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Bi-national research and education cooperation in the U.S.-China EcoPartnership for Environmental Sustainability

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The U.S.-China EcoPartnership for Environmental Sustainability (USCEES), one of 30 EcoPartnerships, was established within the U.S.-China Strategic Economic Dialogue framework in May 2011 by a joint agreement between the U.S. Department of State and China's National Development and Reform Commission. The USCEES has the goal of fostering bi-national research innovation, communication, and entrepreneurship to address the interconnected challenges of environmental, social, and economic sustainability. Research and education programs within the USCEES are focused on understanding current and past degradation of natural resources, investigating the drivers, impacts, and mitigation of global climate change, and assessing options for sustainable use of natural resources. Although both the U.S. and China have embraced a future based on science, technology, and innovation, our bi-national framework acknowledges that these two nations have vastly different cultural, political, and demographic legacies that could pose distinct challenges to uniform solutions or mandated collaborative networks. The peer-to-peer connections that drive the research component of the USCEES program are promoted and initiated from the ground up; they are based on the voluntary participation of scientists and engineers who are fascinated by the intellectual challenge of solving complex problems of inherent interest to them. Herein, we present highlights of USCEES activities that describe our efforts to discover, incubate, and nurture U.S.-China research collaborations to meet our collective goals. We discuss our pilot programs that are designed to highlight university facilities, resources, and technologies for tech transfer and licensing with an environmental solutions-oriented direction. Additionally, programs to promote cross-EcoPartnership collaborations are discussed. © 2015 AIP Publishing LLC. [<http://dx.doi.org/10.1063/1.4928742>]

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I. PROJECT CONCEPT

The U.S.-China EcoPartnership for Environmental Sustainability (USCEES), one of 30 current EcoPartnerships, was established within the U.S.-China Strategic Economic Dialogue (SED) framework in May 2011 by a joint agreement between the U.S. Department of State and China's National Development and Reform Commission. The USCEES has the goal of fostering bi-national research innovation, communication, and entrepreneurship to address the interconnected challenges of environmental, social, and economic sustainability. Research and education programs within the USCEES are focused on understanding current and past degradation of natural resources, investigating the drivers, indicators, impacts, and mitigation of global climate change, and assessing options for sustainable use of natural resources. Communication is enhanced by emphasizing common environmental research challenges, instituting faculty and student exchange programs, and promoting environmental solutions that lower barriers to information and technology. The USCEES promotes commercialization opportunities for the university community to bring the newest technology to bear on environmental challenges in China and the U.S.

Specific strategies that have proven effective include creating research clusters to address bilateral challenges, creating databases that highlight partner research capabilities to encourage collaboration, connecting municipalities with environmental solutions technologies, and facilitating opportunities for research that, through interaction with the USCEES, may find additional resources needed to pilot technologies that hold high-promise for transition to the marketplace. We maintain parallel English (<http://www.purdue.edu/discoverypark/ecopartnership/>) and Chinese (<http://www.purdue.edu/discoverypark/ecopartnership-cn/>) language websites that describe these activities and opportunities.

The six organizations that form the core group of the USCEES combine the capabilities of three U.S. institutions (Purdue University's Global Sustainability Initiative, University of Tennessee's (UT) Institute for a Secure and Sustainable Environment and Institute of Agriculture, and the UT-Oak Ridge National Laboratory (ORNL) Joint Institute for Biological Sciences) with three complementary center and institute partners of the Chinese Academy of Sciences (CAS) (the Institute of Geographic Sciences and Natural Resources Research, the Research Center for Eco-Environmental Sciences, and the Institute of Applied Ecology). These six institutions together bring focused strengths across a relevant spectrum of science, technology, policy, economics, and agriculture. It is important to note that the USCEES was developed from an earlier bi-national program—the China-U.S. Joint Research Center for Ecosystem and Environmental Change (JRCEEC)—which was established in July 2006 between the CAS, the University of Tennessee, and ORNL and later joined by Purdue University (2007). This effort was instrumental in establishing a strong foundation of trust and proven collaboration for expanded engagement.

According to the UN Secretary General's report (2010): "In practical terms, the consensus on sustainable development calls for international cooperation and national leadership to achieve a convergence between the three pillars of sustainable development—economic development, social development, and environmental protection—in particular, by accelerating the upward convergence in living standards around the globe and bringing about a swift downward convergence of environmental impacts."¹ In the USCEES we affirm, along with other recent calls for a multidimensional policy focus on the triple bottom line,² that sustainable development is an international goal likely to be achieved through programs of broad participation including grassroots efforts to implement the best management practices and technology transfer involving a "highly energised era of networked problem solving that engages the world's universities, businesses, nongovernmental organisations, governments, and especially young people."²

II. RELEVANCE TO BOTH COUNTRIES

Top-down mandates to solve critical problems are possible, but they typically require a tremendous investment, and are often unilateral efforts, such as President John F. Kennedy's

mandate to send a man to the moon. The peer-to-peer connections that drive the basic research component of the USCEES program are promoted and initiated from the ground up; they are based on the voluntary participation of scientists and engineers who are genuinely fascinated by the intellectual challenge of solving complex problems of inherent interest to them. Although both the U.S. and China have embraced a future based on science, technology, and innovation, our bi-national framework acknowledges that these two nations have vastly different cultural, political, and demographic legacies that could pose distinct challenges to uniform solutions or mandated collaborative networks. The USCEES aims to bring together Chinese and U.S. researchers from our core and affiliated programs as voluntary cohorts and leverage the scientific investments that have been made in both the countries. Because the USCEES actively promotes and manages a two-way exchange of faculty and students, we emphasize the fundamental importance of a common understanding of our technological, environmental, and economic strengths and needs while promoting cultural exchange and maintaining a foundation of trust.

Although policy development has not been the main focus of our program, through workshops and symposia, we strive to deliver needed research results to decision makers, the global research community, and other relevant stakeholders to help guidelines of inquiry meet policy goals. For example, many USCEES projects address several of the Ten Year Framework (TYF) goals including “Clean and Efficient Transportation,” “Clean Water,” and “Green Growth.” The projects include efforts to mitigate greenhouse gas emissions through increased adoption of alternative energy resources (wind, solar, and biofuels) and production of bio-based feedstocks, increase carbon sequestration through improved ecosystem management and cropping methods, and improve ecosystem services such as water purification by better understanding biodiversity and wildlife conservation.

III. RESULTS TO DATE AND DISCUSSION

Below are the highlights of USCEES activities and products that describe our efforts to discover, incubate, and nurture U.S.-China research collaborations to meet our collective goals. We also discuss our pilot programs that are designed to highlight university facilities, resources, and technologies for tech transfer and licensing with an environmental solutions-oriented direction. Additionally, programs to promote cross-EcoPartnership collaborations are discussed. These achievements and milestones are summarized in Table I, whereas specifics related to manuscripts and workshops can be found in the supplementary material.³

A. Symposia, workshops, and technical training

Through symposia, workshops, special forums, and an annual meeting, the UCEES has engaged nearly 2000 scientists and students from more than 40 institutions. The USCEES annual symposia serves to showcase the results of research projects, share methods and best practices, explore new research directions, network resources and facilities, and provide cultural exchanges. Since 2011, four annual symposia, which alternate venues between the U.S. and China, have been held. A total of 260 technical papers have been presented at these meetings, authored or co-authored by scientists and students from China and the U.S. The meetings also attract representatives from U.S. government agencies (including Department of State, National Science Foundation (NSF), and Department of Energy), industry (including Shell, IBM, Green Tech America, FuturaGene, Zhongke Medicine Company, and Zhongke Fertilizer Company), the Chinese Consulate of Chicago, China’s National Natural Science Fund Committee, and the Shenyang Municipal Science and Technology Bureau.

The fifth annual meeting will be held at Purdue University in October of 2015 and will have the theme “Critical Zone (CZ) Science, Sustainability, and Services in a Changing World.” The Earth’s critical zone, the thin layer of our planet’s surface from the top of the vegetation canopy to the bottom of groundwater aquifers, represents a dynamic arena of interacting physical, chemical, and biologic processes that produce most of our life-sustaining natural resources.⁴ It will host two NSF-funded workshops—one dedicated to the role of runoff and

TABLE I. Annual milestones in faculty/student exchange, manuscripts, high level administrative visits, and funding for the U.S.-China Ecopartnership for environmental sustainability since inception in 2011.

Year	Technical workshops	Annual conferences	Faculty visiting scholarships (1–12 months)	Co-advised graduate student visiting scholarships (3–24 months)	Collaborative manuscripts and special journal issues	Official administrative visits	Collaborative projects funded
2011		In U.S.	2 from U.S. 1 from China		2 manuscripts	1 from China 1 from U.S.	
2012	2 in China	In China	6 from China	5 from China	1 manuscript	1 from China	2 projects
2013	8 in China 2 in U.S.	In U.S.	2 from U.S. 4 from China	2 from U.S. 2 from China	2 manuscripts and 2 special issues	1 from China	1 project
2014	1 in U.S.	In China	7 from U.S. 3 from China	2 from U.S. 2 from China	2 manuscripts	2 from U.S.	
2015	4 in U.S.	In U.S.	4 from U.S. 5 from China		4 manuscripts and 2 special issues	1 from U.S.	2 projects

erosion on soil-carbon stocks and the other focused on organic matter flux, stabilization, and reactivity in CZ science and sustainability. Outcomes from the workshops will include a compilation of recommendations for common measures and supporting methods to better address U.S. critical zone observatory questions related to (a) coupled hydrological, mineralogical, and biological controls on CZ organic matter dynamics, (b) geochemical and microbiological proxies for provenance (source) of organic matter, (c) geochemical and microbiological indices for soil organic matter vulnerability, stability, and health.

To date, four special issues of scientific journals have been published or are in the process of publishing from the annual meetings.³

In addition to thematic symposia at our annual meetings, the USCEES has sponsored a number of targeted workshops and training classes. These courses combine both theoretical and practical subjects and are generally open to graduate students, postdocs, and faculty from core partner members as well as outside groups. They range from highly technical scientific field and lab based instruction to legal and policy related workshops focused on intellectual property issues for U.S.-China relations.³

B. Technology transfer, licensing, and commercialization

In a partnership with Purdue's Office of Technology Commercialization, the USCEES piloted a program in 2014 to highlight environmental, agricultural, and energy technologies currently held by Purdue and licensable in China. A select cohort of Purdue undergraduate science and engineering students from the Peoples Republic of China work with the USCEES to translate the relevant technologies into Chinese and then produce technology booklets that are posted in the "Technological Needs and Solutions" sections of both the English and Chinese language versions of the website. These booklets are directly distributed to relevant corporate and academic partners as well as provincial Offices of International Cooperation and Development in China. These products have been the basis for numerous corporate and provincial engagements to discuss tech licensing.

C. Faculty and student exchanges, collaborative research groups, and publication products

Faculty and student exchanges promote mutual trust and understanding with an eye toward facilitating cross-cultural fluency. Selected outstanding senior faculty members serve as mentors to the next generation of scientists, working closely with students and other young scientists to

guide research projects, publish high-profile journal articles, and facilitate international technical and cultural training.

Among the core USCEES members, agreements have been signed and executed to formalize the processes through which to exchange faculty (such as sabbatical leaves) and students (study abroad or visiting research). For instance, an agreement of a Joint Laboratory of Soil and Water Research has been made between the Institute of Applied Ecology, Purdue University, and the University of Tennessee. Since 2011, more than 40 faculty and students have made cross-institutional visits to receive specialized training in new technologies and methods and participate in industry and science-based field trips. Many of these graduate students and young professors from China visit the U.S. partners for extended times from 3 to 24 months. Additionally, a number of senior U.S. members of the USCEES have been awarded extended research honors including a 3-month Senior Visiting Professorship in the Chinese Academy of Sciences, Institute of Applied Ecology (Tim Filley-Purdue University, 2011), 3-month every year Visiting Professor in Chinese Academy of Sciences, Institute of Applied Ecology (Jie Zhuang-University of Tennessee, 2013 to present), 1-month High End Foreign Expert Status at Qinghai Normal University (QHNU) (Chad Jafvert and Greg Michalski-Purdue University, 2015) and Nanjing Agricultural University.⁵ Partner programs have also opened their resources up to an expanded network of affiliated universities and institutions. For example, Shenyang Agricultural University has sent 6 faculties for 12-month visiting scholarships and seven other universities have each sent one faculty member for 12-month visits. Additional affiliated programs like North West Agriculture and Forestry and Beijing Normal University have sent graduate student visiting scholars. The USCEES is developing innovative ways to make these visiting scholar collaborations sustainable and productive. For example, a visiting scholar's reciprocal travel grant program was established to help fund the research-related travel of U.S. faculty to China. Additionally, a number of collaborative working groups have been established to consider how to effectively utilize the unique resources available in the partnering U.S. and Chinese institutions across broad areas of interest that include biogeochemistry, climate change, wetland ecology, toxicology, environmental behaviors of contaminants, urbanization, and bioenergy sustainability.

While short-term (up to 2 years) visiting scholar stays can be extremely productive, as evidenced by visiting scholar based publications listed below, extended (4+ years) graduate research training abroad can make enormous strides in knowledge creation and personal development. In 2014, an exciting new program in graduate education, the China-U.S. Joint 100-Ph.D. Program of Environment and Energy (DEEP), was launched with the financial support of the China Scholarship Council and the University of Tennessee. DEEP recruits outstanding masters-level students from partnering Chinese universities or research institutes to enroll at the University of Tennessee for doctoral study for 4 years, with tuition and research fees covered by the University of Tennessee and living stipends provided by the China Scholarship Council or Chinese university programs. For 2014, the first cohort of 10 students has been selected to pursue a doctoral degree co-advised by faculty or scientists from UT, ORNL, and participating programs in China.

In addition to the special issues of journals produced from the annual meetings, ten peer-reviewed papers and editorials have been jointly published from these collaborative exchange visits and projects.³

D. Funding of collaborative research activities

The USCEES continues to pursue various opportunities to secure funding for activities from a variety of public and private sector sources. To date, four specific projects have been funded that specifically leverage USCEES member resources to promote bi-national research and educational cooperation. These projects include: (1) "Self-Protection of Organic Carbon in Soils under Organic Practices" (funded by U.S. NSF; Grant No. CBET-1220731, in experimental collaboration with a project funded by NSF of China in 2012). (2) "Intensively Managed Landscapes—Critical Zone Observatory"(funded by U.S. NSF in 2013, EAR-1331906). (3)

“Integrated Water Resources Management for Qinghai Province” (funded Qinghai Science and Technology Department, 2015). (4) “Developing a Self-driven Water-circulating Ecological Treatment System and Suspended Wetland for on-site Purification of Distribution-scattered, Small-scale Stagnated Water in Urban Regions” was funded (funded by the Water Conservation Funds of National Geographic Air and Water Fund, 2012–2013).

The Chinese Visiting Scholars Reciprocal Travel Grant program was piloted in 2014 at Purdue with the aim of funding the reciprocal research stays of Purdue faculty to the home institution of their past visiting scholars from China. This competitive grant program awarded eight \$4500 proposals in 2014 to support the travel and living expenses for a stay of no less than four weeks in China. These projects included a range of sustainability issues related to water quality, food security, urbanization, and metal toxicity.

E. Cross-EcoPartnership activities

2014 was a noteworthy year for USCEES collaborations with other EcoPartnerships that included new research projects, faculty and student exchanges, and new research funding in support of bi-national collaborations.

The U.S. leads/Co-leads of four EcoPartnerships (*Timothy Filley- EcoPartnership for Environmental Sustainability, S.T. Hsieh-US/China Energy and Environmental Technology Center (EETC), Edgar Gomez-Utah-Qinghai EcoPartnership, Devinder Mahajan—Stony Brook University–Tongji University EcoPartnership*) co-authored an article on the important role of sub-national organizations and specifically the EcoPartnerships program in promoting and developing economic and environmental sustainability solutions. Their work, *The US-China EcoPartnerships: How subnational organizations can help solve global environmental challenges*,⁵ was solicited by a new Chinese language magazine-Mandarin Environment (ME)—for its inaugural issue. ME targets as its readership the Chinese business community in the U.S. and China with information about environmental and sustainability best practices and solutions in the U.S.

Starting in 2014, the USCEES, the Utah–Qinghai EcoPartnership, and partner universities of QHNU and Qinghai University (QHU) jointly initiated a multi-tier, multi-year program for water quality improvement in Qinghai, China with projects that span village to provincial-scale applications. In collaboration with faculty at QHNU led by Professor Yang Lin, Purdue faculty and students introduced inexpensive slow-sand biofilter technology designed in the lab of Purdue Professor Chad Jafvert in two rural Qinghai villages that primarily rely on rainwater collection for home drinking water. In support of these projects, two Purdue faculties, Professor Greg Michalski and Professor Chad Jafvert, were selected for China’s High End Foreign Experts program and will be spending a month in Qinghai in 2015. Similarly, faculties from QHNU and QHU have applied for visiting scholar status at Purdue University for 2016. Additionally, Environmental and urban hydrology process models designed and/or modified at Purdue University are being used to assess the impact of urbanization and land use change on water quality in both Xining city and rural areas, to help urban planners and farmers make decisions about land use. One of these water resources projects, which will implement Purdue’s Long Term Hydrologic Impact Analysis (L-THIA) model to Xining city, was awarded a Qinghai Science and Technology Department grant for 2015 in a research collaboration with QHNU Professor Zhao Xia. Overall, from 2013 to 2014 two Purdue graduate students and four Purdue faculties visited Qinghai as hosts of QHNU and QHU. These visits came on the heels of a 2013 delegation visit by Qinghai officials to investigate licensing of clean energy technologies and included Yuan Xie-Director-General of Qinghai Provincial Department of Science and Technology, Hongxian Yu—Vice President of Qinghai University, Youming Qiao—Director of the Foreign Affairs Office of Qinghai University, and Hassan (Dingming)—an Associate Professor at Qinghai University.

F. Official administrative visits

The USCEES also promotes upper level administration visits among existing and new U.S. and China participants in order to deepen and reaffirm institutional commitments, facilitate new

research and education programs, and facilitate the peer to peer interactions. In total, seven separate delegations have traveled between the U.S. and China members. For example, University of Tennessee Chancellor Jimmy Cheek visited China Agriculture University on July 17, 2014 to develop a US-China Joint Ph.D. program in Environment and Energy. The President and Chief Entrepreneurial Officer of Purdue Research Foundation Dan Halser discussed the USCEES as part of his Keynote address at the 20th anniversary of Tsinghua's Tuspark in August, 2014. University of Tennessee Provost Susan Martin visited China Scholarship Council and China Agriculture University on March 16, 2015 to promote the US-China Joint Ph.D. Program. Martin Keller (Associate Director, Oak Ridge National Laboratory) visited CAS in May 2011 to develop a US-China Joint Consortium of Bioenergy Sustainability. The president (Yulong Zhang) of Shenyang Agricultural University visited U.S. partners in July 2011 to explore establishment of joint research center for black soil protection. A ministry-level delegation of Development Research Center of State Council of China, led by Shijing Liu, visited the U.S. partners in December 2012 to explore collaboration in the policy and economics of energy and environment as well as in white paper preparation.

IV. GOING FORWARD

A. Key remaining challenges

While the focus of the USCEES, or any other individual EcoPartnership, may be relatively narrow, changing opportunities and challenges in U.S.-China engagement has led to an increased awareness of the important role that cross-EcoPartnership intellectual collaborations and an expanded USCEES membership can play if we are to best fulfill our mission and goals. This realization is evidenced by the new cross-EcoPartnership collaborations highlighted herein and efforts underway in the USCEES to expand our affiliated membership to additional universities. Indeed, coming off of RIO 20+ and the recommendation from UN Secretary-General Ban Ki-Moon to develop global Sustainable Development Goals,² we, if mobilized as an EcoPartnership Network, have a unique opportunity to inform, test, and recommend best practice technologies and help identify appropriate paths toward sustainability. Acting as a bi-national problem-solving network working within in the largest as well as most rapidly developing economies, we could provide a critical service in the years to come as a networked institution with private and public sector strengths across a variety of areas including energy, food, urbanization, climate resilience, and environmental remediation.

V. CONCLUSIONS

The U.S. and China, the world's two largest economies are the top producers and consumers of agricultural products, energy, and material goods. They are also the leading emitters of greenhouse gases⁶ and technological waste, and have dramatically altered our landscapes in complex ways that are negatively impacting our soils, water resources, and human health.⁷⁻⁹ The U.S.-China EcoPartnership program, now in its 7th year, endeavors to take on some of these shared challenges by focusing on a range of issues: air quality, water availability and quality, efficient transportation, clean and efficient energy, protection of natural reserves, and wetlands conservation. Research universities have long represented centers of excellence in teaching and research on these challenges, but they, along with national laboratories, are increasingly becoming hubs for entrepreneurship and innovation with the express goal of delivering environmental solutions to wide sectors of the marketplace. The U.S.-China EcoPartnership program has recognized the value of academic partnerships and included several university and national lab-driven and supported consortia in the program.

At the creation of the EcoPartnership program in 2008, the expectation was that academic partnerships would nurture the creation and dissemination of knowledge and would bring unique innovation pathways to solutions to our regional and global environmental problems. In keeping with these expectations, the USCEES is making important strides instituting bi-national research and educational collaborations, drawing strength from the contributions and varied

perspectives of two U.S. universities, a national lab, and leading research institutes in the Chinese Academy of Sciences. It is one of the few EcoPartnerships that is a research and education-based effort with a mission that draws on the basic strengths of the university and research institution culture to promote environmental solutions while lowering barriers to communication, the exchange of faculty, students, information, and technology. Our approach has created a tightly linked collaborative network that is showing real progress in ecosystem, contaminant, and energy research and our piloted commercialization and licensing programs are breaking new ground in delivering solutions-oriented intellectual property to our partners. The educational foundation of this partnership strongly positions us to contribute to the “100 000 Strong” initiative of the U.S. State Department which is a national effort designed to increase the number of American students studying in China. In the coming years, we look to create stronger linkages with private and public funding resources and expand our affiliated programs and cross-EcoPartnership ties to ensure the continuation as well as expansion of our programs.

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¹General Assembly Resolution 64/236, Implementation of Agenda 21, the Programme for the Further Implementation of Agenda 21 and the outcomes of the World Summit on Sustainable Development, A/RES/64/236, 2010.

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