST using selected Chinese and U.S. coals
- Configure the research facilities at B&W and HUST for the optimum oxy-combustion flue gas recycling process (e.g., warm-recycle, cool-recycle, or cold-recycle) using a new burner design
- Collect performance data on combustion, heat transfer, furnace exit gas temperature, and emissions over a wide range of practical operating conditions
- Select the most promising design based on modeling predictions and performance criteria for further demonstration

Steady-State and Dynamic Process Modeling Simulations

- Compare Aspen Plus static predictions with pilot-scale data
- Use Aspen Plus Dynamics to simulate transient oxy-combustion processes
- Validate and tune the dynamic process model toward developing a control strategy for start-up, shutdown, modulations, and unit trips (e.g., boiler, air separation unit, compression and purification unit, etc.)

Feasibility Study for Large-Scale Deployment

- Design a larger boiler unit at near-commercial scale
- Conduct an engineering study of a reference wall-fired pulverized coal burning unit for oxy-combustion
- Perform unit and process design of the air separation unit, boiler island, compression and purification unit, and the balance of plant

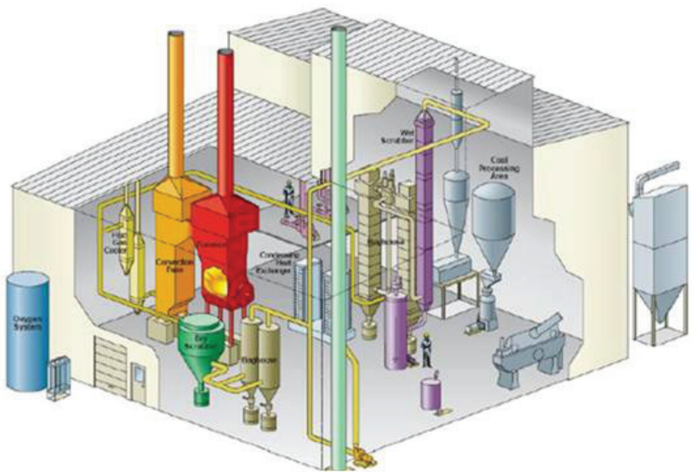
Recent Progress

Several large oxy-combustion plant analyses and configurations have been completed (B&W). The flue gas conditions and a base configuration for the plant environmental equipment will be determined (WVU). Initial laboratory combustion tests of three Chinese coals have been completed (B&W). The results are being used to update combustion models for oxy-combustion processes and will be correlated to U.S. coals to evaluate and process differences in collaboration with HUST.

Recent meetings have been held both in the United States, where HUST was able to review the B&W 1.8 MWt pilot plant and discuss operating and performance characteristics, and in China, where B&W was able to review the design of the new 3 MWt pilot under construction by HUST and provide input on design, functionality, and controls. Discussions continue on large-scale demonstrations and effective collaboration on key opportunities, such as the sub-critical repowering in the United States at 200 MWe (B&W), sub-critical retrofit in China at 100 MWe (HUST), and super-critical new build in China at 350 MWe (B&W).

Expected Outcomes

This project will lead to cost and performance improvements in the laboratory and in the field. Ultimately, the economic and environmental potential of oxy-firing combustion will be attributable to a wider range of solid fuels and at a commercially viable scale.



Oxycombustion pilot facility diagram

1.8 MWth oxycombustion pilot facility

CO_2 Sequestration

U.S. Research Team Lead	China Research Team Lead
• Tim Carr, West Virginia University • Ronald Surdam, University of Wyoming • Phil Stauffer, Los Alamos National Laboratory • Walt McNab, Lawrence Livermore National Laboratory	• Ren Xiangkun, Shenhua Group • Li Xiaochun, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
U.S. Partners	**China Partners**
• University of Wyoming • Los Alamos National Laboratory • Lawrence Livermore National Laboratory • Indiana Geological Survey • West Virginia University	• Shaanxi Provincial Institute of Energy Resources • Yanchang Petroleum Group • Institute of Rock and Soil Mechanics, Chinese Academy of Sciences • Shenhua Group • Qinghua University • China University of Mining and Technology, Beijing • China University of Mining and Technology, Xuzhou

Research Objective

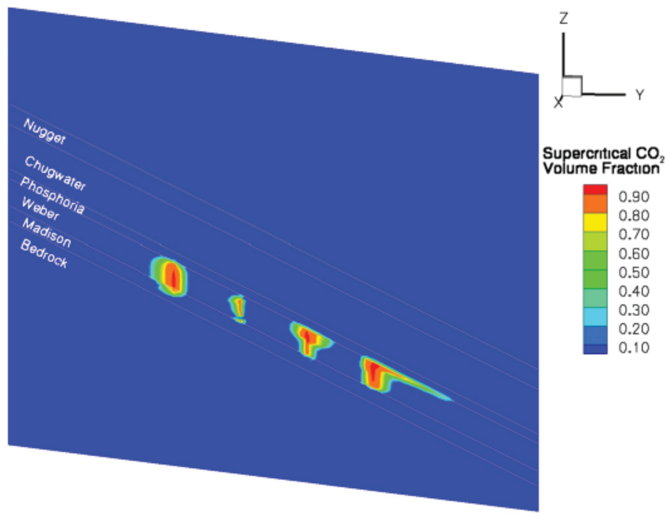
Research for this project focuses on estimating the capacity and identifying near-term opportunities for geological CO_2 storage (CCS and CCUS) in the Ordos Basin, China, and also applicable to formations in the United States. This effort includes the following:

- Simulation technology for CO_2 storage in saline formations
- Research and application of monitoring technology of CO_2 storage in saline formations
- Assessment of safety and risk of CO_2 storage in saline formations
- Geological characterization

Through combined research on the above issues and successful execution of demonstration projects, this effort will improve understanding, provide verification of key technologies for CO_2 storage in saline formations, and provide the scientific evidence to implement large-scale CCS and CCUS in China and in the United States.

The project has two primary objectives:

- To build the scientific, technological, and engineering framework necessary for CO_2 utilization through enhanced oil recovery and the safe, permanent storage of commercial quantities of anthropogenic CO_2 in the Majiagou Limestone of the Ordos Basin, Shaanxi Province, China
- To assess the safety and risk of CO_2 storage in saline formations



Illustrative simulation model output for supercritical CO_2 volume fraction

Technical Approach

In this project, UWY, WVU, IGS, LANL, LLNL, and Chinese partners undertake the work necessary to move from preliminary characterization to commercial development of a premier CO_2 storage site in the Shaanxi Province of China. The team's technical approach to CO_2 storage characterization in the Ordos Basin emphasizes the following five steps:

1. Quick procession from the recently completed general inventory of CO_2 storage potential in the Ordos Basin to detailed, site-specific characterization studies of individual targeted storage sites

2. Experience with the Wyoming Carbon Underground Storage Project and other U.S. Department of Energy characterization projects supports the use of two-dimensional and 3-D seismic surveys, stratigraphic test wells, and existing well bore information as basic elements to the retrieval, evaluation, and interpretation of data vital to project success
    - These data allow the best decisions possible regarding characterization, prioritization, and selection of specific storage sites
3. Numerical simulation techniques, which are vital to the delineation of 3-D geological heterogeneity at selected storage sites, and to the evaluation of caprock distribution, sealing capacity, trap configuration, reservoir storage capacity, reasonable injection rates, optimal injection well patterns, various pressure configurations, potential CO_2 plume distributions, and displaced fluid domains at potential storage sites (i.e., risk reduction)
4. Planning before CO_2 injection for customized fluid production and treatment of displaced fluids, or to develop some other displaced fluid management strategy
5. Assuming success in steps 1 through 4, step 5 involves planning, designing, and implementing a sub-commercial CO_2 storage demonstration (1 Mt per year) to test the validity of the numerical simulation scenarios, and to construct credible monitoring and performance assessment plans

Recent Progress

The team has developed a regional geologic/structural model for the Ordos Basin based on the geologic, geophysical, geochemical, petrophysical, and petrographic data available in the public domain for the Shaanxi portion of the Ordos Basin.

The Shaanxi-Wyoming team is inventorying and prioritizing the highest-priority storage sites and reservoirs in the Ordos Basin. The team has implemented plans to share data in order to effectively characterize and prioritize potential geological CO_2 storage reservoirs in the Ordos Basin. They also used the technology developed by Aines et al. (2010) at LLNL and the Wyoming/SPIERCE team evaluated displaced fluid management strategies for the Majiagou Limestone in the basin. Results suggest that more than 90% of the produced Majiagou formation water (total dissolved solids of approximately 20,000 ppm) could be treated and used beneficially.

To better utilize CO_2 for enhanced oil recovery, the research team made two visits to the Yanchang Oil Company owned by Shaanxi Province. The UWY team is working alongside the Yanchang Oil Company in prioritizing these oil fields according to their potential for EOR using CO_2 flooding. The partnership has developed an assessment strategy that includes screening criteria for Ordos Basin oil fields. Preliminary screening results suggest that in the Yanchang oil fields, the Triassic Yanchang Formation—particularly the Chang 4, 5, and 6 reservoirs, and Yan 8 and 9 reservoirs—have the greatest potential for CO_2 EOR in Shaanxi Province.

The researchers also assessed the risks and safety of CO_2 storage in the Ordos Basin. They collected data from a potential demonstration project site and conducted a risk analysis. The resulting work was turned into a paper that has been submitted to *Energy and Environmental Science* that describes a pore-scale to regional-scale analysis of CCS in the southern United States. A new site-scale pipeline optimization algorithm was developed for this work and this algorithm will be demonstrated and communicated to interested parties. Researchers finalized several numerical simulations of CO_2 plume evolution for a project in the United States. These simulations are designed to reveal details and uncertainty in storage capacity, injectivity, and leakage that are at the cutting edge of current simulation capability. The work incorporates heterogeneity in rock properties and has led to new insights into defining storage reservoirs and will be submitted for publication in 2012. The results will play an important role in demonstrating the value of cutting-edge numerical techniques.

Expected Outcomes

The significant opportunity for storage and utilization of CO_2 in the Ordos Basin in China complements opportunities that are being explored in the United States. The research team is looking at the Ordos Basin parallel to similar research on basins in the United States, such as in Wyoming and Illinois.

The lessons learned will be invaluable to CCS projects particularly in Rocky Mountain basins; the Majiagou Limestone and Ordos Basin are very similar to the Paleozoic Madison Limestone and the Powder River Basin of Wyoming and Montana.

This work ultimately improves global understanding of how to safely and effectively store CO_2 in saline formations or to use the CO_2 for EOR.

CO_2 Utilization

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U.S. Partners	**China Partners**
• University of Kentucky • Duke Energy • National Energy Technology Laboratory • Pacific Northwest National Laboratory	• ENN (XinAo Group) • Zhejiang University • Jinan University

Research Objective

The objectives of this project are to develop and demonstrate an economically feasible technology for CO_2 utilization with microalgae and transform algal biomass into a sustainable source of energy.

This project aims to accomplish the following sequential goals:

- Identify and culture optimal summer and winter algae strains to be used in the CO_2 mitigation system
- Optimize the culturing process and technology; this should include a demonstration of algae cultivation at pilot-plant scale under summer and winter conditions, incorporating optimized nutrient and water recycling
- Identify and evaluate the possible co-products from the process, including fuels and animal feed
- Use the data gained to construct a techno-economic model to estimate the overall cost of CO_2 fixation and utilization at various scales of operation

Photobioreactor under construction at Dale Power Station in Kentucky

Technical Approach

The technical approach focuses on the design of a low-cost, closed-loop photobioreactor, and culminates in a pilot plant demonstration at a coal-fired power plant in Kentucky (Dale Power Station), slated for start-up in early 2012. In the longer term, the research team plans to leverage this expertise and experience with that of the U.S. and Chinese project partners to conduct a detailed techno-economic assessment of the potential of algae for CO_2 mitigation.

Duke Energy and China's ENN Group are conducting similar pilot-plant studies at Duke's East Bend Station, and have captured a slipstream from the plant and are feeding it into a research reactor from China. Field demonstration projects such as ENN's at East Bend and UK's at Dale Power Station are critically important for meaningful comparative analysis and engineering scale-up.

Recent Progress

The design of the Dale Power Station PBR has been completed and significant progress has been made toward its construction. The majority of the parts have been delivered and assembly is almost complete. Separately, laboratory-scale media studies have been conducted in order to fine-tune the media recipe that will be used for algae cultivation at Dale Power Station. Start-up of the PBR is planned for late February 2012.

Expected Outcomes

Construction of the initial phase of the demonstration project will be completed and a fully instrumented, 15,000 L system will be commissioned at Dale Power Station in early 2012. In mid 2012, the system will be expanded to a maximum capacity of 150,000 L. Process data will be collected until the system is taken off-line in November 2012. The accumulated data will be incorporated in a techno-economic model that will enable the costs associated with CO_2 capture and utilization to be calculated at different operating scales. Data sharing between UK and Duke/ENN will enable a range of process configurations to be assessed.

Simulation and Assessment

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• Richard Turton, West Virginia University	• Li Zheng, Tsinghua University
U.S. Partners	**China Partners**
• National Energy Technology Laboratory • Lawrence Livermore National Laboratory • Duke Energy • Babcock and Wilcox	• Shenhua Group • China Power Engineering Consulting Group Corporation • Huaneng Power International, Inc. • Huazhong University of Science and Technology • Chinese Academy of Sciences • ENN (XinAo Group)

Research Objective

The objectives for this project are to apply modeling techniques to a wide variety of issues associated with pre- and post-combustion CO_2 capture and oxy-combustion in order to accomplish the following:

- Assess the economic and operability potential of existing capture technologies in conjunction with removal of criteria pollutants
- Assess the technical feasibility and potential economic benefit and operability of novel carbon capture technologies
- Optimize the economics of different carbon capture technologies

Technical Approach

The approach aims to be inclusive of many projects and areas of interest with the understanding that, due to budget limitations, only a subset of the analyses will be completed. The levels of analysis will vary depending on the maturity of the technology and the availability of data from academic and industrial partners.

Active Research Tasks

- Initialize and augment a technical assessment of Huaneng's post-combustion, amine-based CO_2 capture technology
- Initialize models for existing pre-combustion capture technologies, chiefly physical sorbents, both as individual models and within the two reference plants (including water-gas shift and gas cleanup)
- Initialize models for existing post-combustion capture technologies, chiefly solvent-based, both as individual models and within the two reference plants
- Initialize and augment a dynamic model with immersive visualization capability for a generic IGCC system with a gas turbine and steam bottoming cycle
- Initialize steady-state and dynamic models for an oxy-fired PC plant

Potential Future Tasks

- Initialize models and modules for a subset of novel pre-combustion capture technologies, chiefly advanced membranes
- Initialize at least one advanced gasification technology module (either catalytic gasification or molten metal)
- Perform preliminary performance and cost analyses for IGCC systems based on the above models
- Initialize and augment a poly-generation plant, including coal and biomass co-firing, leveraged off the IGCC plant
- Perform preliminary performance and cost analyses for PC boiler systems based on the above models

Recent Progress

Base-case processes for an ammonia-based and a simple amine-based MEA carbon capture system has been simulated using the Aspen Plus platform (WVU). Currently, base-case steady-state simulations using the same flue gas as cited in Case 11 of the *Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity*, rev. 2, November 2010 (DOE/NETL-2010/1397) have been simulated for the ammonia and MEA systems. Good agreement with the results of Case 12 for the MEA system has been obtained while the ammonia-based process is still being optimized.

Expected Outcomes

Application of advanced modeling and simulation tools will enable improvements in technology and systems integration that would not otherwise be possible. Such improvements will decrease the cost and improve the performance of CO_2 capture technologies.

Communication and Integration

U.S. Research Team Lead	China Research Team Lead
• Sarah Forbes	• Wu Tianhua
U.S. Partners	**China Partners**
• World Resources institute • West Virginia University	• Huazhong University of Science and Technology • Tsinghua University • Huaneng Clean Energy Research Institute

Research Objective

The research team will provide efficient and effective communication among ACTC members in both countries, ensuring effective sharing of information and facilities. Researchers will facilitate personnel exchanges among the different teams of the two countries and the different tasks of the consortium. A communication network inside the U.S.-China consortium will be established to maximize the achievements of the cooperation. This effort includes integrating other technical tasks within each national team as well as international coordination. The primary goals of these efforts are three-fold:

1. Publicize the ACTC's progress and achievements to governments and the public, providing decision makers with information on how to further improve cooperation
2. Provide the ACTC with a platform to effectively share information, including a program for personnel exchanges
3. Integrate collective research results from within each national team, as well as the research work of the entire bilateral ACTC consortia

Technical Approach

The team will develop a plan for how to share information, such as knowledge and data, within the ACTC, and establish an information-sharing model. Researchers will develop a plan for joint research projects, information sharing, technique export, and cooperation between the large energy companies on the ACTC teams.

The integration approach includes the following tasks:

- Construct a bilingual website for the ACTC for sharing news, progress, and achievements with decision makers and other interested stakeholders. The website should be updated at least quarterly
- Develop and produce a bilateral and bilingual quarterly CERC newsletter that outlines the key outcomes under each research theme and highlights the projects
- Integrate achievements and progress from both countries to produce an annual report for decision makers with updated cooperation modes, research progress, and suggestions for future improvement

The communications approach includes the following tasks:

- Organize regular and ad-hoc bilateral meetings
- Organize regular and ad-hoc meetings within each national consortium
- Provide networking opportunities and platforms to enable smooth communication among the different teams and tasks. This may include site visits at relevant research centers in both countries
- Provide a mechanism for personnel exchange

Recent Progress

On July 1, 2011, the oxy-combustion team organized a start-up meeting at the Huazhong University of Science and Technology, where eight team members from China and B&W, a team lead from the United States, discussed their work via video conference. Other task teams also held task start-up meetings.

In order to report the consortium progress, eight newsletters have been produced:

- Introduction to the ACTC and its organization, working modes, and tasks
- Introduction to the 2011 Beijing Joint Meeting
- Introduction to the 2011 Wuhan IP Workshop
- Start-up meeting of the oxy-combustion team in Wuhan, China
- China-ACTC visited the U.S.-ACTC and signed the technology management plan
- China-ACTC Advisory Board Meeting held in ENN
- Meeting of China-U.S. Steering Committee on clean energy science
- China-ACTC held a plenary meeting in Beijing, China

A website for the China-ACTC has been established to share news and other materials.

Expected Outcomes

This work will provide support and suggestions to decision makers about the model of cooperation between China and the United States. It will establish an information-sharing model that is acceptable to ACTC partners from both countries based on thorough communication between them. Most importantly, it will establish smooth communications and a program of personnel exchanges between the two countries.

Real-Time Monitoring and Energy Database

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Tianzhen Hong, Lawrence Berkeley National Laboratory	• JIANG Yi, Tsinghua University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory • Honeywell	• Tsinghua University • Persagy

Research Objective

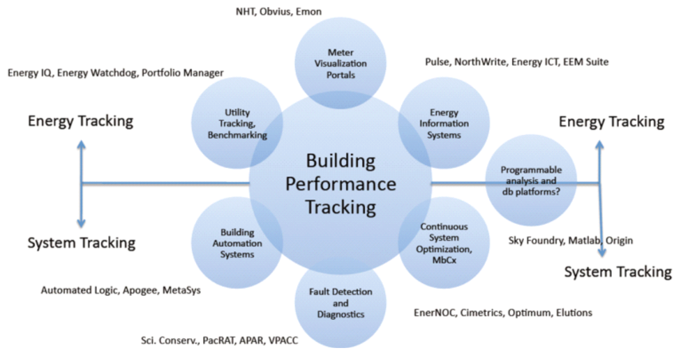
The objectives of the project are to help develop a standard methodology for building energy data definition, collection, presentation, and analysis; apply the developed method to a standardized energy monitoring platform, including hardware and software, to collect and analyze building energy use data; and compile off-line statistical data and online real-time data in both China and the United States for a full understanding of the current status of building energy use.

Technical Approach

- Help develop and install a standardized energy-monitoring platform, including standardization of energy data description, hardware, and software, to collect and analyze energy use data for a few selected office (or mixed-use office) buildings in both countries
  - The real-time monitoring platform can also be used to troubleshoot operation and control system problems and equipment faults and be further linked to building energy benchmarking and rating/labeling systems

Recent Progress

- Completed a final joint research plan
- Reviewed and selected candidate buildings
- Reviewed existing energy monitoring and analysis systems
- Developed a standard uniform subentry energy data definition
- Started drawing up an ISO standard of building energy definition and uniform index
- Defined building energy monitoring points
- Started collecting energy use and operating data for a few selected buildings
- Conducted a preliminary analysis of building energy data



A building performance tracking schematic

Expected Outcomes

- A standard real-time building energy monitoring and analysis platform for better interoperability
- The ability to visualize energy use and operation conditions to identify operation deficiencies or problems that cause energy waste/leaks
- Enhanced performance tracking and commissioning to continuously improve building energy efficiency
- Building energy performance benchmarks that can be used to identify retrofit opportunities
- Improved databases of building energy use
- Data sharing and comparisons between different monitoring systems based on the ISO standard
- Research on standard simulation input patterns and default settings for codes, evaluation, etc.
- Joint development on an occupant behavior module based on both EnergyPlus (E+) and Designer's Simulation Toolkit
- Data mining on U.S. and Chinese building energy data based on energy usage index

Building Performance Simulation

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Tianzhen Hong, Lawrence Berkeley National Laboratory	• YAN Da, Tsinghua University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory • Bentley Systems	• Tsinghua University

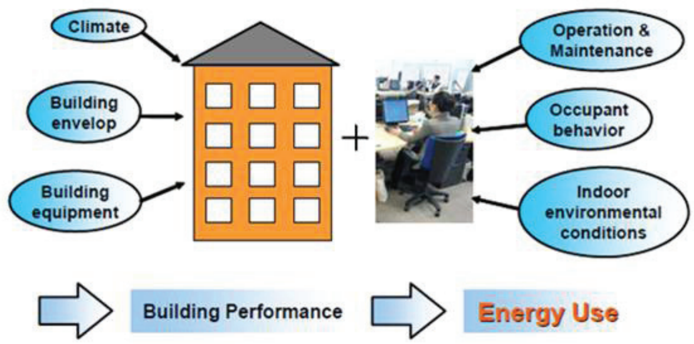
Research Objective

This project aims to improve and expand the use of building simulation to support the design and operation of low-energy buildings through better understanding and predicting of the energy performance of buildings. The specific research objectives are the following:

- Use and improve simulation to better understand energy use data of buildings in China and the United States
- Incorporate the behavior of building operators and occupants in building performance simulation
- Evaluate and compare capabilities of DOE-2.1E, Designer's Simulation Toolkit (DeST), and EnergyPlus (E+) to better understand their strengths and weaknesses, which will support their use for China energy code development and compliance

Technical Approach

- Perform sensitivity and scenario analysis to quantify the relative impact of the six driving factors of the energy performance of buildings
- Identify the key energy-related behavior of building operators and occupants based on measured and survey data, develop algorithms to model the effects of variations in behavior, integrate the behavior models into EnergyPlus and DeST and make them available to the public to encourage broader use, and assess the impact of behavior on building energy use in selected buildings in the United States and China
- Compare simulation programs to evaluate their capabilities and limitations in energy modeling, especially for low-energy buildings with innovative designs
- Explore a new software framework for the next generation of building simulation programs and establish the possibility of creating a new building energy simulation program that builds on the strengths of previous programs and the expertise of modelers from both China and the United States



Aspects of building energy performance

Recent Progress

- Completed a final joint research plan
- Identified and assessed key driving factors: design efficiency, operations, and climate
- Compared simulation results with building databases
- Provided insights to support design and operation of low-energy buildings

Expected Outcomes

- Improved use of simulation to better understand and evaluate key drivers of the energy performance of buildings
- Enhancements to EnergyPlus to model building operation (with potential faults), maintenance, and occupant behavior
- Reduced uncertainty in using simulation to predict actual building energy performance
- Standards of inputs to building simulations
- Research on standard simulation input patterns and default settings for codes, evaluation, etc.
- Joint development on an occupant behavior module based on both E+ and DeST

Building Energy Analysis, Comparison and Benchmarking

Joint Project

U.S. Research Team Lead	China Research Team Lead
• David Hathaway, ICF International	• XIA Jianjun, Tsinghua University
U.S. Partners	**China Partners**
• ICF International • Energy Foundation – China Sustainable Energy Program	• Tsinghua University

Research Objective

The primary objectives of this project are the following:

- Develop an understanding of the key drivers for top energy performance in hotel, commercial office, and government office buildings in China and an understanding of how those compare to key performance drivers in the United States
- Gain an initial understanding of how building energy performance in China compares to building energy performance in the United States
- Identify lessons and best practices that can be shared between the two countries to improve building energy performance in both countries

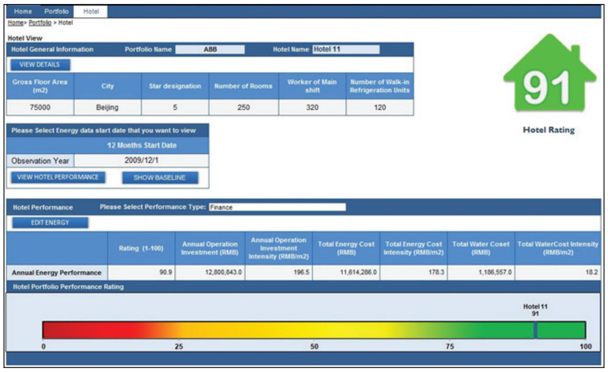
As a secondary objective, researchers will conduct analyses of large homogenous portfolios of building data to identify the factors that cause common energy performance variations across those data sets.

Technical Approach

- Perform both high-level statistical analysis and detailed building-level analysis
  - Use nationally representative data sets (when available) to conduct building energy analysis
  - Obtain and use local data sets when nationally representative data sets are not available
- Base statistical regression analysis on the U.S. Environmental Protection Agency model, which was used to develop the ENERGY STAR Portfolio Manager tool

Recent Progress

- Completed a final joint research plan
- Developed an energy performance benchmarking tool for hotels in China
- Determined preliminary key drivers of Chinese hotel energy performance
- Developed an initial, rough comparison of hotel energy performance in the United States and China



An ICF-Tsinghua benchmarking tool hotel rating page

- Initiated collaboration with Tsinghua University on benchmarking tool development and building portfolio analysis
- Initiated development of the website tool

Expected Outcomes

- Web-based benchmarking tools for hotels, commercial offices, and government offices housed at permanent sustainable institutes in China
- Data sources and processes for ongoing updates to the tools developed
- Key channels for establishment of tools among existing and new voluntary policies and programs to promote energy reductions in the building sector in China, such as a national-level working group, pilot programs, workshops, and policy papers
- Improved understanding of key drivers for energy performance in hotel, commercial, and government buildings in China and how those compare to key performance drivers in the United States
- Initial understanding of how building energy performance in China compares to building energy performance in the United States, once external factors, such as building size, occupancy, and location are taken into account
- Lessons learned and best practices that can be shared to improve building energy performance in both countries

Complex Glazing Materials and Shading Systems

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Eleanor Lee, Lawrence Berkeley National Laboratory	• DING Yong, Chongqing University • LI Zhengrong, Tongji University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory • Saint-Gobain	• Chongqing University • Tongji University • CISDI Engineering Co., Ltd • CNOOC and Industrial Co., Ltd • Zhong Ji Yuan Xiong Energy Storage Technology Co., Ltd • Shanghai Xian Dai Architectural Design Co., Ltd • Shanghai Qing Ying Industrial Shares Co., Ltd

Research Objective

The primary objectives of this project are the following:

- Identify and develop methods needed to characterize, compare, and evaluate the energy use and comfort performance of window and shading technologies
- Identify, develop, and evaluate window and shading technologies needed to attain energy efficiency goals for residential and commercial buildings in a diverse set of climates in China
- Develop application guidelines for selection of energy-efficient window systems for different climatic regions

Technical Approach

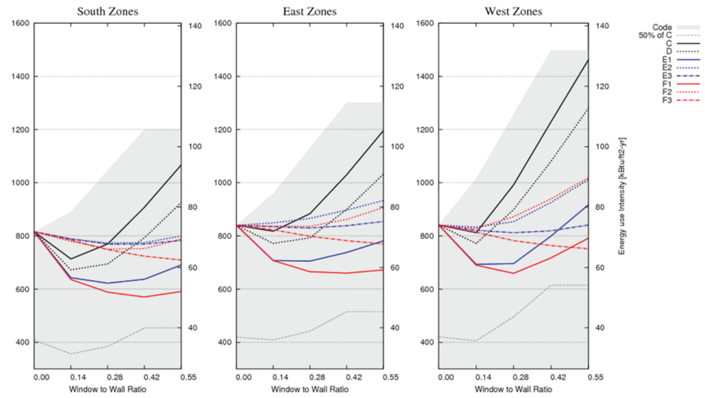
- Define and share the current methods for characterizing and modeling the energy efficiency performance of window systems
- Identify, develop, and evaluate window systems that enable performance goals
- Promote the use of identified energy-efficient solutions through application and technical guidelines

Recent Progress

- Completed a final joint research plan
- Began defining the commercial building prototype characteristics; parameters for the envelope, lighting, and heating, ventilation, and air conditioning systems; and the performance metrics that will be used to evaluate glazing, shading, and daylighting technologies
- Began defining the workflow needed between the various tools used to model optically complex fenestration systems and dynamic, controllable glazing/shading systems; identifying the simulation tools needed to be modified in order to model such systems; and making plans for such modifications in the software
- Initiated the first-stage report on the U.S. and China window performance comparison
- Initiated the first-stage report on the U.S. and China shading technology comparison
- Simulated energy savings levels (see figure). Use of triple-pane, low-emittance insulating windows can yield up to 30% reductions in cold climates compared to China's GB 50189-2005 (ASHRAE 90.1-2004) code levels. With daylighting controls (line F1), EnergyPlus simulations indicate that savings can approach levels of 50%. These savings are achieved through an integrated, not component-based, approach to façade design and specification, where window area and type are determined by optimizing both HVAC and lighting energy use.

Expected Outcomes

- Reduced complexity in designing innovative window technologies and strategies for new and retrofit construction
- Improvements in indoor environmental quality
- Dissemination of window application guidelines for building designers



Simulated energy savings

Upper edge of gray region: code-compliant window with no daylighting controls.

The following window types with daylighting controls:

C: code compliant window

E1: spectrally selective, low-e window

F1: highly insulating, R5 window

F2: highly insulating, R5 window with fixed interior roller shade

F3: highly insulating, R5 window with fixed exterior roller shade

Insulation Materials and Systems

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Therese Stovall, Oak Ridge National Laboratory	• SONG Bo, China Academy of Building Research
U.S. Partners	**China Partners**
• Oak Ridge National Laboratory • Dow Chemical • Saint- Gobain	• China Academy of Building Research • Wall Insulation Committee in China • Association of Building Energy Efficiency • National Center for Quality Supervision Test of Building Energy Efficiency

Research Objective

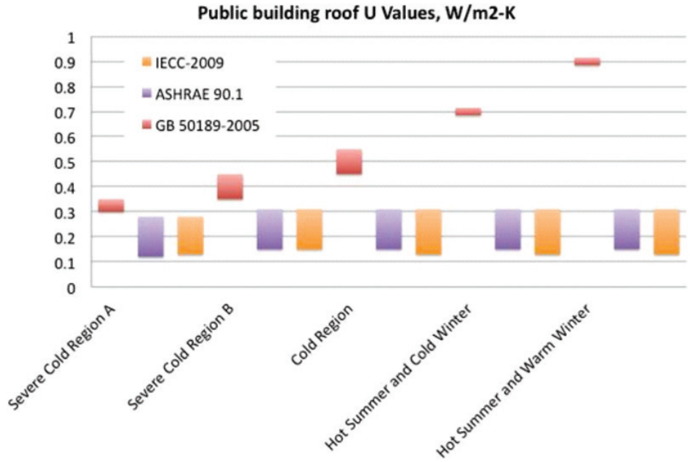
This project will identify and investigate candidate high-performance, fire-resistant building insulation technologies that meet the goal of building code compliance for exterior wall applications in green buildings in multiple climate zones.

Technical Approach

- Investigate candidate building insulation materials and systems that meet the goals of fire safety, cost effectiveness, and performance; noting that the target goals may be very different in one economy and location than another
  - This research will cover areas of thermal performance, including the changes that may occur over time due to exposure to the elements and moisture
- Investigate system issues that can affect performance, such as attachment systems and thermal breaks
  - Make direct laboratory and field measurements in some cases
- Use simulations to support the research and to explore the efficacy of systems in multiple climates where necessary
- Make maximum use of existing experimental data to increase the efficiency of the research effort in all cases
- Perform a market analysis to identify barriers and gaps preventing the widespread adoption of the best technologies in China
  - Identify best practices and lessons learned in both countries based on this survey

Recent Progress

- Completed a final joint research plan
- Completed the initial review and comparison of both U.S. and Chinese building codes and standards according to climate and building type



Public building roof U values for multiple climate zones

- Started reviewing Chinese building standards to select three critical materials for laboratory evaluation
- Reviewed retrofit and weatherization strategies for single- and multi-family residential buildings from a building envelope perspective

Expected Outcomes

- A comparison of Chinese and U.S. building codes
- A summary of all material property measurements
- A summary of all moisture simulations in multiple Chinese climates
- A report on wall insulation systems with high-fireproof performance for green buildings
- A report on wall insulation systems with low costs and high efficiency for use in rural areas
- A report on wall insulation systems with high-cost performance for use in concrete building reconstruction
- Identification of barriers and gaps preventing the widespread adoption of the best technologies in China

Cool Roofs

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Ronnen Levinson, Lawrence Berkeley National Laboratory	• GAO Yafeng, Chongqing University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory • Dow Chemical	• Chongqing University • Guangdong Provincial Academy of Building Research • China Icepower Energy Technology Co., Ltd

Research Objective

This project will quantify the potential energy and environmental benefits of cool roofs in China—especially carbon reduction—and help develop the infrastructure (including policies and rating systems) needed to promote the appropriate use of cool roofs.

Technical Approach

This project will investigate how cool roof technology may best be adapted to Chinese climates, urban design, and building practices. In particular, the research team will accomplish the following:

- Understand through technical exchange the state-of-the-art of materials, measurement techniques, and energy efficiency standards for cool roofs
- Quantify for Chinese climates, urban design, and building practices the benefits of cool roofs, such as energy savings, greenhouse gas reductions, urban cooling, improved air quality, and improved human health
- Assess for Chinese climates, urban design, and building practices the advantages and disadvantages of cool roofs when compared to traditional roofs
- Initiate the infrastructure needed to promote the appropriate use of cool roofs in China
- Design (and possibly initiate) a large-scale cool roof/cool pavement demonstration project in China

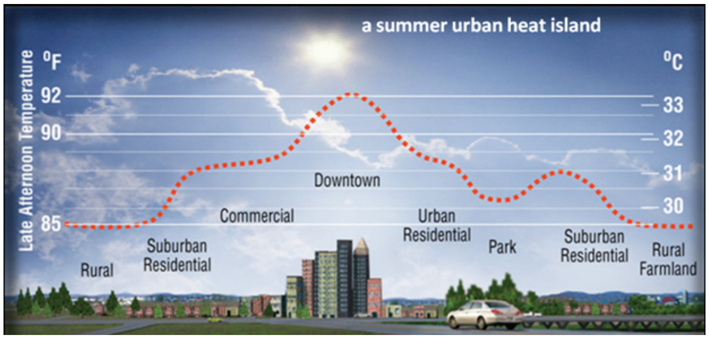


Illustration of the urban heat island effect

Recent Progress

- Completed a final joint research plan
- Trained Chinese researchers in the characterization of radioactive properties, modeling of cool roof benefits, and measurement of cool roof energy savings
- The U.S.-China Cool Roofs Working Group has developed and is executing a joint study to compare the benefits of cool roofs, garden roofs, and rooftop photovoltaics in China

Expected Outcomes

- A model code for cool roof incentives/requirements for local and/or national building energy efficiency standards and greenhouse gas reduction plans in China
- Measurement techniques needed to identify and market cool roofing products
- A large-scale cool roof/cool pavement demonstration project in China

Building Natural Ventilation and Cooling Technology Research

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Leon R. Glicksman, Massachusetts Institute of Technology	• LI Nan, Chongqing University • MA Xiaowen, Shenzhen Institute of Building Research
U.S. Partners	**China Partners**
• Massachusetts Institute of Technology	• Chongqing University • Shenzhen Institute of Building Research

Research Objective

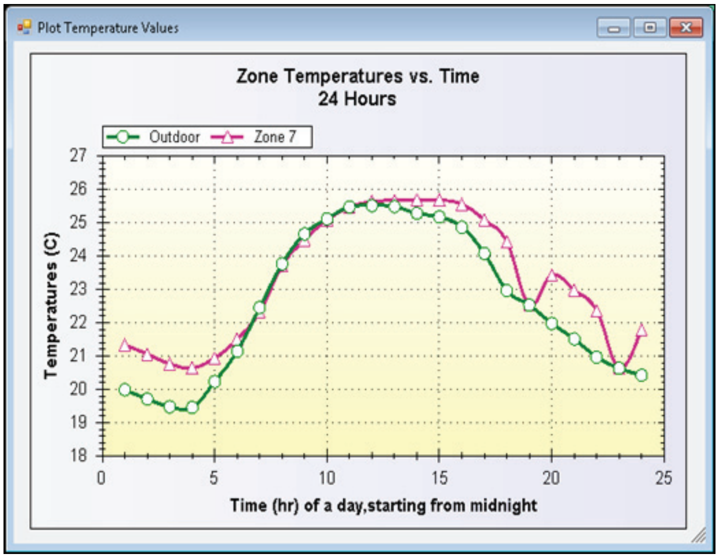
This project will determine the potential of natural ventilation to provide comfortable conditions that will reduce or eliminate the need for air conditioning over the important climatic zones in China and the United States. Implementing this technology in China, the United States, and other countries, and developing design tools that can be used in new or retrofit designs will promote the widespread application of this technology for energy efficiency and improved indoor climatic conditions.

Technical Approach

- Conduct a survey of natural ventilation in the United States and China and consider adaptable ventilation techniques—this will identify methods and systems of cooling by ventilation that are effective in different climate zones
- Conduct an analysis of the impacts of different ventilation systems on the indoor thermal environment
- Use an enhanced edition of MIT design programs using multi-node solutions that include buoyancy, transient thermal mass heat transfer, and wind-driven flows programs to design prototype natural ventilation cooling systems that will act as retrofit natural ventilation demonstrations in several existing MIT academic buildings and Chinese demonstrations
- Perform data analysis and design program development using existing computer resources at the respective universities
- Identify potential demonstration sites in important climatic zones first in the United States, and then in China during the next phase

Recent Progress

- Completed a final joint research plan
- Started making improvements to CoolVent, a design software for naturally ventilated buildings developed by MIT, so that it can be tailored for CERC BEE research
- Completed the comparison report of ventilation technology applications in China and the United States



Sample results obtained using CoolVent

Expected Outcomes

- Identification and design of natural ventilation demonstration buildings
- Application guidelines for natural ventilation techniques that are adaptable for different building types and climate zones
- An improved CoolVent program that can be used for the following:
  - Generating guidelines for successful design of naturally ventilated buildings
  - Evaluating the performance of demonstration buildings in relevant climate zones in both countries
  - Assisting the Shenzhen Institute of Building Research in the evaluation of a new construction project in China

Heat Reform Status Review

Cooperative Project

China Research Team Lead
• SONG Bo, China Academy of Building Research
China Partners
• China Academy of Building Research

Research Objective

This project aims to analyze China's heat metering policies, guidelines, technologies, and product development, as well as establish technical and policy frameworks for heat reform. It also seeks to promote heat metering policies and product marketing analysis.

Technical Approach

- Conduct surveys in key cities (i.e., Beijing, Gansu, Hebei, and Shenyang)
- Investigate product manufacturing processes
- Collect data
- Conduct demonstration projects

Recent Progress

- Initiated drafts of the following reports:
  - "Current Status Heat Metering"
  - "The Technology System for Heat Metering"
  - "Heat Metering Equipment"
  - "Policy and Market Mechanism on the Promotion of Heat Metering"
  - "The Billing System for Heat Metering"

Expected Outcomes

- Deliver the following reports:
  - "Current Status Heat Metering"
  - "The Technology System for Heat Metering"
  - "Heat Metering Equipment"
  - "Policy and Market Mechanism on the Promotion of Heat Metering"
  - "The Billing System for Heat Metering"

Heat Metering Product Testing and Standards

Cooperative Project

China Research Team Lead
• YANG Xubin, Leye Energy • ZOU Yu, China Academy of Building Research
China Partners
• Leye Energy • China Academy of Building Research

Research Objective

This project involves conducting a survey of international experience on heat metering standards, as well as developing and refining China's heat metering policies and product testing platforms.

Technical Approach

- Survey heat metering devices and testing platforms in Chinese provinces and companies, including Beijing, Hebei, Shandong, Ningxia, Xinjiang, Shandong and Weihai Tiangang, and Shandong Lichuang

Recent Progress

- Initiated a research report on heat metering product testing equipment
- Started work on a first draft of the standard "Technical Specifications on a Heat Metering Device Measuring Heat Flow and On/Off Time"
- Conducted work on the design of a heat metering products testing platform

Expected Outcomes

- A standard for technical specifications of a heat metering device measuring heat flow and on/off time
- A standard for a flow-temperature method for a heat distribution metering system design

Radiant Heating and Cooling Systems

Cooperative Project

China Research Team Lead
• TIAN Ze, Tianjin University • ZOU Yu, China Academy of Building Research
China Partners
• Tianjin University • China Academy of Building Research

Research Objective

This project involves radiant cooling and heating system adapativity research. Researchers will establish a radiant cooling and heating product performance testing method and testing procedures/standards, as well as develop a radiant cooling equipment testing platform.

Technical Approach

- Collect and compile information on relevant domestic and international standards
- Carry out a comparative analysis on testing methods
- Build the product testing platform (construction of the test chamber, water system, internal heat source simulation systems, data acquisition system, and terminal radiation cooling)
- Conduct a benchmark study of radiant cooling terminal unit products

Recent Progress

- Designed the testing platform
- Started drafting a report entitled "Feasibility Study of Radiant Heating and Cooling of HVAC Equipment and System in Buildings"

Expected Outcomes

- Patent 2011 No.20119844.X – large capacity convective radiant cooling terminal
- A national standard for a radiant cooling and heating device performance testing method

Evaporative Cooling Systems

Cooperative Project

China Research Team Lead
• YU Zhen, China Academy of Building Research • CAO Yang, Tsinghua University
China Partners
• China Academy of Building Research • Tsinghua University

Research Objective

This project involves summarizing the evaporative cooling system design methods used in dry climate zones by comparing the U.S. and Chinese project experience. Researchers will establish evaporative air conditioning and evaporative chiller design methods, as well as create a set of national or industrial codes and standards on evaporative chillers.

Technical Approach

- Survey different types of evaporative cooling systems and applications in different locations in China
- Compare the applicable areas where evaporative cooling can be used in China and the United States
- Compile national standards and engineering codes for evaporative chillers and cooling systems

Recent Progress

Drafted the following documents:

- National standard entitled "Evaporative Cooling Air Conditioning System"
- National technical guideline entitled "Evaporative Cooling Air Conditioning System Technical Guideline"
- Report entitled "Feasibility Study of the Evaporative Cooling Air Conditioning System"
- Report entitled "New Commercial Building HVAC System Commissioning and Operation Optimization Methods"

Expected Outcomes

- A national standard for evaporative cooling air conditioning systems
- A national technical guideline for evaporative cooling air conditioning system
- A report entitled "Feasibility Study of the Evaporative Cooling Air Conditioning System"
- A report entitled "New Commercial Building HVAC System Commissioning and Operation Optimization Methods"

Remote Monitoring and Controls of HVAC Systems

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Jack Wu, Honeywell • Jason Lo, Honeywell	• CAO Yong, China Academy of Building Research
U.S. Partners	**China Partners**
• Honeywell	• China Academy of Building Research

Research Objective

The overall objective is to develop an optimal operation management system using HVAC system operation data. Improved systems will be tested in separate projects conducted in China and the United States. The effectiveness of these systems will be verified through practice. The project has the following major objectives:

- Study data acquisition and transmission protocols and optimal operation models
- Develop a remote data transmission and an optimal operation management platform
- Select one or two projects in China to implement the optimal operation management system
- Validate performance with remote data transmission and the optimal operation management platform

Technical Approach

- Study improved technology for operation of HVAC systems
- Develop optimal operation management software that will be compatible with the current sensors and data communication protocol
- Develop remote monitoring demonstration projects that utilize expert operation management that optimizes the operating modes of the HVAC systems by connecting sensors and controllers from Honeywell and Schneider to the platform

Recent Progress

- Completed the onsite energy use survey of 40 public buildings in 10 different cities in China
- Established structure of the remote data transmission and optimal operation management platform

Expected Outcomes

- Research report on remote data transmission and an optimal operation management platform of HVAC systems' optimal operation
- One or two demonstration projects

HVAC Systems for Data Centers

Cooperative Project

China Research Team Lead
• YU Zhen, China Academy of Building Research
China Partners
• China Academy of Building Research

Research Objective

This project seeks to develop a methodology for energy efficiency data center design, including using CFD simulation, heat recovery technologies, and intelligent control systems in data centers.

Technical Approach

- Select a representative data center for a case study and compare data center design standards and energy efficiency standards between China and the United States
- Establish a data center energy consumption calculation model and conduct simulation analysis
- Conduct CFD simulation on data center design, optimization, operation, and energy efficiency

Recent Progress

- Collected one building's energy data and room conditions for analysis; identified areas for future optimization
- Drafted a guidebook on energy-efficient technology for HVACs in a large-scale data center

Expected Outcomes

- A comparison of energy efficiency design standards for data centers in China and the United States
- Improved understanding of climate conditions and their influence on data center design and performance
- Improved understanding of heat recovery technologies in data centers
- A guidebook on technologies and applications for energy-efficient HVAC systems in large data centers

Solar Thermal, PV Building Integration Research

Cooperative Project

China Research Team Lead
• RUAN Yingjun, Tongji University
China Partners
• Tongji University

Research Objective

This project seeks to understand PV and solar thermal technologies' performances in different climate zones and building types to evaluate the energy efficiency performance of PV and solar thermal systems.

Technical Approach

- Survey demonstration projects with PV and solar thermal applications for different building types and climate zones
- Conduct analysis of the market, policy, and engineering barriers for PV and solar thermal applications
- Analyze the adaptability of PV and solar thermal applications

Recent Progress

- Initiated solar thermal and PV market barriers analysis in China

Expected Outcomes

- Evaluation models to further understanding of buildings' solar energy utilization

Ground Source Heat Pump

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Xiaobing Liu, Oak Ridge National Laboratory	• CHEN Jinhua, Chongqing University • LV Shilei, Tianjin University • TAN Hongwei, Tongji University
U.S. Partners	**China Partners**
• Oak Ridge National Laboratory • ClimateMaster	• Chongqing University • Tianjin University • Tongji University • ENN Group Co., Ltd • Zhuhai Singyes Green Building Technology Co., Ltd • Suntech Power Holdings Co., Ltd • Zhejiang Shield Equipment Company Limited • Ever Source Science and Technology Development Co., Ltd • Himin Solar Energy Group Co., Ltd • Jiangsu Joint Hot and Cold Energy Saving Equipment Co., Ltd • Landsea Group Co., Ltd • Futian Air Conditioning Equipment Co., Ltd

Research Objective

Researchers will compare the status and trends of GSHP technology, as well as its applications, market, and related policies in both China and the United States to identify differences and areas in which each country can learn from each other. Through this investigation, researchers will gain a better understanding of the bottleneck that constrains the application of this technology in both countries. To address this bottleneck, researchers will develop methodologies, including protocols for data collection, a performance matrix, and evaluation algorithms as well as the tools necessary to assess the suitability of GSHP applications in various conditions in both countries. Researchers will also evaluate emerging system designs and equipment, such as the integrated heat pump and enhanced ground heat exchangers, to determine the potential of these emerging technologies in reducing the cost and/or improving the performance of GSHP systems.

Technical Approach

- Investigate the applications of GSHP (including the shallow surface ground source heat pump, the surface water and wastewater source heat pump, and the standing column well ground water heat pump) technology in both China and the United States to understand the status and trends of the technology; its applications, market, and related policies; the barriers preventing further development of the technology; and solutions to overcome the barriers
- Develop methodologies and tools to evaluate the suitability of GSHP applications at various conditions based on performance data collected from GSHP systems installed in both China and the United States
- Evaluate emerging technologies or products in both countries, including system configurations, ground coupling technologies, heat pump equipment, monitoring and control systems, and design software that may help break the cost barrier and/or further improve the efficiency of GSHP systems

Recent Progress

- Drafted preliminary reports on the status of GSHP applications in the United States and China
- Initiated field testing of emerging GHXs in collaboration with the Oklahoma Gas and Electric Company and ClimateMaster
- Surveyed available geological information that is useful for the design and installation of GHXs in the United States

Expected Outcomes

- A report on the comparative study of GSHP applications in China and the United States
- A full set of performance data of selected GSHP systems
- Recommended solutions for improving the performance and reducing the cost of GSHP systems
- A few new/underutilized GSHP system designs and controls, as well as equipment, that have been field tested and evaluated
- Modeling capabilities for new/underutilized GSHP system designs and controls, as well as equipment

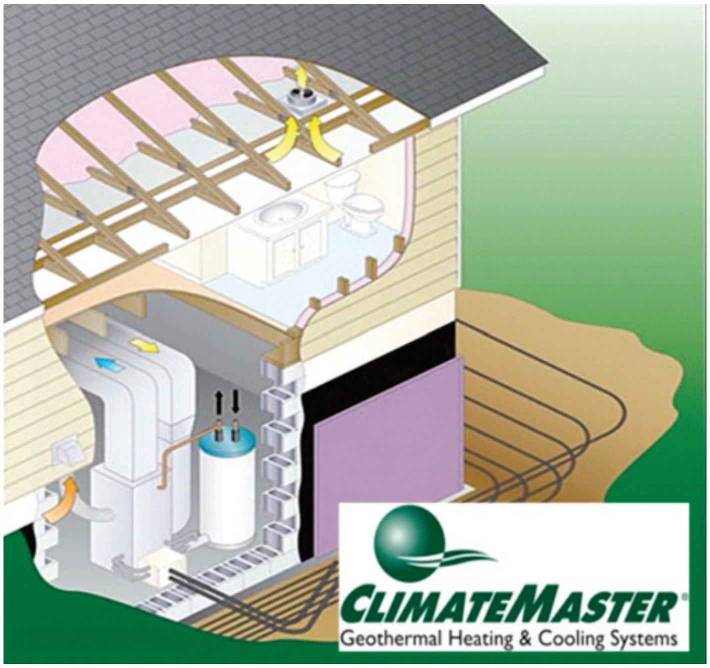


Illustration of integrated ground source heat pump

Standing Column Well Ground Source Heat Pump

Cooperative Project

China Research Team Lead
• ZHU Qingyu, China Academy of Building Research
China Partners
• China Academy of Building Research

Research Objective

This project aims to evaluate energy-efficient buildings in different climatic regions through the energy monitoring platform, analysis by synthesis, and establishing the energy-saving technology evaluation system function with diagnosis. The project team will perform research on overall methods for energy savings in integrated energy-efficient buildings, as well as select energy-efficient buildings in the Chongqing area or in the vicinity and perform case studies on these buildings.

Technical Approach

- Survey demonstration projects with surface and sewage water heat pumps for different building types and climate zones
- Conduct analysis on the market, policy, and engineering barriers for surface and sewage water heat pumps
- Analyze the adaptability of surface and sewage water heat pumps

Recent Progress

- Initiated analysis of surface and sewage water heat pump market barriers in China

Expected Outcomes

- Adaptability analysis of surface and sewage water heat pump technologies

New and Renewable Energy Technologies

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Chris Marnay, Lawrence Berkeley National Laboratory • Michael Stadler, Lawrence Berkeley National Laboratory • Nan Zhou, Lawrence Berkeley National Laboratory	• TAN Hongwei, Tongji University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory	• Tongji University

Research Objective

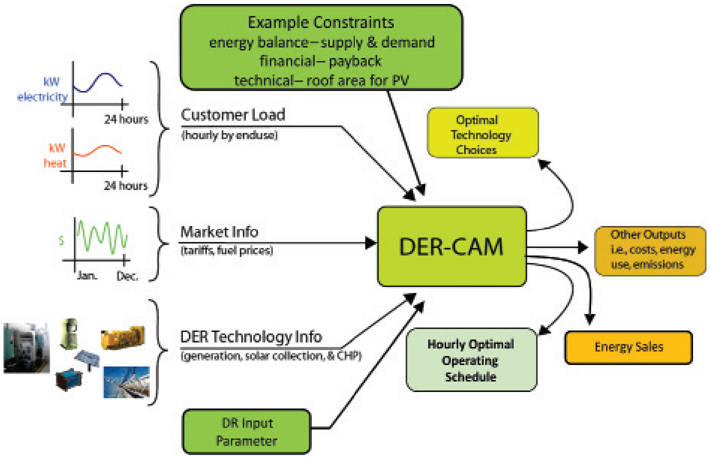
This project aims to develop a platform for adaptability evaluation and operation optimization of building energy systems involving renewable energy, including building a related database and optimization tools.

Technical Approach

- Set up an operation monitoring system and apply optimization tools to study existing building renewable energy systems (building-integrated photovoltaics/solar thermal/GSHP)
- Create an open-access website (Low Energy Building Optimization Web Service [WebOPT])
- Use the LBNL Distributed Energy Resources Customer Adoption Model (DER-CAM), which will provide rolling week-ahead optimum operating schedules for renewable and associated building energy systems to be executed in selected Tongji test buildings
  - A client application on a user computer sends relevant inputs to WebOPT via a mutually designed application-programming interface
  - WebOPT executes the optimization and returns a schedule that can be directly implemented in a building energy management and control system or other control method
- Integrate the database and tools to improve the platform and apply it to case studies

Recent Progress

- Completed a final joint research plan
- Completed analysis of the Shanghai shopping mall distributed energy optimization
- Completed the GSHP model, developed in DER-CAM
- Completed the bottleneck report on renewable energy technologies



DER-CAM schematic

Expected Outcomes

- An open-access website that takes into account building service requirements, available distributed energy resources technologies, possible efficiency and passive measures, the cost of electricity/natural gas and other fuels under complex tariffs, and available local energy harvesting opportunities
  - Low-energy or low-carbon building solutions will be returned in the form of an optimal technology installation choice and operation schedules, cost analyses, scenario comparisons, etc.
  - The service will simulate whole building and ultimately multi-building environments in the United States, China, and elsewhere

U.S.-China Energy Efficiency Building Comparison

Cooperative Project

China Research Team Lead
• ZHAO Jing, Tianjin University
China Partners
• Tianjin University

Research Objective

This project aims to compare the building energy efficiency differences between China and the United States as well as analyze the building energy consumption characteristics. The research objectives are the following:

- Investigate and compare energy structure, energy consumption, and technologies for high energy efficiency buildings in China and the United States
- Compare and analyze the building energy efficiency differences in similar climate conditions in both countries
- Summarize building energy characteristics and development in both countries

Technical Approach

- Collect advanced energy efficiency buildings' performance data
- Conduct comparative research analysis to contrast building energy performance in China and the United States under similar climate conditions

Recent Progress

- Investigated and analyzed 16 energy-efficient buildings in northeast, north, east, south, and southwest China
- Completed stage reports of the research on energy consumption and the integration of different energy-efficient technologies

Expected Outcomes

- A report entitled "Report on Energy Consumption of the Advanced Energy Efficient Buildings in Typical Areas of China and the United States"

Distributed Energy Supply System Integration

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Chris Marnay, Lawrence Berkeley National Laboratory • Nan Zhou, Lawrence Berkeley National Laboratory	• ZHU Neng, Tianjin University • TAN Hongwei, Tongji University
U.S. Partners	**China Partners**
• Lawrence Berkeley National Laboratory	• Tianjin University • Tongji University

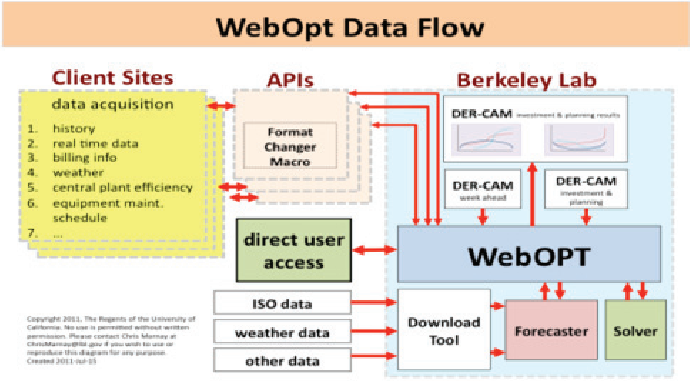
Objective

This project's goal is to create an open-access web service, the Low Energy Building Optimization Web Service (WebOPT), based on the LBNL Distributed Energy Resources Customer Adoption Model (DER-CAM). The service will permit optimization of building equipment selection and operation for building-scale zones, evaluation of the technology and operating schedules in existing buildings, and assessment of various candidate building types and climate zones for renewable and distributed energy adoption.

Initial work will focus on single building optimization. The longer term objective of this project is to develop capabilities in the United States and China for building operations optimization. The objective of this analysis is to provide a week-ahead optimum operating schedule for controllable building equipment.

Technical Approach

- Extend distributed energy resources optimization capabilities based on DER-CAM for executing equipment choice and operation optimization in order to provide optimizations to building operators in near real-time, including consideration of passive building and efficiency measures
- Use WebOPT to expand on existing DER-CAM capabilities linking to building management/data gathering systems used in China, and to expand to focus on conditions in China



WebOpt data flow

Recent Progress

- Demonstrated capability to run DER-CAM over the web from China
- Developed a heat pump module for DER-CAM capability
- Established a test data set for a Shanghai shopping mall
- Found optimal equipment for the test building for two climate zones

Expected Outcomes

- Operating improvements that are based on cost and/or carbon footprint minimization
- A fully integrated building optimization approach
- Software tools for researchers, engineers, and architects for evaluating the design and operating energy performance of integrated low-energy buildings

Green Buildings' Seasonal Efficiency Testing and Assessment

Cooperative Project

China Research Team Lead

- SONG Yehui, China Academy of Building Research

China Partners

- China Academy of Building Research

Research Objective

This project aims to compare international green building performance evaluation systems, as well as understand green building, four seasons applicable technologies by conducting investigations on different building types in typical climate zones.

Technical Approach

- Investigate green buildings, including offices, campus buildings, shopping malls, and residential buildings in cities such as Shenyang, Beijing, Shanghai, Ningbo, Chongqing, Nanjing, Shenzhen, and Tianjin
- Collect buildings' energy end-use data
- Identify applicable technologies suitable for buildings in different climate zones
- Compare international green building performance evaluation systems and summarize the evaluation systems' best practices for China

Recent Progress

- Collected energy performance data from several buildings, which increased understanding of building seasonal performance and energy intensity levels in different climate regions
- Drafted the following reports:
  - "International Green Building Evaluation System Analysis and Comparison"
  - "Green Building Energy Performance Evaluation Parameters Technical Manual"
  - "Tianjin University New Campus Green Building Design Guideline"

Expected Outcomes

- A report entitled "Report on Energy Consumption of the High Energy-Efficient Building in Typical Areas in China and the United States"

Energy Monitoring and Diagnosis Systems for Energy Efficiency Buildings

Cooperative Project

China Research Team Lead
• DING Yong, Chongqing University
China Partners
• Chongqing University

Research Objective

This project aims to evaluate energy-efficient buildings in different climatic regions through the energy monitoring platform, analysis by synthesis, and establishing the energy-saving technology evaluation system function with diagnosis. The project team will perform research on the overall merit of the energy-saving methods in integrated energy efficiency buildings, as well as select energy-efficient buildings in the Chongqing area or in the vicinity and conduct case studies on these buildings.

Technical Approach

- Obtain actual energy consumption data from selected demonstration projects
- Conduct a comprehensive evaluation of energy savings and CO_2 emissions reductions
- Complete a technical report on the application of evaluation systems that integrate high energy-efficient building technologies based on detection and computer simulation tools

Recent Progress

- Determined the targets to be monitored in a monitoring system

Expected Outcomes

- A report on the evaluation of methodologies for energy-efficient buildings

Rainwater Harvesting, Reclaimed Water Use, and Building Integration

Cooperative Project

China Research Team Lead
• SONG Guohua, Beijing University of Civil Engineering and Architecture
China Partners
• Beijing University of Civil Engineering and Architecture

Research Objective

This project aims to compare rainwater harvesting and grey water utilization technologies and practices with similar precipitation levels between the United States and China. The project also seeks to identify characteristics of effective building operations and evaluate the adaptation of technologies that have been used in Chinese demonstration projects with different precipitation levels to set up the rainwater and grey water utilization evaluation systems and platforms.

Technical Approach

- Survey rainwater collection and grey water utilization technologies in different Chinese climate regions and analyze rainwater and grey water data in buildings
- Develop an integrated software platform to monitor building rainwater and grey water utilization

Recent Progress

- Initiated comparisons of U.S. and Chinese water usage policies
- Sought understanding of the potential grey water use in buildings
- Conducted site visits to investigate several grey water utilization facilities in Beijing, Tianjin, Shenyang, and Chongqing
- Surveyed typical Chinese buildings' water usage and grey water production

Expected Outcomes

- A report entitled "China and U.S. Building Rain Water Utilization Policy Study"
- A grey water and rainwater evaluation software platform

Research, Development and Demonstration of New Municipal Lighting Systems

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Michael Siminovitch, California Lighting Technology Center, University of California, Davis	• HUANG Yuehui, Chinese Society for Urban Studies
U.S. Partners	**China Partners**
• California Lighting Technology Center, University of California, Davis	• Chinese Society for Urban Studies

Research Objective

This project will develop, integrate, and complete healthy, secure, high-efficiency, energy-saving, low-carbon, adaptive lighting technologies for a new municipal lighting system. The project will compare Chinese and U.S. lighting energy consumption data, establish a common experimental plan for measuring and assessing the high-performance lighting application, and produce collaborative demonstrations of new municipal lighting systems in select cities.

Technical Approach

- Establish a new municipal lighting system containing real-time monitoring, accurate measurement and analysis, and advanced controls and management by utilizing the modern infrastructure of digitalization and reliable communication technologies

Recent Progress

- Established agreements with municipal partners for the demonstration phase of the project (Peking, Shanghai, Shenzhen)
- Established working partnerships with lead universities and industry partners
- Established a cross effort with the codes and standards portion of the U.S.-China CERC

Expected Outcomes

- A comparison of Chinese and U.S. lighting energy consumption data
- A demonstration of a new municipal lighting system

Example of new municipal lighting system

Building Energy Commercialization and Market Research

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Barbara Finamore, Natural Resources Defense Council • William Nesmith, National Association of State Energy Officials	• HAO Bin, Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development
U.S. Partners	**China Partners**
• Natural Resources Defense Council • National Association of State Energy Officials	• Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development

Research Objective

This project will use different perspectives to review, compare, and analyze laws, regulations, and incentives designed to promote building energy efficiency in the United States and China and investigate how to formulate policy recommendations and measures to more effectively promote building energy efficiency in the two countries. The objective is to provide information and recommendations on achieving carbon reduction goals and energy efficiency through market and regulatory mechanisms that drive energy efficiency in existing and new buildings.

Technical Approach

For each of the three research tasks, the technical approach will include the following:

- Develop criteria to define the focus of the research
- Compile information and best practices from literature review and expert consultation
- Conduct analyses through an expert network and working group
- Utilize peer-to-peer interaction to process and refine analysis
- Make recommendations
- Lay the groundwork for governments to initiate and market pilot projects, where feasible and desirable

Recent Progress

- Completed a final joint research plan
- Completed initial research comparing U.S. and Chinese building efficiency labeling systems
- Initiated research on policy origins and applications of the U.S. systems
- Completed a draft matrix spreadsheet for comparing U.S. and Chinese labeling programs

Expected Outcomes

- A final report on the comparative analysis and research on building energy labeling systems in China and the United States
- Research reports on the feasibility of energy trading implementation and development strategies in China and the United States
- A research report on the comparative analysis of building energy efficiency policies

Participants at a joint workshop on Eco Labeling in Shenzhen in November 2011

Design Principles of Distributed Energy and Low-Carbon Communities

Cooperative Project

China Research Team Lead
• HAO Bin, Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development
China Partners
• Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development

Research Objective

This project seeks to understand the factors influencing community energy usage (electricity, cooling, and heating) and establish a low-carbon community load prediction method/model. It also aims to study the distributed energy system optimal configurations for Chinese building communities.

Technical Approach

- Analyze factors that may affect the energy demand of the district
- Build a model that predicts the heat and cooling energy load of the district
- Develop a design standard based on the analysis

Recent Progress

- Drafted the following reports:
    - "International Experience and Application of Distributed Energy System"
    - "Method of Building Energy Load of Low Carbon District Heat Prediction"

Expected Outcomes

- Deliver final reports entitled:
    - "International Experience and Application of Distributed Energy System"
    - "Method of Building Energy Load of Low Carbon District Heat Prediction"

Green Building Labels and Standards

Cooperative Project

China Research Team Lead
• LIU Gang, China Institute of Building Standard Design and Research
China Partners
• China Institute of Building Standard Design and Research

Research Objective

This project aims to understand green buildings' characteristics under different climate zones and building types based on existing green building standards. The project team will conduct research for a design standard for public buildings in the hot summer/cold winter climate zone and develop a draft standard for green building operation, management, and evaluation.

Technical Approach

- Divide the green building standard system into three levels: the target level, engineering level, and product level
  - Different standards are distributed in different levels to make the system more organized
  - The standard system also includes the consideration of different climate zones and different stages of the building design phases and performing phases

Recent Progress

- Determined the framework of green building systems for different climate zones and different building types
- Completed the outline of the standard on green building performance evaluation

Expected Outcomes

- A report on the green building standard systems study
- A standard on green building performance evaluation

Mechanisms to Promote Green Buildings

Cooperative Project

China Research Team Lead

- WANG Qingqin, Green Building Committee of Chinese Society for Urban Studies

China Partners

- Green Building Committee of Chinese Society for Urban Studies

Research Objective

This project seeks to develop a green campus and green shopping mall evaluation index system. It also aims to develop a green building promotion mechanism in different Chinese climate zones and regions.

Technical Approach

- Survey existing green building energy usage and other performance data
- Develop a green building code and a green building standard for shopping malls and university campuses

Recent Progress

- Completed a survey of green building labeling system promotion methods
- Drafted a version of the report "Green Shopping Mall Building Assessment Criteria and Methods"

Expected Outcomes

- Deliver final reports on the following:
  - Analysis of green building policies in China
  - Green building labeling systems and promotion methods
  - Green shopping mall building assessment criteria and methods
  - Green campus assessment criteria and methods

Characterization of Degradation Mechanisms in Li-Ion Batteries

Joint Project

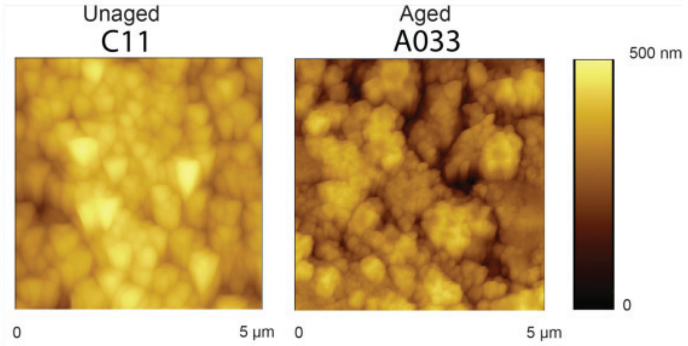
U.S. Research Team Lead	China Research Team Lead
• Bharat Bhushan, The Ohio State University • S. S. Babu, The Ohio State University • Raymond Cao, The Ohio State University • Marcello Canova, The Ohio State University • Terry Conlisk, The Ohio State University	• Feiyu Kang, Tsinghua University • Xiangming He, Tsinghua University • Borong Wu, Beijing Institute of Technology • Daobin Mu, Beijing Institute of Technology
U.S. Partners	**China Partners**
• The Ohio State University • Argonne National Laboratory • University of Michigan • Sandia National Laboratories • Oak Ridge National Laboratory	• Tsinghua University • Beijing Institute of Technology • Xiamen University

Research Objective

The objective of this project is to characterize the aging mechanisms of $LiFePO_4$ batteries on different scales and through varying techniques. The project team will improve the robustness of current-generation lithium-ion batteries via detailed characterization of degradation and aging mechanisms. Researchers will also combine direct atomistic measurements and density functional theory calculations to elucidate the mechanisms resulting in degradation of the solid-electrolyte interphase layer during lithium-ion battery cycling. Additionally, the team will develop computational tools and models as well as physical insights about the role of (1) phase transformations, (2) electrode-electrolyte interface evolution, and (3) electrode particle fracture on degradation of lithium-ion batteries.

Technical Approach

- Characterize cells using optical microscopy and acoustic emission. Nanoscale features in both cathode and anode will be examined using AFM-based methods
- Study electrode-electrolyte interactions, interfaces, and electrochemistry using a TEM platform combined with Electron Energy Loss Spectroscopy chemical identification
- Combine first-principles electronic structure methods with statistical mechanical tools and continuum-level simulations to develop a hierarchy of computational tools integrating various length scales to describe interface migration, electrode-electrolyte interface kinetics, and decohesion in electrode particles



AFM morphological studies of unaged and aged cells

Recent Progress

The team has acquired, installed, and calibrated new characterization instruments for AFM. The new AFM can provide atomic-scale resolution for electrochemistry and electrical measurements, and it comes with an environment chamber and allows for temperature control. For NDP, the components of the NDP facility—including the neutron collimator, bio-shield, vacuum chamber with silicon detectors, and the data acquisition system—have been installed.

AFM morphological studies of $LiFePO_4$ cathode materials harvested from unaged cells and cells aged to end-of-life under varied aging conditions were conducted. A sample set of images has been obtained that show the coarsening of particles. Similar studies were conducted using an SEM to obtain high-magnification images of cathode harvested from the same samples. The coarsening effects can also be observed in the SEM micrographs.

X-ray microtomography of $LiFePO_4$ cathode material has been performed on an unaged sample. The objective of the experiment was to calculate geometric factors, such as porosity, and establish quantitative evidence for coarsening observed in earlier experiments performed using the above-mentioned characterization techniques. Currently, the team is exploring methods to extract as much quantitative data from these images as possible (porosity, density, and phase composition).

Expected Outcomes

- Standardized Li-ion testing protocol
- Refined AFM techniques for ex-situ characterization of cathode, anode, and separator materials
- Developed and standardized approaches for in-situ characterization for thermal/mechanical degradation of battery materials
- Identification of key degradation mechanisms in lithium-ion battery cells
- Transfer of the above techniques to industrial participants in the United States and China

High Energy Density Battery Chemistries

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Don Siegel, University of Michigan • Anton Van der Ven, University of Michigan • Yang Shao-Horn, Massachusetts Institute of Technology	• Feng Wu, Beijing Institute of Technology • Borong Wu, Beijing Institute of Technology • Xiangming He, Tsinghua University
U.S. Partners	**China Partners**
• Argonne National Laboratory • University of Michigan • Massachusetts Institute of Technology	• Beijing Institute of Technology • Tsinghua University

Research Objective

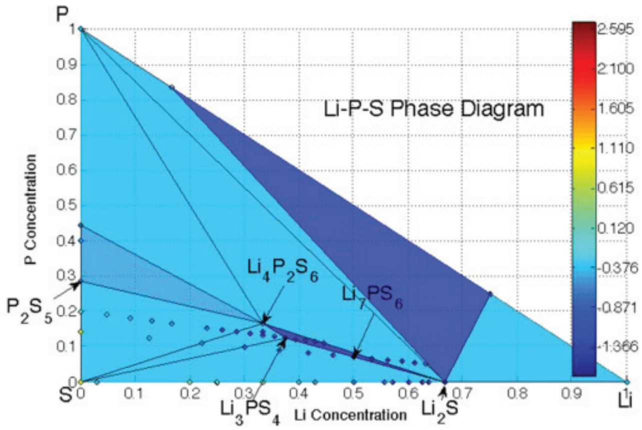
This project aims to identify mechanisms that limit the performance of lithium-air batteries, including high charging potentials, poor reversibility, and limited capacity/capacity fade. Researchers will develop computational tools and models to study and predict properties related to degradation and degradation mitigation in advanced batteries. This includes studying (1) phase transformations in electrodes, (2) lithium transport in solid electrolytes and solid electrolyte interphases, and (3) mechanisms of electrode fracture.

Technical Approach

- Use a combination of first-principles computational modeling, experimental electrochemical analyses, and highly precise materials characterization
- Elucidate mechanisms by which cathode catalysts improve the rates of discharge in lithium-air batteries and lower overpotentials for charging
- Elucidate reaction mechanisms between sulfur electrode and electrolyte and improve the electrochemical compatibility of materials

Recent Progress

Lithium-air batteries: The team has completed its study of the structure, composition, and electronic structure of lithium-oxygen surfaces. The results of this study were published in the *Journal of the American Chemical Society*, a top-tier chemistry journal. The thermodynamic stability and electronic structure of 40 surfaces of lithium peroxide and lithium oxide were characterized using first-principles calculations. As these compounds constitute potential discharge products in lithium-oxygen batteries, their surface properties are expected to play a key role in understanding electrochemical behavior in these systems.



Characterization of lithium peroxide and lithium oxide

Solid electrolytes: The team is investigating the structure of several compounds found in solid electrolytes in the lithium-phosphorus-sulfur ternary system, focusing primarily on compounds on the tie line between Li_2S-P_2S_5, as these have garnered the most interest experimentally.

Expected Outcomes

- Determination of optimal cathode catalyst compositions for lithium-air batteries
- Optimized sulfur electrode design and preparation, resulting in improved cycle life
- Next-generation lithium-ion batteries with improved energy density without sacrificing safety and performance

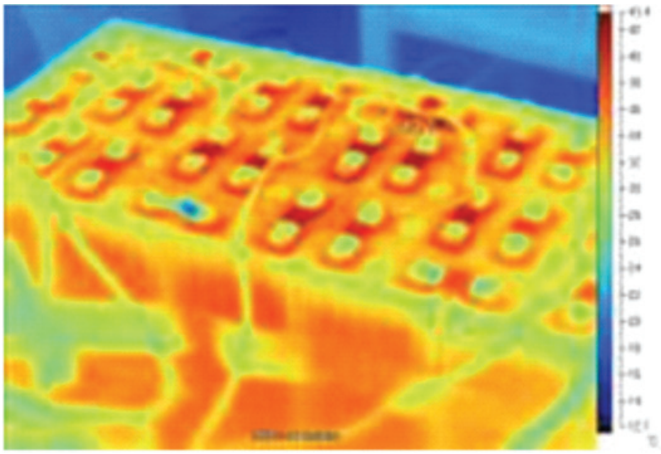
Modeling & Control of Li-Ion Batteries

Cooperative Project

China Research Team Lead
• Languang Lu, Tsinghua University
China Partners
• Tsinghua University

Research Objective

This project will determine the factors that most strongly impact the performance of primary and secondary batteries. It will provide a theoretical basis for battery pack integration (battery series-parallel connection, battery size, battery radiation, etc.) and battery management (thermal-electrical safety) through multi-scale and multifaceted modeling. Researchers will work to understand performance variation of the battery pack and provide a theoretical basis for the battery matching and cell-to-cell balancing through experiments, modeling, and simulation. This project will also work to establish the SOC, SOH, and SOF algorithms as well as reduce capacity variation and extend battery life by active balancing.



Temperature distribution of a lithium-ion battery cell

Technical Approach

- Adopt a multifactor orthogonal experiment and take the following factors into consideration: the operating temperature, charging cut-off voltage, discharging cut-off voltage, charging current rate, discharging current rate, and time
- Compare current integration, OCV, load-voltage, resistance, linear modeling, neural network modeling, and kalman filtering
- Develop an SOC and SOH algorithm for various types of batteries
- Use Monte Carlo techniques to estimate battery variation and cell-to-cell balancing and resistor dissipation, or use non-resistor dissipation to balance the battery

Recent Progress

Researchers conducted an energy-type battery durability test and identified the main factors affecting battery life. The coupling between each factor and the coupling strength calculation method has been studied, and the energy life forecast model has been established, reaching an error control within 15%. The temperature distribution of a lithium-ion battery cell and a battery pack were modeled, which can reveal the different inside and outside temperatures of the battery—the battery temperature consistency—and provide a reference for battery management. An energy-type battery performance test and analysis for an SOC and SOF algorithm was carried out, including capacity, resistance, and OCV. A preliminary study on the consistency of the battery and the basic phenomenon of battery pack inconsistency, including impedance spectroscopy, discharge voltage, charge voltage, and charge temperature inconsistencies, was completed. It was found that the distribution is not normal after the uniformity degrades. Researchers also completed the first round of active battery balancing hardware design.

Expected Outcomes

- Lifetime system models
- SOC, SOH, and SOF estimation algorithms
- Cell balancing control scheme

Energy Conversion

Joint Project

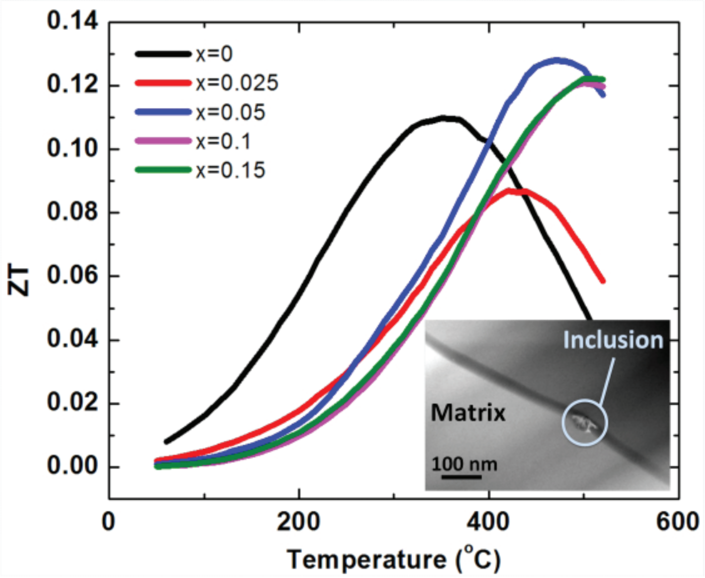
U.S. Research Team Lead	China Research Team Lead
• Ctirad Uher, University of Michigan • Rachel Goldman, University of Michigan • Kevin Pipe, University of Michigan • Joseph Heremans, The Ohio State University • Hsin Wang, Oak Ridge National Laboratory • Doug Medlin, Sandia National Laboratories	• Xinfeng Tang, Wuhan University of Technology • Han Li, Wuhan University of Technology
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University • Oak Ridge National Laboratory • Sandia National Laboratories	• Wuhan University of Technology

Research Objective

This project will convert waste heat of cars and trucks into electricity; develop new, highly efficient TE materials with ZT = 1.5~2; develop synthesis methods for bulk nanocomposites; and develop materials that are inexpensive, environmentally green, and mechanically robust.

Technical Approach

- Seek a high Seebeck coefficient and high electrical conductivity while simultaneously attempting to lower the lattice thermal conductivity to the level of amorphous materials



Transport characterization of tin-doped cobalt triantimonide samples

Recent Progress

The researchers have completed transport characterization of the initial batch of tin-doped $CoSb_3$ samples measured over a broad temperature range from 4 K to 800 K (UM and OSU). Transport data have been analyzed (UM and OSU) and researchers observed a signature of the presence of a band resonant level due to tin lying deep in the valence band. A decision was made to synthesize a new batch of samples with a smaller content of tin. Gallium-doped and indium-doped $CoSb_3$ samples were also synthesized and characterized to determine if resonant levels are closer to the valence band edge and hence more effective at increasing ZT. Additional synthesis at lower dopant concentrations is currently in progress (UM).

SNL carried out the initial structural characterization of tin-doped $CoSb_3$ using high-resolution transmission electron microscopy. UM and WUT also carried out transport studies of $Mg_{2(1+z)}Si_{0.5-y}Sn_{0.5}Sb_y$ to establish the influence of overstoichiometry of magnesium on thermoelectric properties. Transport measurements were further started on gallium-doped $Mg_2Si_{0.3}Sn_{0.7}$ samples to explore and improve p-type forms of these solid solutions.

Work began on the development of a new Seebeck probe technique for nanoscale profiling of TE properties. An appropriate existing UVH-STM and the required modifications were identified. Work is currently underway to add a relay to convert the STM tunneling current to a voltage and to add an external heater capable of providing a 5–30 K temperature difference between tip and sample.

Expected Outcomes

- Development of high-performance p-type skutterudites
- Development of low-resistance contact to skutterudites
- Development of low-resistance contact to $Mg_2Si_{1-x}Sn_x$
- TE module based on skutterudites
- TE module based on $Mg_2Si_{1-x}Sn_x$

Biofuel Chemistry & Physics

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Blake Simmons, Joint BioEnergy Institute • Craig Taatjes, Sandia National Laboratories • Angela Violi, University of Michigan	• Zhen Huang, Shanghai Jiao Tong University
U.S. Partners	**China Partners**
• University of Michigan • Sandia National Laboratories • Joint BioEnergy Institute	• Shanghai Jiao Tong University

Research Objective

This project will develop chemical kinetic mechanisms for novel bio-derived fuels, consisting of molecules such as farnesene (e.g., 3, 7, 11-trimethyl-1, 3, 6, 10-dodecatetraene), and a database of chemical and physical properties of various fuels and their blends.

Technical Approach

- Analyze and synthesize biofuels
    - Classes of compounds of interest are alkanes, branched alkanes, and esters as representatives of gasoline, diesel, and biodiesel molecules
- Characterize new fuels through the auto-ignition of fuels
- Determine physical properties of biofuels through atomization, fuel-air mixing, and the injection rate of bio-fuels in low-temperature combustion mode to investigate the effects of chemical/physical properties
- Select new molecules

Recent Progress

By law, national laboratories cannot commence funded research without research contracts in place. Due to contracting and intellectual properties delays, the contracts are now being finalized and work is planned to commence in the second quarter of 2012.

Expected Outcomes

- Sequential rounds of fuel targets and other advanced biofuels include molecules produced from biomass via biochemical and thermochemical conversion
- A database of the chemical behavior of target fuels in simple combustion reactors
- A compilation of the physical properties of fuel targets
- Potential new molecules, including C8-12 fatty acid ethyl esters and alcohols

Chemical and Physical Models for Novel Fuels

Cooperative Project

U.S. Research Team Lead

- Angela Violi, University of Michigan

U.S. Partners

- University of Michigan

Research Objective

This project will develop chemical kinetic mechanisms for novel bio-derived fuels consisting of molecules such as Farnesene (e.g., 3, 7, 11-trimethyl-1, 3, 6, 10-dodecatetraene), as well as identify future fuel molecules in collaboration with the Joint BioEnergy Institute, including biofuels from biomass.

Technical Approach

- Potential energy surfaces of main reaction pathways of fuel molecules
- Reaction rates for fuel pathways
- Thermochemical properties of fuels
- Assemble the kinetic mechanisms and validate them with experimental data
- Analyze discrepancies between models and experiments

Recent Progress

Efforts have focused on establishing a base for mechanism development, which includes evaluating and comparing existing kinetic models for n-heptane, as well as building a database of experimental data to evaluate future improvements. Concurrent to studying existing mechanisms qualitatively and quantitatively, the team has identified areas that suggest improvements can be made to the models, namely in the chemistry of small carbon species.

The team has continued to apply this analysis to cyclohexane and alkylcyclohexanes due to the presence of the cyclohexane structure in novel biodiesel molecules, such as bisabolane. Understanding the chemistry of the ring structure will be integral to the development of mechanisms for bisabolane. The team has identified mechanisms for cyclohexane and methylcyclohexane, as well as mechanisms for alkylcyclohexane chemistry contained in JetSurF 2.0. Work continues in identifying and synthesizing other modeling efforts of these molecules, including ab initio, experimental, or other reaction pathway studies.

Expected Outcomes

- Discovery of the reactivity of classes of compounds and potential energy and reaction rates
- Reaction mechanisms for heptane, octane, and methylbutanoate as main representatives of diesel, gasoline, and biodiesel
- Validation of mechanisms versus experiments

In-Cylinder Biofuel Combustion Behavior

Joint Project

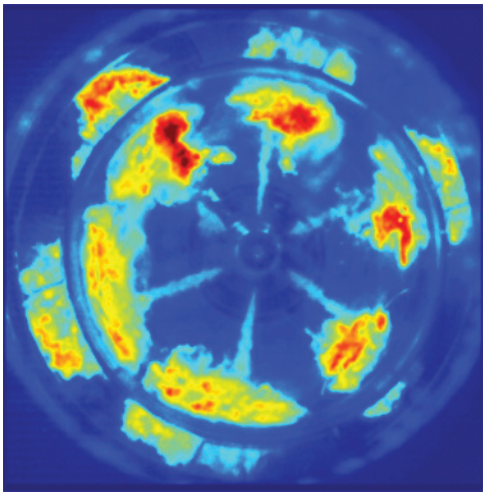
U.S. Research Team Lead	China Research Team Lead
• Dennis Assanis, University of Michigan • Dennis Siebers, Sandia National Laboratories	• Zhen Huang, Shanghai Jiao Tong University • Mingfa Yao, Tianjin University
U.S. Partners	**China Partners**
• Stony Brook University/ University of Michigan • Sandia National Laboratories	• Shanghai Jiao Tong University • Tianjin University

Research Objective

Characterize the performance, combustion, and emissions of biofuels and their blends under advanced diesel and novel combustion modes, including LTC.

Technical Approach

- Develop efficient CFD tools for incorporation of detailed chemical kinetics for biofuels (SBU/UM)
- Validate the modeling analysis with optical engine and chamber data (SBU/UM, SNL, SJTU)
- Investigate engine fuel economy, performance, and emissions under operation with different biofuels and blends (SJTU, SBU/UM)



Recent Progress

This project will commence when Professor Asssanis has established a laboratory setup at SBU.

Expected Outcomes

- An understanding of advanced and novel combustion modes and a validated CFD model with coupled chemistry to guide engine design for operation with biofuels
- Optimizing engine calibration and operating tolerance for a clean and highly efficient combustion mode using various biofuels and blends

Integrated Powertrain and Aftertreatment System Control for Clean Vehicles

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Junmin Wang, The Ohio State University • Jing Sun, University of Michigan • Jim Parks, Oak Ridge National Laboratory	• Fuyuan Yang, Tsinghua University • Min Xu, Shanghai Jiao Tong University
U.S. Partners	**China Partners**
• The Ohio State University • University of Michigan • Oak Ridge National Laboratory	• Tsinghua University • Shanghai Jiao Tong University

Research Objective

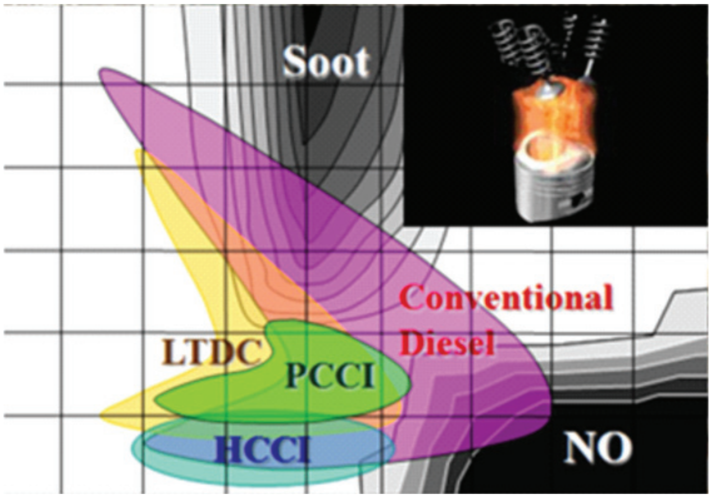
This project will develop synergistically integrated, systematic, optimal, and generalizable control methodologies for clean vehicle powertrain systems. Such control systems will optimally coordinate fuel property estimation, advanced combustion modes, exhaust aftertreatment systems, and hybrid powertrains to enable maximization of the energy efficiency and emission reduction potentials of clean vehicles.

Technical Approach

- Develop a fuel property adaptive engine control strategy (OSU, UM, ORNL)
- Establish transient control methods for advanced combustion engines with consideration for fuel property uncertainties (OSU, UM, ORNL, THU)
- Create an integrated and optimal engine, aftertreatment, and hybrid powertrain control methods for clean vehicles (OSU, UM, ORNL, THU)
- Complete a comparative study on the requirements for clean vehicle powertrain control methods for different markets (OSU, UM, THU, SJTU)

Recent Progress

Researchers have designed and validated observations estimating the temperatures and oxygen concentrations across diesel oxidation catalyst-diesel particulate filters, developed direct fuel property estimation methods based on measurable engine input-output signals, and started an initial literature review and preliminary study on integrated engine and aftertreatment system control methodologies.



Temperatures and oxygen concentrations across diesel oxidation catalyst-diesel particulate filters

Expected Outcomes

- Adaptive engine control methodologies for maintaining optimal engine performance with uncertainties in fuels and consideration of advanced combustion modes
- Framework for integrated engine, aftertreatment, and hybrid powertrain system control method development
- An understanding of the powertrain control system design requirements for different configurations and markets

Development of APU-Oriented Boxer Engine

Cooperative Project

China Research Team Lead
• Min Xu, Shanghai Jiao Tong University
China Partners
• Shanghai Jiao Tong University

Research Objective

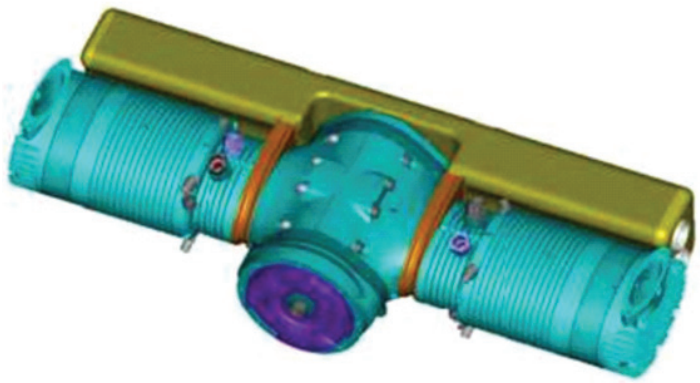
The objective of this project is to develop a small displacement boxer engine that will be used as a special APU engine. The boxer engine has the advantages of a low fuel consumption rate, high NVH performance, a light weight, and an extremely compact structure. A prototype boxer engine will ultimately be provided.

Technical Approach

- Develop a small displacement boxer engine as an APU-specific engine by:
  - Designing an engine concept
  - Analyzing subsystems
  - Designing a CAD component
  - Validating CAE
  - Optimizing structure
  - Testing

Recent Progress

A benchmark of three engines was completed for this project to study the design of the two-stroke engine, horizontally opposed engines, direct-injection engines; a 0.5-liter unmanned aerial vehicle two-stroke engine; a two-cylinder horizontally opposed engine from BMW; and a gasoline direct-injection engine from Volkswagen 1.4TSI. Dozens of patents about horizontally opposed boxer engines were analyzed to consider the intellectual property problem. According to the project plan, the concept design and layout design of the APU-oriented boxer engine are finished. The geometric three-dimensional design of intake/exhaust systems, cooling systems, crankshaft systems, lubrication systems, and combustion systems have been completed, including the one-dimensional performance and NVH simulation. Detailed three-dimensional CFD and structure simulation work is ongoing.



Displacement boxer engine

Expected Outcomes

- CAD model of a boxer engine and a CAE analysis report
- Prototype boxer engine
- Testing report and an optimized engine control strategy

APU-Oriented High Efficiency and Clean Combustion System

Cooperative Project

China Research Team Lead
• Jianxin Wang, Tsinghua University
China Partners
• Tsinghua University

Research Objective

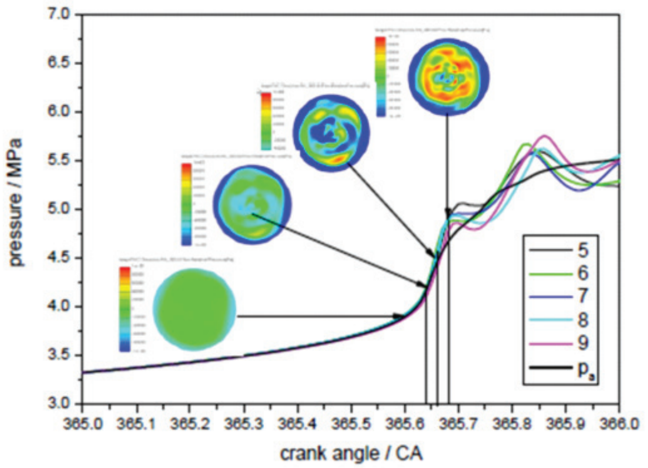
The objective of this project is to reveal the ignition mechanism of an HCCI under a high compression ratio and diluted atmosphere. The principle obtained from the research will be used for the high-efficiency and clean combustion system design of APU engines. HCCI is the ideal combustion mode with low fuel consumption and low emissions. For gasoline engines, HCCI is realized under a high compression ratio and diluted atmosphere.

Technical Approach

- Conduct research on engine knocking mechanisms on an optical engine to search for reasonable knocking suppression approaches for HCCI combustion under a high compression ratio and a diluted atmosphere
- Apply fuel-specific ignition strategies based on unique fuel ignition performance
- Use a high compression ratio, high internal EGR rate, and intake/exhaust temperature control for high-octane-number fuel
- Use dual fuel and dual fuel injection systems for high-cetane-number fuel, ignition, and combustion ratio control

Recent Progress

A new method of engine knock suppression using stratified stoichiometric mixture was proposed for GDI engines at high loads. A three-dimensional CFD model for GDI engines was established based on the integration of CFD with chemistry (KIVA-CHEMKIN) with a G-equation code. Researchers also numerically simulated GDI engine combustion processes, including intake, spray, compression, ignition, combustion, and emissions. Two-ignition models were developed for super-knock simulation in a heavy boosted, downsized GDI engine, and the flame characteristics and pressure wave during knocking were investigated using the enhanced model. In 2011, the project was granted invention patent CN101338694: "A combustion method and combustion system of stratified stiochiometric mixture in gasoline direction injection engines."



Enhanced model of flame characteristics and pressure wave during knocking

Expected Outcomes

- New proposed knock suppression methods
- Design schemes and control criteria of two highly efficient, low-emission combustion systems

Integration and Systematic Control of APU System

Cooperative Project

U.S. Research Team Lead	China Research Team Lead
• Junmin Wang, The Ohio State University	• Fuyuan Yang, Tsinghua University
U.S. Partners	**China Partners**
• The Ohio State University	• Tsinghua University

Research Objective

The objective of the project is to develop the control technology of low-temperature combustion APU to reduce engine emissions substantially. An optimized APU system construction and control strategy are key approaches to improving APU efficiency and reducing vehicle emissions. LTC in part engine load conditions will take advantage of the high-pressure common rail systems' EGR and variable nozzle turbine.

Technical Approach

The management tasks include engine control, communication management, and coordination control of the engine and generator. By establishing dynamic simulation models, different system energy management strategies will be tested.

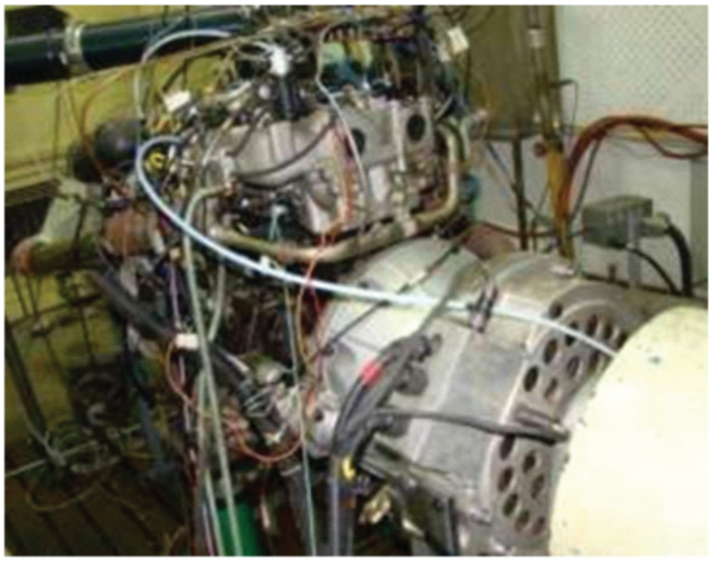
The technical approach includes:

- Develop compression ignition for other operating regimes
- Apply in-cylinder, pressure-based, closed loop combustion control to improve combustion stability and reduce cycle-to-cycle and cylinder-to-cylinder variation
- Propose a switching control method between LTC mode and compressed ignition combustion mode for smooth engine combustion mode conversion
- Develop an integrated, microcontroller-based, real-time controller for APU management

Recent Progress

The team published several papers, including:

- *Optimal Feedback Control with in-Cylinder Pressure Sensor under Engine Start Conditions* by Ying Huang, Fuyuan Yang, Minggao Ouyang, Lin Chen, and Xueqing Yang
- *Dynamic Control for Low-Cost Auxiliary Power Unit of Electric Bus* by X. Wu, F. Yang, L. Lu, and M. Ouyang
- *Development of TPU Kernel Code for Diesel Engine* by Cheng Fang, Jin Li, and Fuyuan Yang



Emission and fuel economy performance test bed with PCCI-CI and CI + ISG motor

The team applied for several patents, including:

- Kexun Zhang, Fuyuan Yang, et al. "One Type of EGR & VGT System and Its Control Method," China patent applying no.: 201110094588.8
- Minggao Ouyang, Fuyuan Yang, et al."One Type of APU and Its Control Method for a Serial Hybrid Bus," China patent applying no.: 201110130472.5
- Kexun Zhang, Fuyuan Yang, et al. "One Balancing Method and System for Electronic Diesel Engine," China patent applying no.: 201110116306.X

Expected Outcomes

- An integrated APU control system
- An APU prototype and automatic switching control method between HCCI and compressed ignition
- A coordination control algorithm of an engine and generator and an optimized APU energy management strategy

Efficient and High Power Density Electric Powertrain

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Heath Hofmann, University of Michigan • Longya Xu, The Ohio State University	• Wen Xuhui, Chinese Academy of Sciences • Tao Fan, Chinese Academy of Sciences
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University • Oak Ridge National Laboratory	• Chinese Academy of Sciences • Jing-Jin Electric • Hunan CSR Electric Vehicle Company

Research Objective

This project will develop innovative and optimized electric machines and power electronic converters to achieve an electrified powertrain with significantly higher power density and efficiency. It will also work to develop a computationally efficient steady-state magnetoquasistatic finite element solver to be used in the analysis of both synchronous and asynchronous alternating current electric machines.

Technical Approach

- Develop computationally efficient yet accurate finite element models of electric machines so that concurrent electric drive and powertrain designs become possible
- Develop innovative electric machine topologies that are integrated with vehicle transmission
- Complete life cycle evaluation studies of clean vehicle technologies
- Reduce loss so that air cooling becomes feasible, dramatically increasing the power density of the overall system

A sample motor of armouphous metal material, 20 kW

Recent Progress

Researchers have developed a user interface for the steady-state FEA solver for synchronous machines developed in early 2011 that is based in the frequency domain. The team also improved the speed of an existing time-domain-based steady-state solver through the use of higher-order numerical integration techniques. They initiated design and computer simulations of the EVTT, the proposed high-efficiency powertrain for hybrid electrical and electrical traction and transmission applications. The team established the EVTT system block diagram that can identify the six major operation modes that are significant to in-hybrid electrical and electrical vehicle applications. Researchers obtained benchmarked reports of two types of amorphous alloy permanent magnet machines; however, the maximum efficiency and continuous power rating is not as high as supposed; the reason for that is being explored. The team researched and simulated the measurement method of an amorphous alloy sample and component from a material supplier using a conventional soft magnetic measurement device. The measurement approach has been proposed and summarized, but the data was not obtained due to intellectual property issues. The team also developed a first step of a mathematic model for an amorphous alloy machine that takes into account magnetic saturation.

The team published the following: Pries, J.; Hofmann, H. “Harmonic balance FEA of synchronous machines using a traveling-wave airgap model,” in proceedings of the 2011 Institute of Electrical and Electronics Engineers Vehicle Power and Propulsion Conference, Sept. 6–9, 2011. It also submitted the following Chinese patent: CN 201010121452, “An innovative amorphous alloy machine with radial magnetic flux structure.”

A sample armouphous metal material motor was built based on a vehicular electric motor with rated speed of 2,500 rpm, rated power of 20 kW, and rated power density of 1 kW/kg. Through the optimization method, the volume of the sample motor can be reduced by 32% while maintaining the output performance.

Expected Outcomes

- Computationally efficient two- and three-dimensional finite element solvers for synchronous/asynchronous machines
- Analysis of a combination of clean vehicle technologies to evaluate life cycle performance
- A novel EVTT design by real-time hardware-in-loop valuation
- Design rules aiming at trade-offs between harmonic core losses and harmonic power for saturated amorphous alloy permanent magnet machines

Control and Optimization of Distributed Vehicle Network

Cooperative Project

China Research Team Lead

- Chengliang Yin, Shanghai Jiao Tong University
- Jianqiu Li, Tsinghua University
- Zaimin Zhong, Tongji University
- Liangfei Xu, Tsinghua University

China Partners

- Shanghai Jiao Tong University
- Tsinghua University
- Tongji University

Research Objective

The objective of this project is to study optimized distributed vehicle network systems for electrified vehicles.

Technical Approach

- Define the architecture of network control systems for electrified vehicles
- Study the requirements and optimized vehicle network designs to ensure smooth operations of future electrified vehicles
- Complete two design case studies: (1) efficient transient torque control for coordinated driving and (2) braking and optimal power management through drive cycle recognition

Recent Progress

Researchers have designed four new components of a network control system, including (1) a new generation of vehicle controller units using a 32-bit microcontrller MPC5644 as a digital core, (2) an automatic code generation technical platform based on real-time workshops, (3) a custom driver blockset MPC5644 toolbox for Simulink Library, and (4) a prototype system for FlexRay communication. The team has also designed an optimal coordinated torque control among multiple sources to achieve better drivability, performance, and emissions. A real-time optimal energy management strategy with four discharging stages of battery for a range-extended electric vehicle was also established. In addition, a novel energy management strategy based on multi-sensor data fusion technology was proposed. With this technology, the road slope and vehicle mass can be estimated online, providing possibilities for real-time optimization.

Expected Outcomes

- New distributed vehicle network architecture
- Demonstration of a new vehicle network on test vehicles
- Demonstration of a coordinated torque control algorithm on test vehicles
- Demonstration of new power management concepts on test vehicles

System Integration Technologies for Improved Efficiency, Safety, Reliability and NVH Performance

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Huei Peng, University of Michigan • Jing Sun, University of Michigan • Giorgio Rizzoni, The Ohio State University • Simona Onori, The Ohio State University	• Jianqiu Li, Tsinghua University • Geng Yang, Tsinghua University • Zhichao Hou, Tsinghua University • Yu Zhu, Shanghai Jiao Tong University • Chengliang Yin, Shanghai Jiao Tong University • Li Chen, Shanghai Jiao Tong University • Liangfei Xu, Tsinghua University
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University	• Tsinghua University

Research Objective

The objective of this project is to develop models, designs, and control tools for system integration, diagnosis of electric powertrains, and NVH performance analysis. The ultimate goal is to enable rapid powertrain designs and integration that are reliable and achieve optimal efficiency.

Technical Approach

- Develop a systematic, top-down design and analysis environment for conceptual design, analysis, and evaluation
- Develop a modular and hierarchical model structure to facilitate configuration optimization and trade-off analysis
- Combine model-based investigation and experimental verification for intelligent diagnosis and prognosis
- Perform NVH and safety analysis for components and subsystems

Recent Progress

The project team has completed the analysis of power-split hybrid vehicles with one-planetary gear. They used the dynamic programming technique to obtain best-execution results, which identified potential design candidates (configurations with different number of clutches and operating modes). The conceptual "Prius+" and "Volt-" vehicles were designed and analyzed for their fuel economy performance compared with the original designs. Key subsystems for diagnosis/prognosis were modeled, and key faults were studied and modeled. Researchers analyzed the clean vehicle system using hazard analysis and defined the solution requirements for diagnostics and prognostics. The failure mode and effects analysis and fault tree analysis for electrified vehicles was completed with a focus on powertrain subsystems, including high-voltage battery systems and electric machines. The automatic modeling, configuration searching, and control algorithm were programmed and can be used to explore other single planetary-gear power-split hybrid vehicles. The fundamental dynamic programming codes were also finished. The China team also started research on the optimal configuration of electrified city buses and conducted an early survey about the Chinese market.

Expected Outcomes

- Models and modeling tools for components and systems
- Software tools for efficient analysis, design, and optimization of electrified powertrain systems
- Model-based fault diagnostic/prognostics methods and software tool development for plug-in hybrid electric vehicle systems/subsystems
    - NVH models and analysis of electric machines
    - High-voltage safety system model, design, and demonstration on test vehicles

Warm Forming Processes for Al and Mg Alloys

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Jun Ni, University of Michigan • Shuhuai Lan, University of Michigan	• Xinming Lai, Shanghai Jiao Tong University
U.S. Partners	**China Partners**
• University of Michigan	• Shanghai Jiao Tong University

Research Objective

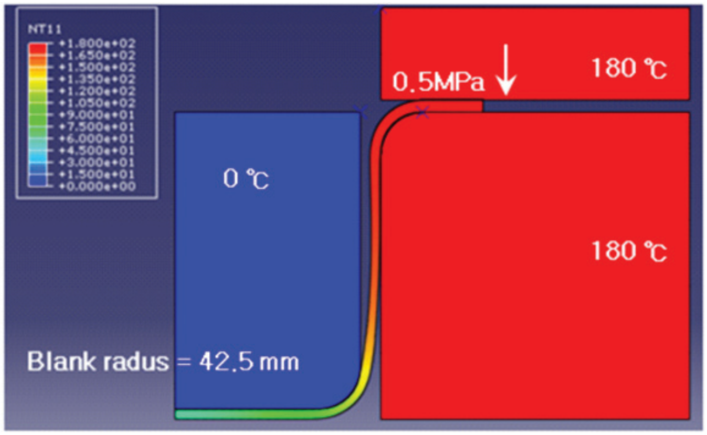
This project seeks to develop low-cost, high-quality, robust, and economical warm forming processes that can dramatically improve the formability of aluminum and magnesium alloys.

Technical Approach

- Study the material flow behavior of lightweight sheet alloys in the warm forming processes
- Utilize and refine numerical finite element modeling for predicting the formability limit of lightweight alloys
- Develop methods to ensure robust tuning of process parameters (e.g., temperature distribution, forming speed, and blank holding pressure)

Recent Progress

Current work sought to introduce simultaneous heating and cooling treatment on a blank sheet to obtain a temperature gradient with a relatively larger temperature gap. A design of an experiments sensitivity study was carried out to investigate the parameter influence on the limiting drawing ratio, which demonstrates that a larger temperature gap on the blank from the region that is in contact with the die and blank holder to the region that is in contact with the punch induces a larger LDR. Further numerical study will occur to investigate the effect of the temperature gradient. An optimization algorithm will be adopted for optimal temperature gradient analysis. FEA models are developed to simulate the deep warm drawing process of aluminum sheet alloys for the study of the limiting drawing ratio.



Experiments sensitivity study investigating the parameter influence on the limiting drawing ratio

Expected Outcomes

- Larger numbers of parts will be made out of these lightweight materials
- Improved ductility and limiting drawing ratio through warm or hot forming of lightweight materials

Bulk Forming Processes of Lightweight Materials

Cooperative Project

U.S. Research Team Lead	China Research Team Lead
• Jun Ni, University of Michigan • Glenn Daehn, The Ohio State University	• Baicheng Liu, Tsinghua University • Xinmin Lai, Shanghai Jiao Tong University
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University	• Shanghai Jiao Tong University • Tsinghua University

Research Objective

This project will develop high-quality and economical bulk forming processes for lightweight materials, including aluminum and magnesium alloys, carbon-fiber composites, and high-strength steel and ultra-high-strength steel.

Technical Approach

- Complete a high-vacuum die casting and squeeze casting of aluminum and magnesium alloys (THU), including porosity reduction and brittleness improvement, with close collaboration on warm forming research at UM
- Pursue continuous compression molding of carbon-reinforced polymer composites (OSU) using inexpensive feedstock resign design
- Achieve the stamping of high-strength steel and ultra-high-strength steel (SJTU) as well as formability improvement and robust parameter tuning

Recent Progress

A high-vacuum die casting system was developed and the influences of process parameters, valves, and pistons on the cavity pressure before injection were investigated, along with the influences of process parameters on mechanical properties of AM60B alloy under vacuum and non-vacuum conditions. A cellular automaton model was developed to simulate the microstructure evolution of magnesium alloy during the cold-chamber, high-pressure die casting process. The nucleation and crystal growth of the primary phases in the melt in the shot sleeve and in the die cavity were taken into account. An experimental station for squeeze casting process and a technique for measuring the temperature inside the casting during the pressurized solidification process were developed. A quantitative model for describing the crystal nucleation in pressurized solidification of aluminum alloys and a preliminary microstructure model for simulating the primary dendrite evolution in squeeze casting of aluminum alloy A356 were developed.

Expected Outcomes

- Experimental data of desirable windows of process parameters
- An experimentally validated simulation model of the processes
- Part design rules for higher part quality and lower production costs
- Optimized process designs
- New out-of-autoclave processes for high-strength carbon-fiber thermoplastic composites

Joining in Multi-Material Vehicle Structures

Cooperative Project

U.S. Research Team Lead	China Research Team Lead
• Glenn Daehn, The Ohio State University	• Xinmin Lai, Shanghai Jiao Tong University • Qing Zhou, Tsinghua University
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University • Oak Ridge National Laboratory	• Shanghai Jiao Tong University • Tsinghua University

Research Objective

This project will develop new methods to join dissimilar materials into vehicle structures based on conformal interference joints. Such joints can be inexpensively produced, have the full strength of the parent components, and can join arbitrary materials to a ductile metal. The key objectives of this work are to develop the design science that is required for high-velocity deformation and design of the electromagnetic actuators as well as the geometry of the mating pair. Past research has demonstrated the ability to assemble dissimilar metals and produce joints with the 100% joint efficiency in tension and torsion. This work will extend this by considering systems with an insulating interlayer to defeat possible galvanic corrosion, considering strength and design aspects.

Technical Approach

- Improve strength and reduce cracks in electro-plastic, self-piercing rivets (SJTU/ORNL)
- Improve strength and tool life of ultrasonic-assisted friction stir welding (UM)
- Design standard equipment for various geometry and materials using conformal interference joining (OSU)
- Reduce distortion due to thermal expansion mismatch using adhesive bonding (UM)

Recent Progress

Progress has focused on designing a process that can enable joining of a multi-material front end where high-strength steel and low-density materials may meet. At the process design level, this project is concerned with developing joint geometries that can give high long-term strength and can accommodate a dielectric insulating barrier between two dissimilar metals. At the vehicle level, this project has been developing strategies for joints at the location where the lower window, A-pillar, and beltline meet.

Specific activities include progress on a comprehensive review of the literature to enable optimal design and consideration of high strain rate properties of polymeric materials and experimental design to measure properties of these materials as a barrier material. An invention disclosure is under development for corrosion-resistant dissimilar metal joints.

Expected Outcomes

- Experimental data of desirable windows of process parameters
- Experimentally validated simulation models of the process
- Part design rules for higher assembly quality and lower production costs
- Optimized process design

Multi-Material Lightweight Body Subsystem and Vehicle Optimization

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Kazuhiro Saitou, University of Michigan	• Qing Zhou, Tsinghua University • Dafeng Jin, Tsinghua University • Xinmin Lai, Shanghai Jiao Tong University • Zhigang Yang, Tongji University
U.S. Partners	**China Partners**
• University of Michigan	• Tsinghua University • Shanghai Jiao Tong University • Tongji University

Research Objective

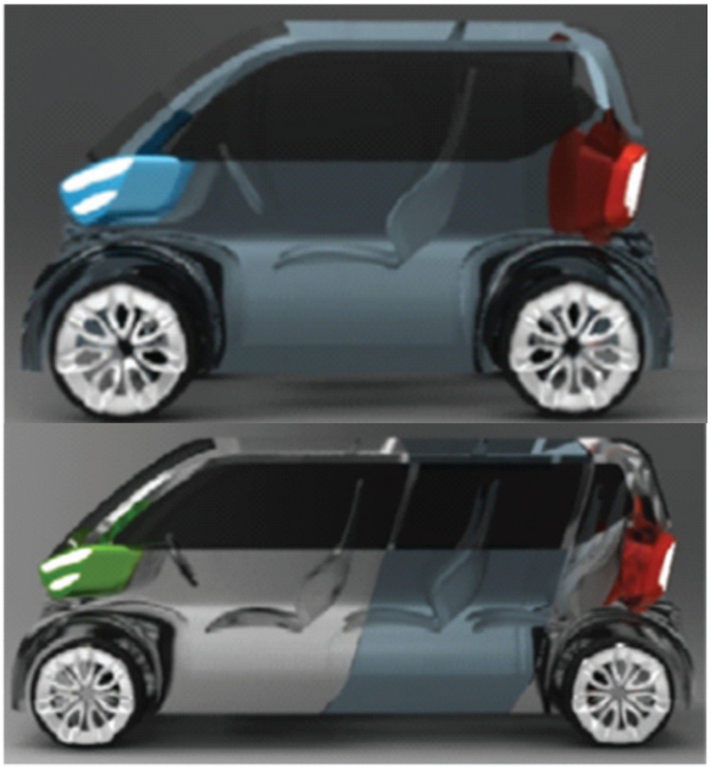
This project seeks to develop a methodology for economically integrating components made of lightweight materials in vehicle body structures with maximum weight reduction benefits.

Technical Approach

- Explore innovative load paths, crash modes, and component layouts to prevent failure and control deformation (THU)
- Model lightweight material processes variations to predict assembly dimensional variations (SJTU)
- Model constraints for lightweight material processes to create evaluation criteria for manufacturing and assembly (UM)
- Optimize body subsystems (UM, THU, SJTU, and Tongji University)

Recent Progress

The team agreed upon two-fold target applications: a clean-slate concept for a small, lightweight EV (China) and evolutionary introduction of lightweight parts to a midsize vehicle (United States). Researchers from THU completed exterior styling design of a small, lightweight EV and started construction on an FE model of a small, lightweight EV. Tongji team members built a CAE model to analysis CFD performance and to conduct the optimization work. The UM team conducted crash analysis and a multi-material design of experiments study of a baseline midsize vehicle, as well as demonstrated the incorporation of new part geometries into a public FE model of a midsize vehicle. SJTU researchers simulated propagation of assembly variation in heterogeneous material auto body parts.

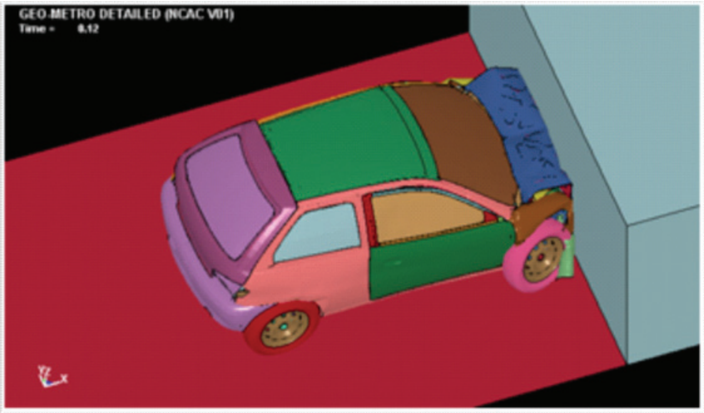


Exterior styling design of a small lightweight EV (top) and its scaled variant (bottom).

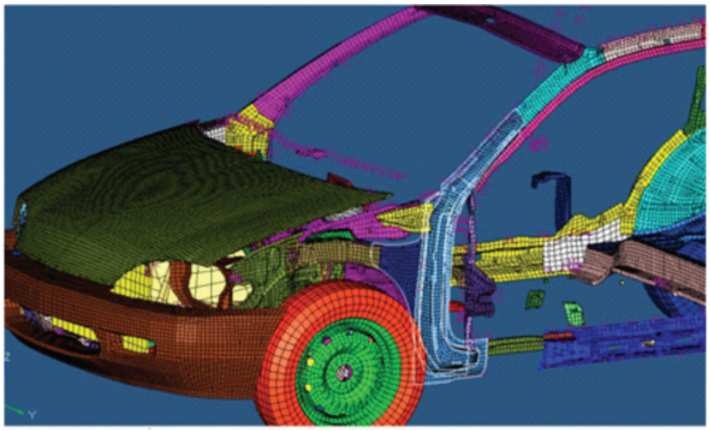
In 2012, the team plans to (1) establish a scalable platform for small EV body families (THU), (2) determine evaluation criteria for a small EV body (THU), (3) integrate exterior and BIW FE models of a small EV body and conduct crash simulation (THU), (4) obtain optimal weld locations in heterogeneous material auto body parts to minimize assembly variation (SJTU), (5) design a composite A-pillar to be incorporated in a public FE model of a midsized vehicle (UM), and (6) characterize the crash performance and geometric constraints of composite-to-steel joints (UM).

Expected Outcomes

- Architecture and material selection strategy for crashworthiness
- A dimensional variation model
- Manufacturing and assembly measurements
- Optimization methods



Full-frontal crash simulation of 2004 Geo Metro after 130 ms



Geo Metro FE model with a modified A-pillar

System Architecture and Interaction Mechanism of ITS Based V2G

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Giorgio Rizzoni, The Ohio State University • Umit Ozguner, The Ohio State University	• Keqiang Li, Tsinghua University • Hongbin Sun, Tsinghua University
U.S. Partners	**China Partners**
• The Ohio State University	• Tsinghua University

Research Objective

This project will investigate the mechanism of the energy interaction between transportation systems and power systems. Researchers will develop an integrated communication platform and information exchange mechanism of an ITS-based V2G system.

Technical Approach

- Investigate the mechanism of the energy interaction between transportation systems and power systems by simulating charging behaviors based on EV owners' naturalistic driving patterns from historical traffic surveys
- Study the interaction between the energy flow of EVs and the grid based on the real-time traffic information from ITS
- Develop a communication platform integrating EVs, ITS, power grid, and road infrastructure, as well as the communication interfaces between each other
    - Develop a multisource information integration technology for an ITS-based V2G system from this platform

Recent Progress

Researchers designed the architecture of an SCGS. The SCGS was presented to guide the driver charging to the best charging station for the sake of the EV and the grid, as well as to forecast the charging load. The SCGS is based on ITS, which can gather the spatial and energy information of the EVs and use them to interact with the power system. A charging load model was established to predict the total charging power of a number of EVs. The sample of the charging schedules of many EVs is essential when developing the model, which is not presently available. Therefore, an algorithm was developed to simulate the sample based on the real-world travel data set National Household Travel Survey. A linear model was built that describes the relationship between the charging load and some crucial factors associated with the charging, such as battery capacity, charging rate, penetration level of the charging infrastructures, and charging preferences. This allows the impact of the factors on the charging load to be investigated.

As important parts of Projects 2 and 3, assessment methods of EVs' charging impacts have been studied. A new method based on GPF that includes transmission and distribution grids—defined as the GPF-based method—was proposed to improve the evaluation results. Compared with conventional methods, the GPF method reflects the power and voltage distribution of both transmission and distribution power systems, namely global power systems. Thus, the evaluation results seem more reliable. A master-slaver iteration solving method makes GPF-based evaluation highly efficiency and requires little information exchanged.

The coordination of EV and wind energy has been investigated, including large-scale wind farms that have been integrated into the transmission grid in China. The concepts of wind-EV coordination on the transmission grid side have been proposed, and a corresponding hierarchy and distributed control frameworks have been designed. From the case studies, it was proven that the emissions and abandoned wind energy would both be reduced greatly under coordination. With promising carbon capture power plants assumed to be integrated in the future, an investigation into the coordination of EV and those plants has commenced.

Expected Outcomes

- A naturalistic driving model for EV owners that is characteristic of the temporal and spatial distribution of the energy flow of EVs
- An integrated communication platform of ITS-based V2G systems and EVs' on-board real-time information management systems

Approaches for the Assessment of the PEV Impact on the Grid Based on Naturalistic Driving Patterns and Temporal Distribution Information

Cooperative Project

U.S. Research Team Lead	China Research Team Lead
• Tae-Kyung Lee, University of Michigan • Zoran Filipi, University of Michigan	• Hongbin Sun, Tsinghua University • Qinglia Guo, Tsinghua University
U.S. Partners	**China Partners**
• University of Michigan • The Ohio State University	• Tsinghua University

Research Objective

This project will develop a modeling and analysis framework for assessing the relationship between real-world driving/charging cycles and the impact of PEV charging on the grid. Based on this analysis, the researchers will propose optimal charging policies. Specific objectives include (1) constructing a naturalistic driving cycle set that represents naturalistic driving patterns dependent on driving distances, (2) developing a computationally efficient approach for the assessment of the PHEV impact on the grid, and (3) developing a temporal distribution model that captures the relationships between departure and arrival time distributions.

Future plans include extending the proposed driving cycle analysis and synthesis approaches to the China side. An additional goal for discussion with the U.S.-China Clean Energy Research Center leadership is driving pattern recognition for PHEV control.

Technical Approach

- Develop driving/charging cycle synthesis and construct representative synthetic driving/charging cycle sets
- Model daily driving temporal distributions
- Create multilevel simulation approaches to capture PEV behavior under naturalistic driving conditions

Recent Progress

The team has developed an approach to characterize PHEV behavior relevant to assessing the impact on the grid based on naturalistic driving information. The proposed approach enables a computationally efficient technique for dealing with large data sets to predict the load on the grid due to PHEVs. Analysis of the distribution of the departure/arrival time and rest time, based on real-world data at the key locations, is ongoing. This complements driving and energy consumption modeling by adding temporal information. The results for typical locations such as residences, work, large businesses, and small businesses are examined. Researchers are pursuing a methodology capable of correlating departure times with arrival times to facilitate assessment of charging opportunities during daily missions.

Expected Outcomes

- An analysis of real-world driving and charging data
- Due to the departure of Prof. Zoran Filipi, this project will no longer continue

Vehicle Grid Integration

Vehicle-Grid System Modeling for Technology Deployment

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Ramteen Sioshansi, The Ohio State University • Vincenzo Marano, The Ohio State University • Ian Hiskens, University of Michigan	• Hongbin Sun, Tsinghua University • Qinlai Guo, Tsinghua University
U.S. Partners	**China Partners**
• The Ohio State University • University of Michigan	• Tsinghua University

Research Objective

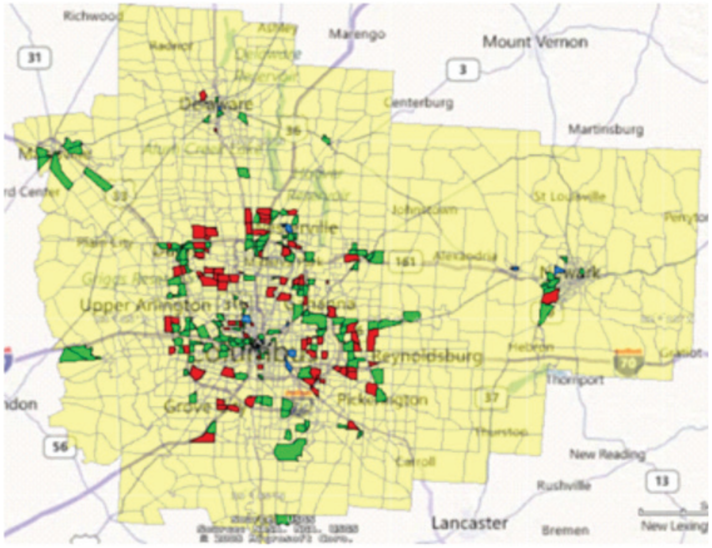
This project will assess the impact on the electric grid of a large-scale deployment of PEVs as well as develop a technology roadmap and policy recommendations for accelerating EV deployment in the United States and China.

Technical Approach

- Adopt technology and economic models to determine what demographic characteristics contribute to PEV adoption and any resulting clustering of PEVs and charging loads within the distribution networks
- Simulate PEV driving and grid-connection behavior
- Develop technology and policy roadmaps showing the results of these modeling efforts

Recent Progress

Researchers have developed and refined a PEV charging infrastructure location optimization model and conducted extensive case studies examining optimal PEV charging infrastructure locations in the central Ohio region. They have also developed a simulation model of interactions between PEV driving patterns and charging patterns and charging infrastructure. An initial literature survey of technology adoption models is in progress, along with the initial development of PEV adoption modeling frameworks.



Plug-in electric vehicle charging infrastructure location optimization model

Expected Outcomes

- A flexible model to optimize the location of public charging infrastructure in different geographic regions
- Technology adoption models that capture the effects of demographics and social and spatial networks on PEV adoption
- An analysis of PEV impacts on the electric grid, at both the local distribution and bulk power system levels
- Policy recommendations for cohesive development and deployment of PEV technologies and related infrastructures in the United States and China
- Optimized control strategies for vehicle-electricity grid interactions, including centralized and market-based control approaches

Control Strategies for Vehicle-Grid Integration

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Ian Hiskens, University of Michigan	• Hongbin Sung, Tsinghua University • Qinglai Guo, Tsinghua University
U.S. Partners	**China Partners**
• University of Michigan	• Tsinghua University

Research Objective

This project seeks to develop control strategies that mitigate distribution-level issues associated with high penetrations of PEVs and allow PEVs to provide operational services to the wider grid. A range of operational services will be considered, including peak reduction, regulation, spinning reserve, and the use of load-to-track variability in renewable generation.

Technical Approach

- Investigate both price-based and direct control strategies
- Explore hierarchical and distributed control architectures
- Investigate the impact of communication delays and develop methods of alleviating delay-induced performance degradation

Recent Progress

Researchers developed a centralized scheduling scheme for coordinating the charging of a heterogeneous PEV fleet to prevent overheating of distribution transformers. Through the use of a dual-ascent method, the project derived an iterative, incentive-based, and non-centralized implementation of the PEV charging algorithm, which achieves optimality upon convergence. This distributed open-loop control solution has been embedded in a predictive control scheme to introduce robustness against exogenous disturbances.

In prior work, the project developed an iterative scheme in which each PEV minimized its own charging cost, and the collective behavior of the PEV population converged to a Nash equilibrium that optimally filled the overnight demand valley. The project made two important extensions. First, it relaxed the requirement that a common energy price function be used over all time instants—now the energy price function can vary with time. Second, it introduced a terminal cost that allows PEVs to price in a cost for not fully charging the battery.

The team aims to establish a communications platform for implementing control algorithms that are distributed across PEVs and other control devices. A Zigbee-based network for establishing connectivity between multiple devices is under development.

Expected Outcomes

- Distribution-level control of PEV charging
- Control strategies for grid operational services
- Decentralized control strategies for PEV charging
- An understanding of the impact of non-ideal communications on the coordination of a PEV charging load
- Distributed energy management systems that integrate smart charging, metering, billing, and power-system supervision
- Coordination of renewable generation

EV Intelligent Control Based on Vehicle-Grid-Infrastructure Interaction

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Junmin Wang, The Ohio State University	• Keqiang Li, Tsinghua University • Yugong Luo, Tsinghua University
U.S. Partners	**China Partners**
• The Ohio State University	• Tsinghua University

Research Objective

Transportation with large-scale vehicles can be managed and programmed through the coordination of ITS, smart grid, and large-scale EVs. Based on this idea, the goal of this project is to design a control system to maintain a comprehensive performance of large-scale EV traffic safety, fuel efficiency, and ride comfort, including EV path planning and driver assistance control based on Vehicle-Grid-Road safety and efficiency coordination. In addition, EV charging guidance based on vehicle-charging station communication, while considering the constraints of driving destination and charging demand, will be developed.

Technical Approach

- Develop EV on-board information management systems based on man-machine interfaces by setting up standard communication platforms of large-scale EVs, road infrastructure, ITS centers, and power grids
- Optimize the EV driving path considering both traffic safety and EV fuel economy, while designing a driver assistance system utilizing MPC theory, taking into account EV longitudinal/lateral safety, fuel economy, and ride comfort
- Develop autonomous guidance in the charging station using a hierarchical control with three layers:
    - EV trajectory based on vehicle-road safety and the target of charging spot
    - Longitudinal and lateral force distribution algorithms
    - Coordinated control algorithm of the driving/ braking/steering system

Recent Progress

The integrated information communication platform of EV-traffic-grid has been investigated. The coordination communication system uses DSRC and is composed of large-scale EVs, road infrastructure, charging stations, ITS centers, and grid management centers. Local wireless communications and cable communications, based on the hardware platform and basic interacted information, have also been defined. Specifically concerning the communications of vehicle-to-vehicle and vehicle-to-infrastructure, DSRC communication protocol, which regulates the data exchange process of the application program and the communications management platform of the vehicle-net-road system, has been designed. This protocol consists of basic communication parameters, message types, and data structures, and maintains the connections, physical connection process, handshake process, and disconnect process.

Expected Outcomes

- A communications platform integrating EVs, ITS, power grid and road infrastructure
- An EV path planning algorithm with regard to traffic safety and EV efficiency
- Multi-objective coordinated control algorithms based on EV safety, fuel economy, and ride comfort
- EV charging guidance and the EV global chassis control algorithms

Adaptive Battery Management System On and Off the Grid

Joint Project

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U.S. Partners	**China Partners**
• University of Michigan	• Shanghai Jiao Tong University • Chinese Academy of Sciences

Research Objective

This project seeks to develop intelligent monitoring (while driving), diagnosis/prognosis, and conditioning (while connected with the grid) strategies to improve the reliability, performance, and life cycle of battery systems. The current research objective is to develop a design framework and computational algorithms that are capable of performing parameter identification without measuring individual cells' current or with a minimum required number of current sensors.

Technical Approach

- Improve understanding of the aging and environmental effects on batteries' cycle performance
- Identify and adapt the energy management strategies to the changing characteristics of the battery systems

Recent Progress

To separate the difficulty of modeling OCV from the identification of the rest of the parameters in the individual cell model, efforts have been directed to applying a high pass filter to the terminal voltage and investigating the performance of identification with the filtered data. More specific research activities include the (1) evaluation of the performance of parameter identification with a high pass filter incorporated, (2) study of the effects of filter parameters on identification results, and (3) investigation of noise effects on the algorithm.

Preliminary studies show that, with certain charging profiles, the identification algorithm with filtered data can achieve good parameter convergence accuracy. The effect of noise may be reduced by adjusting the charging profile.

For the first-order resistor-capacitor model adopted, the project has focused on the sensitivity functions of the system output with respect to the change of the two resistances and one capacitance. The following activities are performed to understand these sensitivity functions and their correlation with the input charging profiles: (1) formulate parameter sensitivity functions analytically and verify the validity of the formulation through simulations, (2) identify the correlation between parameter sensitivity and input current profile by analytical study and simulation (i.e., how different charging profiles affect the amplitude of each sensitivity function), and (3) investigate the effects of different parameterization.

Simulation results show that different charging profiles can result in different amplitudes of sensitivity functions. The project is in the process of capitalizing this property to identify the desired characteristics of parametric models and charging profiles.

Expected Outcomes

- Parametric models of battery system states of health and states of charge for system identification
- Sensitivity analysis of battery system performance to charging/discharging patterns
- Simulation models of grid power systems with aggregated PHEV/PEV loads
- Algorithms and methodologies for online battery system identification and adaptation
- Recommendations on battery system prognosis and diagnosis strategy
- Validation and verification of an integrated off-grid/on-grid battery power management system

Set CV Technology Energy Efficiency and GHG Targets and Evaluate Life Cycle Performance

Joint Project

U.S. Research Team Lead	China Research Team Lead
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U.S. Partners	**China Partners**
• University of Michigan • Argonne National Laboratory • Ford Motor Company • General Motors • Delphi	• Tsinghua University

Research Objective

The objective of this project is to define energy efficiency and GHG targets for CV technologies and systems as well as evaluate their performance from a life cycle perspective. Different combinations of CV technologies will be evaluated from a life cycle perspective such that greenhouse gases are minimized while vehicle performance is maintained.

Technical Approach

- Develop life cycle models that encompass both the vehicle life cycle (materials production, manufacturing, operation, and end-of-life management) and the total fuel cycles (upstream and combustion) based on vehicle simulation
- Apply target cascading to identify best combinations of vehicle technologies that minimize GHG emissions subject to constraints of cost, performance, and other consumer attributes

Recent Progress

This project has developed a lightweight PHEV model to evaluate life cycle benefits of material substitutions and engine/battery downsizing (colleagues at ANL provided input on Autonomie and the potential for GREET integration). A method to systematically evaluate different vehicle technologies for vehicles with different levels of hybridization and biofuel gasoline blend has been developed. This method expands upon the previous method presented at a CERC-CVC conference to include a design of experiment in Autonomie. The design of experiment can then be optimized to find the vehicle, technology, and fuel combination with the lowest lifecycle GHG. Analysis was also conducted to study the life cycle fuel consumption and carbon reduction of PEV based on a different grid mix in China.

Expected Outcomes

- Technology performance targets that are in line with energy security and carbon reduction strategies
- Life cycle models for key CV and fuel technologies (developed in other thrusts)
- An analysis of a combination of CV and fuel technologies to evaluate optimal life cycle performance
- Life cycle models of CV fuel systems for diverse driving and fueling patterns

Fuel Mix Strategies and Constraints

Cooperative Project

U.S. Research Team Lead

- Ming Xu, University of Michigan
- Dawn Manlay, Sandia National Laboratories

U.S. Partners

- Sandia National Laboratories
- University of Michigan

Research Objective

This project aims to identify and evaluate constraints posed by critical infrastructure systems and natural resources to meet CV targets in both the United States and China. Resource availability and constraints for renewable electricity including wind, solar, biomass, and geothermal will be evaluated. The infrastructure systems to be studied will initially include the power grid and water supply system. The project will understand regional resource constraints and competition with demands from other sectors, such as agriculture, urban, and industrial, and will develop regional optimized strategies to maximize the reduction of GHG emissions and fossil fuel use given resource constraints.

Technical Approach

- Complete a national assessment to understand resource constraints and competition with demands from other sectors (agriculture, urban, industrial activities, etc.)
- Analyze regions to develop optimized strategies to maximize the reduction of GHG emissions and fossil fuel use given resource constraints
- Apply the modeling framework to China

Recent Progress

Researchers developed an integrated modeling framework synthesizing a biofuel feasibility assessment model developed at SNL and CV targets developed in TA Project 1. A thorough literature review was conducted and governing equations to evaluate natural resources use (water and land) by CVs based on different degrees of car electrification and time span were developed. Data collection for a national-scale analysis is in progress. The initial results of the national-scale analysis will be two three-dimensional graphs to present how car electrification will affect water and land use over time.

Expected Outcomes

- A feasibility assessment of large-scale biofuel production
- Evaluation of constraints posed by critical infrastructure systems and natural resources to meet CV targets in both the United States and China

Fuel Economy and GHG Standards and Labels for PEVs from a Life Cycle Perspective

Joint Project

U.S. Research Team Lead	China Research Team Lead
• Greg Keoleian, University of Michigan • Jarod Kelly, University of Michigan	• Hewu Wang, Tsinghua University • Jiuyu Du, Tsinghua University
U.S. Partners	**China Partners**
• University of Michigan • Environmental Protection Agency	• Tsinghua University • China Automotive Technology Research Center

Research Objective

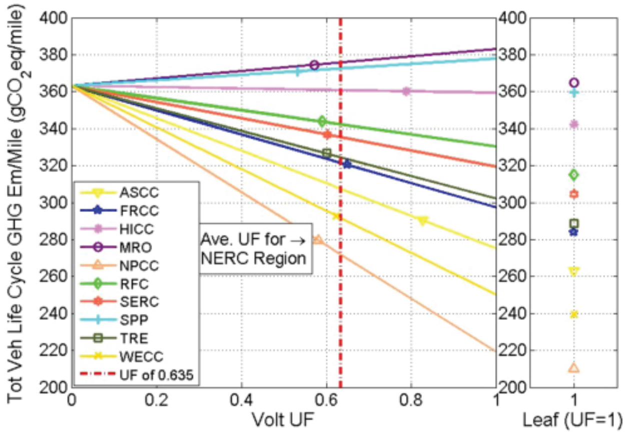
The objective of this project is to evaluate proposed fuel economy labels and GHG standards from a life cycle perspective, as well as to evaluate and provide recommendations for alternative fuel economy and GHG assessment methods, standards, and consumer labels. This project will recommend standards based on an examination of the relationship between the EPA fuel economy metric, used for labeling, and life cycle GHG emissions for electrified vehicles. The project will quantify variations in vehicle life cycle GHG emissions due to differences in vehicle production, driving patterns, and regional electric grids. It will also design optimal parameters for PEV based on the urban travel mode (e.g., vehicle miles traveled, duty cycle, etc.).

Technical Approach

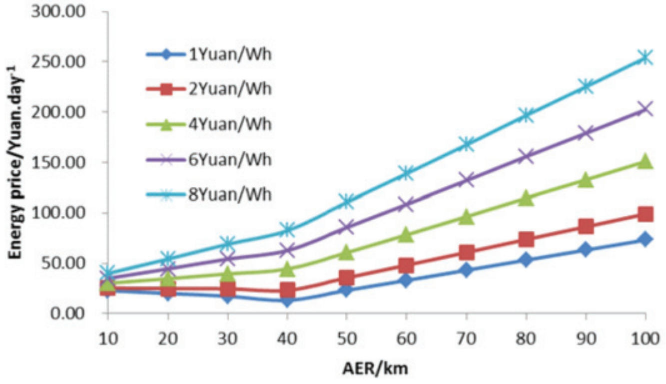
- Develop a framework to explore the effectiveness of alternative assessment methods, regulatory instruments, and labeling formats to accurately represent vehicle energy and environmental performance from a life cycle perspective

Recent Progress

Researchers evaluated current internal combustion vehicle and hybrid electric vehicle markets to establish life cycle GHG correlation to fuel economy for the United States. PEV life cycle GHG emissions were compared for varying utility factors and grids with current EPA labels. A literature review was conducted and researchers began planning for the next phase of the project, which will focus on modeling emissions from electrified vehicles due to changes in fueling (both liquid and electric) as well as distributions in factors such as driving patterns. Additionally, the project team plans to make recommendations to the EPA on improving its labels to reflect PHEV environmental performance variations.



Comparison of plug-in electric vehicles' life cycle greenhouse gas emissions



Comparison of AER designs of PHEV

Expected Outcomes

- Research in life cycle modeling of fuel economy and GHG standards and labels for PHEVs will be incorporated in the Sustainable Energy Systems curriculum
- Strong collaborative relationship between CERC and the EPA, which develops new fuel economy and GHG standards

CV Technology Roadmap and Policy Recommendations

Cooperative Project

U.S. Research Team Lead	China Research Team Lead
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U.S. Partners	**China Partners**
• Massachusetts Institute of Technology • University of Michigan • Argonne National Laboratory • Oak Ridge National Laboratory	• Tsinghua University • China Automotive Technology Research Center

Research Objective

This project will analyze China's in-use vehicle fleet, including the impact of high vehicle fleet growth rates anticipated in China on the deployment rates of higher efficiency CV technologies. A fleet model for China will be developed and used to compare future deployment rates, growth scenarios, overall energy consumption, and GHG emissions with the U.S. fleet model.

Technical Approach

- Create a roadmap that will organize short- and long-term goals according to forecasts of the life cycle performance and market readiness of vehicle-fuel systems, map pathways for achieving energy and GHG emissions goals, and analyze the relation of these pathways to policies

Recent Progress

Researchers conducted a literature review of previous fleet modeling efforts for the Chinese market and identified five major efforts as well as other relevant studies. They compared methodologies and results of these in order to guide future efforts and collected information on the central government's automotive and clean energy policies. A more detailed plan for the Chinese fleet model was developed, including the modifications from the existing U.S. model that will need to be made. It was decided to introduce uncertainties in key parameters through simulation.

Expected Outcomes

- Data analysis and a validated in-use fleet model for light-duty transportation in China
- Scenario analysis for U.S. and Chinese CV technologies and fuel sources
- A roadmapping model for analyzing relationships among technologies, vehicle-fuel system life cycle performance, and policy levers
- An assessment of policy options for accelerating deployment of CV technologies standards
- An analysis of different kinds of PEV commercial solutions based on results from a demonstration project

Appendix E. Acronym List

ACTC	Advanced Coal Technology Consortium
AEP	American Electric Power
AFM	Atomic force microscopy
Al	Aluminum
ANL	Argonne National Laboratory
APU	Auxiliary powertrain unit
B&W	Babcock & Wilcox
BEE	Building Energy Efficiency
BIT	Beijing Institute of Technology
BIW	Body-in-white
CaC_2	Calcium carbide
CAD	Computer-aided design
CAE	Computer-aided engineering
CBK	Char burnout kinetics
CCS	Carbon capture and storage
CCUS	Carbon capture, use and storage
CEF	U.S.-China Clean Energy Forum
CERC	U.S.-China Clean Energy Research Center
CFD	Computational fluid dynamics
CGS	CO_2 geological storage
CO_2	Carbon dioxide
COMO	Combustion model at B&W
CPECC	China Power Engineering Consulting Group Corporation
CSTC	Center of Science and Technology of Construction
CV	Clean vehicles
CVC	Clean Vehicles Consortium
DER-CAM	Distributed Energy Resources Center Customer Adoption Model
DeST	Designer's Simulation Toolkit
DOE	Department of Energy
DSRC	Dedicated short-range communications
E+	EnergyPlus whole building energy simulation program
EGR	Exhaust gas recirculation
EOR	Enhanced oil recovery
EPA	Environmental Protection Agency
EV	Electric vehicle
EVTT	Electrical variable traction-transmission
FE	Finite element
FEA	Finite element analysis
FURN	Furnace code at HUST
GDI	Gasoline direct injection
GE	General Electric
GHG	Greenhouse gas
GPF	Global power flow
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GSHP	Ground source heat pump
H2	Hydrogen
HCCI	Homogeneous charge compression ignition
HCERI	Huaneng Clean Energy Research Institute
HUST	Huazhong University of Science and Technology
HVAC	Heating, ventilation, and air conditioning
IGCC	Integrated gasification combined cycle
IGS	Indiana Geological Survey
IP	Intellectual property
ITS	Intelligent transportation systems

JWP	Joint Work Plan
kg	kilogram
kW	kilowatt
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LDR	Limiting drawing ratio
LLNL	Lawrence Livermore National Laboratory
LTC	Low temperature combustion
MEA	Monoethanolamine
Mg	Magnesium
MIT	Massachusetts Institute of Technology
MOHURD	Ministry of Housing and Urban-Rural Development
MOST	Ministry of Science and Technology
MPC	Model predictive control
MW	Megawatt
NASEO	National Association of State Energy Officials
NDP	Neutron depth profiling
NEA	National Energy Administration
NETL	National Energy Technology Laboratory
NHTSA	National Highway Traffic Safety Administration
NRDC	Natural Resources Defense Council
NVH	Noise vibration and harshness
OCV	Open circuit voltage
ORNL	Oak Ridge National Laboratory
OSU	The Ohio State University
PBR	Photobioreactors
PCC	Post-combustion capture
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
pKa	Acid dissociation constant
PRC	People's Republic of China
PSB	Private Sector Board
PV	Photovoltaics
R&D	Research and development
SBU	Stony Brook University
SCGS	Smart charging guide system
SEM	Scanning electron microscopy
SJTU	Shanghai Jiao Tong University
SNL	Sandia National Laboratories
SOC	State of charge
SOF	State of function
SOH	State of health
TE	Thermoelectric
TEM	Transmission electron microscope
TGA	Thermogravimetric analyzer
THU	Tsinghua University
TJU	Tianjin University
TMP	Technology Management Plan
UHV STM	Ultra high vacuum scanning tunneling microscopy
UK	University of Kentucky
UM	University of Michigan
USC	Ultra supercritical
UWY	University of Wyoming
V2G	Vehicle-to-grid
WebOPT	Low Energy Building Optimization Web Service
WHUT	Wuhan University of Technology
WRI	World Resources Institute
WVU	West Virginia University

U.S.–China Clean Energy Research Center

中美清洁能源研究中心