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Managing intellectual property rights in cross-border clean energy collaboration: The case of the U.S.–China Clean Energy Research Center

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HIGHLIGHTS

- The CERC has been able to generate new IP through collaborative RD&D activities.
- Minimal IP has come from cross-national collaborative activities.
- The TMP has mitigated IP concerns, though few have tested its enforceability.
- The CERC provides a unique model for collaborative clean energy RD&D.
- The TMP may ultimately help to build trust among the consortia participants.

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ABSTRACT

This paper examines how the United States and China are implementing the most ambitious model of bilateral clean energy technology cooperation to date: The U.S.–China Clean Energy Research Center (CERC). It finds that the CERC has been able to generate new IP through RD&D activities, though minimal IP has come from collaborative activities involving both U.S. and Chinese participants. Many participants reported that the CERC's Technology Management Plan (TMP) mitigated their IP concerns, though few have tested its efficacy or enforceability. While it is too early to comprehensively assess the efforts of the CERC, it is increasingly evident that the CERC provides a model for collaborative clean energy RD&D that is unique in the history of U.S.–China collaborations in this area. The TMP may ultimately play an important role in building trust among the consortia participants, which could lead to even more constructive collaborations in the future, and serve as a model for future bilateral cooperation agreements. Without sustained support, and continued attention to IP concerns, it will be even harder for China and the United States to make progress towards true cross-national research collaborations which ultimately could produce considerable global benefits, particularly in the clean energy field.

1. Introduction

As global interest in technologies that can either replace or improve the efficiency of fossil fuels increases, we are seeing increasing calls for international clean energy research and development (R&D) partnerships, both to harness the unique technical capacities and market characteristics of partner countries, and to promote high-level political cooperation. International technology partnerships vary widely in scope, targeting different stages of the technology development process, posing different intellectual property (IP) concerns and encompassing different actors across the public and private sectors. This paper examines how the United States and China, the two largest energy consuming and greenhouse gas emitting nations, are designing international clean energy partnerships contribute to the development, deployment and dissemination of clean energy technologies.

This paper examines the origins and structure of the most ambitious model of U.S.–China clean energy technology cooperation to date: The U.S.–China Clean Energy Research Center (CERC). It presents the first investigation of the CERC's IP framework analyzed in the context of the existing literature on clean energy R&D, China's innovation system and international technology partnerships. Based on this analysis, the study presents broader conclusions about how IP can be better managed to promote cross-national technology cooperation in the clean energy sector, and how specific IP concerns in U.S.–China collaborations can be effectively navigated.

1.1. International partnerships in clean energy RD&D

While international partnerships occur in a variety of technology sectors, technologies that result in or are aimed at improving

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environmental protection, including clean energy technologies, have some unique characteristics. In order to establish what models of international technology cooperation might work for clean energy technology, it is important to both understand what we can learn from technological innovation models in other sectors, and what distinguishes the clean energy case.

First, clean energy technologies are in fact comprised of a diverse range of technological sectors. While energy-supply technologies bring energy forms to a point of final use, energy end-use technologies are applied at this point of use to covert an energy form to a service. In addition, an energy technology is not just hardware but also the software, practices and knowledge relating to its use (Gallagher et al., 2006). Clean energy technologies also span a range of stages of technological development, from the research and development stage (e.g. next generation biofuels or high efficiency solar photovoltaics), to the demonstration stage (e.g. Integrated Gasification Combined Cycle (IGCC) coal fired power stations), to the commercial stage (e.g. wind turbines and crystalline photovoltaic solar modules). Clean energy technologies also come from dissimilar origins. For example, while solar cell innovation stemmed from R&D in the satellite and semiconductor industries, innovation in modern wind turbines was linked to R&D in the aerospace, shipbuilding and agriculture industries (Colatat et al., 2009; Lewis, 2012c). Given the diversity of sectors, markets and technologies involved, policies designed to promote the innovation and utilization of clean energy need to be flexible and consider the specific characteristics of the technology or technologies in question.

Second, because the social benefit of reducing greenhouse gas emissions is not yet generally reflected in cost structures, the deployment of socially desirable technologies is generally not economically profitable (Chao and Peck, 2000; Feiveson and Rabl, 1982). Like many other types of technologies, clean energy technologies can require significant R&D investments and pose a high risk to investors while still in the early stages of development. Unlike many other technologies; however, the benefits of investment in R&D are not readily appropriable to the firm making the investment due to the current pricing system of fossil fuels which may suppress the demand for low-carbon energy technologies. As a result, there is in fact a powerful disincentive against investing in clean energy technologies. For pre-commercial technologies that lack a market rationale, policymakers must also consider the role of demonstration projects and creating early adopters (Huang and Liu, 2008; Consortium for Science, Policy and Outcomes and Clean Air Task Force, 2009).

The factors discussed above suggest a different paradigm for technological innovation and deployment is required for the clean energy sector than what was employed in other industrial sectors. These political, economic and technical factors must inform the way in which clean energy partnerships are structured and financed.

1.2. Benefits and challenges to technology cooperation with China

China has emerged as a key center of innovation as China's government research laboratories, universities, and domestic and multinational corporations have increased their innovative activity in recent years (Li and Yue, 2005). High-level government economic plans now regularly call for increased attention to both indigenous innovation and the promotion of foreign investments in fields of strategic importance for the country such as clean energy (Zhi et al., 2013; OECD, 2008). Having recently become a global leader in the manufacturing of many core clean energy technologies, China has seen increases in both public and private R&D spending across clean energy fields, with concrete examples of innovative activity regularly reported (Huang et al., 2012). In 2010 it was the leader in new clean energy investments, surpassing the United States and the European Union (Fig. 1). China has also been increasing its annual number of patent applications in renewable energy generation, and by 2009 ranked fifth globally after the United States, Japan, Germany and South Korea (Fig. 1). Technology partnerships with overseas firms further expand the access of Chinese firms to global learning networks of knowledge and innovation, which are likely a crucial determinant in a firm's ability to obtain success with a new technology (Karnoe, 1990; Van Est, 1999; Kamp, 2002). But as China attempts to move away from its historical reliance on foreign firms and foreign technology, the environment for international technology cooperation is increasingly complex.

As a location for innovation, China is simultaneously desired and feared by overseas firms. The technology development strategies of transnational firms are becoming increasingly global in

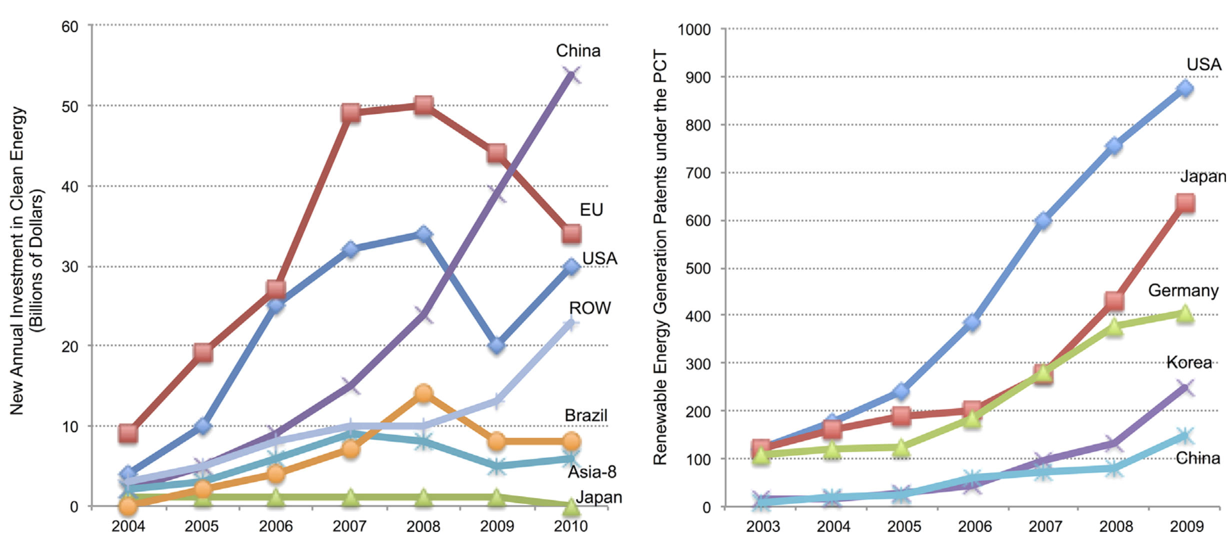

Fig. 1. Clean energy investment and patenting: China and the USA in an international context. *Notes*: Clean energy and technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency. New investment includes private and public R&D, venture capital, private equity, and public markets (mergers and acquisitions are excluded). Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. ROW = Rest of World; EU = European Union; USA = United States of America; UK = United Kingdom; PCT = Patent Cooperation Treaty.
Sources: Investment data from Science and Engineering Indicators 2012 (National Science Board, 2012); patent data from OECD Patent Database (OECD, 2013).

scope, and multinational firms are moving their own R&D activities into China as China is increasingly becoming an important center of innovation globally. But despite the ever more central role of China in the global innovation system, substantial challenges to international technology collaboration with China remain. While many foreign firms and governments have participated in successful technology partnerships in China that have contributed to new technical discoveries and generated new market opportunities, others have experienced costly economic losses or political repercussions, frequently due to disputes over intellectual property rights (Lewis, 2012c). Technology partnerships often must navigate complex technology transfer agreements, and foreign collaborations have failed for reasons ranging from simple cultural misunderstandings to high-profile IP disputes (Suttmeier and Yao, 2011).

The reasons that firms opt to engage in joint R&D activities are well understood and documented. Joint R&D allows firms to utilize external resources directly and systematically for their own purposes (Becker and Dietz, 2004). Benefits include joint R&D financing, reducing uncertainty, realizing cost-savings, and realizing economies of scale and of scope (Becker and Peters, 2002; Camagni, 1993; Robertson and Langlois, 1995); while costs include transaction costs related to coordinating the activities of the parties involved, costs associated with combining complementary assets and resources and fixing the transfer prices of intangible goods (such as information or know-how), and the costs of regulating the exploitation or appropriation of the results of joint R&D (Pisano, 1990; Williamson, 1979). Less well understood, however, is whether these "costs" can be effectively managed, particularly in the context of joint R&D activities with actors from China where the costs associated with each of these areas may be high, or even worse, unknown. There are substantial risks associated with joint R&D where national intellectual property protections are less stringent than in the partner country, with particular concern often directed towards such collaborations in China due to widespread piracy.

While the IP rights system in China lags that of most industrialized nations, it is evolving rapidly, particularly as China becomes a source of innovative activity in its own right (Dechezlepretre et al., 2011). However, China's efforts to create a more innovation-oriented economy, and particularly its indigenous innovation strategies, have been widely criticized (Simon, 2012). China still lags the leading industrialized nations of Japan, the United States and Germany in clean energy technology inventions, but it is playing an increasingly important role in international clean energy technology collaborations, and even is becoming the source of technology transfer to other emerging economies in the clean energy sector (Lewis, 2012c).

The relatively recent global expansion of Chinese clean energy firms has contributed to an increasingly competitive industry and an increasingly challenging environment for cooperation. The Chinese government has consistently conveyed the goal not just of promoting the increased utilization of clean energy in China, but of increasing the use of domestically manufactured technology and therefore fostering the establishment of domestic industries (Government of the People's Republic of China (PRC), 2010). In the effort to develop indigenous high-tech industries, the Chinese government has become gradually more selective and restrictive in the type of imports and investments that it allows or officially encourages. As a result there have been increasing tensions in the clean energy industry reflected in a series of recent international trade disputes between the United States and China targeting renewable energy industries (Lewis, 2012a; Janzen, 2010; Sugathan and Melendez-Ortiz, 2011). In addition, a recent high profile IP dispute between a U.S. and Chinese wind company has elevated concerns of some U.S. clean energy firms looking to cooperate with Chinese firms (Goossens, 2012). It is within this complicated environment wrought with risks and political tensions that The U.S.–China Clean Energy Research Center has been launched.

2. Material and methods

The literature reviewed above points to a need to mitigate the risks associated with joint R&D, and particularly in the context of establishing research collaborations with a country perceived as having a relatively low level of intellectual property rights (IPR) protections. The CERC has implemented a Technology Management Plan with the explicit goal of protecting IPR of consortium participants in order to foster clean energy innovations. This paper therefore assesses the intellectual property framework utilized in the context of the CERC to identify first, whether the CERC has been able to generate new IP through collaborative R&D activities, and second, whether the TMP has served to mitigate any potential problems or concerns of the CERC participants related to IP.

In order to answer these questions, the author spoke directly with numerous CERC project participants from the United States and China representing all of the different stakeholder groups involved, selected from the list of participants provided in Appendix A. Interviews were conducted periodically between 2010 and 2013. For this qualitative case study, unstructured interviews were conducted with the goal of identifying as broad a range of perspectives among CERC participants as possible, rather than a representative perspective. To this end the author relied on non-probability, purposive sampling via personal networks as well as networks of those interviewed to identify additional people to speak with that might represent a new or different perspective (Tansey, 2007). Given the relatively large number of stakeholders involved in the CERC, not all participating organizations were interviewed. While the CERC involves hundreds of researchers, it became evident that some were far more directly involved in the activities of the CERC than others, and therefore the author attempted to speak with those participants most directly involved in CERC activities. When a highly active organization was identified, the author attempted to speak with multiple representatives from that organization to try to encompass as many perspectives as possible.

In addition, the author attended two workshops as a participant observer that were arranged for CERC participants by the U.S. Department of Energy (DOE) and the China Ministry of Science and Technology (MOST) to specifically learn about and discuss their IP concerns related to the CERC. The discussions that took place during these workshops, which have been documented by the author in workshop reports, were used to supplement and in many cases to reaffirm or clarify information collected in interviews (Lewis, 2012b, 2013).

Key information about the operation of the CERC and its consortia was obtained from primary source materials. These include progress reports provided to the respective governments on a periodic basis, company press releases of CERC member companies, presentations from CERC consortia workshops, as well as other official CERC documentation that is publicly available on the CERC website.

3. Results

3.1. The U.S.—China Clean Energy Research Center: Background and Context

The U.S.—China Clean Energy Research Center (CERC) was established in the CERC Protocol signed in November 2009 as

one of 7 Sino-U.S. clean energy agreements signed that year by Presidents Hu and Obama. The CERC had been first announced in July 2009 during former U.S. energy secretary Steven Chu′s first official visit to Beijing, and while many contributed to the initial idea behind establishing the CERC (including China′s Science and Technology Minister Wan Gang), Chu has been widely credited with making it happen. The protocol calls for the establishment of a joint U.S.–China Clean Energy Research Center, although the center is a virtual one, not a physical one. The goals of the CERC are to spur innovation of clean energy technologies, diversify energy supply sources, improve energy efficiency, accelerate the transition to a low-carbon economy, and help to avoid the worst consequences of climate change (Marlay, 2011). The focus on innovation through joint R&D and particularly the emphasis on the creation of intellectual property makes the CERC is unique from previous U.S.–China clean energy cooperation agreements, over 30 of which have been signed over the past three decades (Lewis, 2012c).

The CERC includes a relatively modest funding commitment of $150 million jointly pledged over five years, divided across the three CERC issue areas (Marlay, 2013). Funds received from the U.S. government for the implementation of the CERC can only be used for the U.S. partners; the Chinese government is supplying matching funds to support their partners. Other key aspects of the initial CERC agreement include (1) equality, mutual benefit, and reciprocity; (2) the timely exchange of information relevant to cooperative activities; (3) the effective protection of intellectual property rights; 4) the peaceful, non-military uses of the results of collaborative activities; and (5) respect for the applicable legislation of each country (Marlay, 2011).

While many of the projects are still in their early stages, at a January 2013 meeting of the CERC steering committee, the CERC directors from each technology consortium reported substantial progress and signs of success across the projects (CERC Consortia Directors, 2013). Since 2009, additional industrial partners and business ventures have approached the U.S. DOE wanting to join the CERC, with many offering funds or in-kind contributions to join (Marlay, 2013). In addition, other countries are beginning to take notice of the CERC and are looking to build on this model. For example, in November 2010, one year after the CERC was established, the U.S. DOE and the Planning Commission of India established the Joint Clean Energy Research and Development Center (JCERDC) to promote clean energy innovation by consortia of scientists and engineers from India and the United States (US Department of Energy, 2012). In 2012 the National Center for Science & Technology Evaluation of China (NCSTE) conducted an independent evaluation of the CERC. The evaluations called CERC a "milestone initiative" that is both pragmatic and win-win, and that it "enables a new kind of relationship built on mutual understanding and trust," referring to the Technology Management Plans (TMPs) as "groundbreaking" (Marlay, 2013).

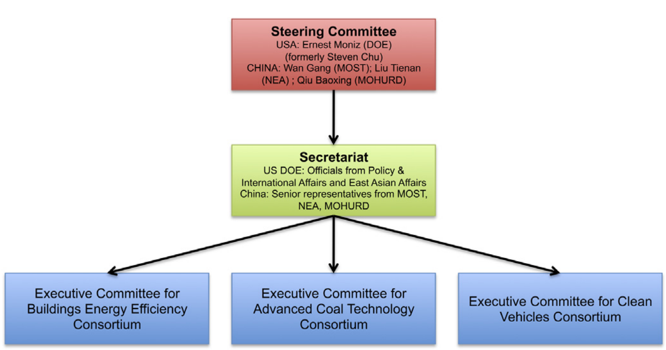

Fig. 2. CERC governance structure. *Notes*: DOE=US Department of Energy; MOST=China Ministry of Science and Technology; NEA=China National Energy Administration; MOHURD=China Ministry of Housing and Urban–Rural Development.
Source: Adapted from U.S. Department of Energy (2012).

3.1.1. Participants

The CERC is governed by a steering committee that includes ministerial- or secretary-level oversight from the relevant government agencies. From the United States, the lead agency is the Department of Energy (DOE). In contrast, China has 3 different government ministries all playing a leadership role in the CERC, including the Ministry of Science and Technology (MOST), the National Energy Administration (NEA), and the Ministry of Housing and Urban-Rural Development (MOHURD). There are three different agencies involved on the Chinese side due to the fact that the energy technologies areas being addressed in the CERC fall under the oversight of multiple agencies. Such overlapping regulatory jurisdictions have led to challenges in coordination within the CERC′s administration, and there was disagreement at the outset over which ministry would take the leading role. While MOST, the key ministry for energy research and development activities, has taken the official lead in the CERC for the Chinese-side, NEA plays an important role in both domestic energy policy and international energy cooperation, and MOHURD plays a crucial role in building construction policies which are important to research activities in efficient building technologies. The governance structure of the CERC is illustrated in Fig. 2.

The CERC originally involved 35 unique organizations from the Chinese side and 51 organizations from the U.S. side (Marlay, 2011). Since 2009 some members have joined and others have left, and by August 2013 there were 86 unique organizations from the Chinese side and 41 from the U.S. side involved as CERC consortia participants (U.S. Department of Energy, 2013). Approximately 1100 researchers in the U.S. and China are supported by the work of the CERC, and each of the partner organizations are either contributing funds or directly performing research (Marlay, 2013).

While both the U.S. and Chinese sides of each of the three consortia include participants from universities, government research laboratories and private companies, the U.S. side contains several non-governmental organization participants, while the Chinese side does not. The extensive private sector participation in the CERC is illustrated in Fig. 3. While the U.S. side initially counted many large companies among its CERC consortia participants, such as GE, General Motors, and American Electric Power (AEP), many of these large corporations have since opted to withdraw from the CERC′s membership roster.

The consortium members on the U.S. side were chosen through a competitive call for proposals to participate in the CERC. On the Chinese side, participants were selected through a variety of channels, though many participants were selected by the government to participate. A full list of participating members in each of the three CERC consortia is included in Appendix A.

3.1.2. Technology focus

The CERC has three technology areas that were targeted for initial cooperation activities: advanced coal technologies, efficient building technologies and clean vehicle technologies, as defined in Table 1. The CERC currently consists of 88 individual projects within these three tracks, and almost all of these projects are joint collaborations between U.S. and Chinese researchers (Marlay, 2013). The types of projects that are included in the CERC are varied along the technology research, development, demonstration and deployment (RDD&D) continuum, ranging from basic science research to technology demonstration. In addition, several projects focus on policy analysis to support the technologies being

developed. A detailed list of the topics focused on in the CERC projects in the three consortia is included in Appendix B, with each of these topics including multiple discrete projects. The CERC may be expanded to include other technology areas in the future although as of December 2013 no new CERC focus areas had been announced.

3.2. The CERC's Technology Management Plan

In order to address intellectual property concerns related to the CERC's R&D activities head-on, each CERC consortia has agreed upon and signed a contract that details the IP rules for participation called a Technology Management Plan (TMP) (U.S. Department of Energy et al., 2011). The TMP was established after months of negotiations between U.S. and Chinese lawyers and the respective government agencies involved, namely DOE and MOST. All participants involved in the CERC's activities are subject to the provisions of the TMP, and any new participants that join the CERC consortia must agree to its terms. The TMP sets up a framework that to date is unique in collaborative research in the clean energy space, but builds upon collaborative research in other sectors. It serves as a "template" and provides guidance to the CERC, establishing a more flexible international IP regime than previous S&T agreements (Marlay, 2013). While it leaves room for additional details to be negotiated as needed by the CERC participants, it sets overarching guidelines with respect to frequently contentious issues such as background IP and licensing terms. While the TMP does not add any new IP protections that the law does not otherwise provide, it plays an important role in establishing a clear framework surrounding the ownership and protection of IP rights. As one of the lawyers involved with negotiating the TMP stated, "uncertainty is the enemy of both collaboration and innovation," and as a result inventors need to be comfortable with regard to a mutual understanding of rights and responsibilities (Baird, 2012).

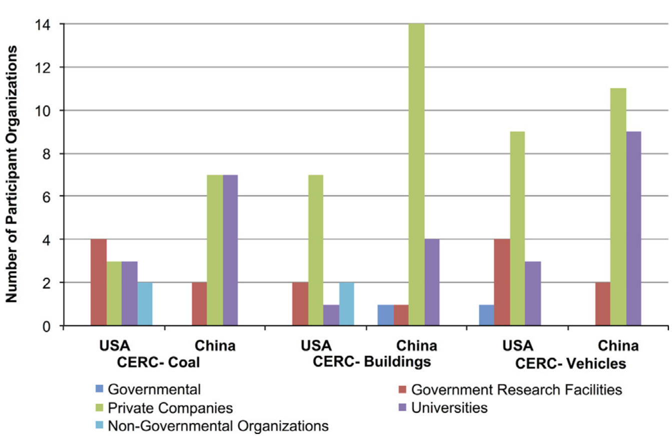

Fig. 3. Stakeholder distribution in the CERC. *Notes*: Several of the Chinese private companies listed are state-owned; however, as they are not governmental agencies they are designated as private companies for the purposes of this table.
Source: Organizations coded by author based on Appendix A.

The TMP addresses the key issues related to IP protection in conjunction with international, collaborative research: namely by attempting to remove the risk associated with sharing existing IP, and the uncertainty surrounding the creation of new IP. The TMP states that the owners of background IP retain "all right, title, and interest in their background IP" and they are not required to "license, assign or otherwise transfer" it, although using it may require an appropriate license (U.S. Department of Energy et al., 2011). Anyone bringing background IP into the CERC is encouraged to agree in writing to the scope and nature of the background IP upfront (Baird, 2012). While the TMP requires disclosures in the form of public reports, it also allows for protection of confidential information, and confidentiality or non-disclosure agreements may be used among participants to protect confidential information in a variety of situations such as the protection of trade secrets, patentable information, and state secrets (Baird, 2012). There are a few situations under the TMP in which licenses are required, including for cooperative activity from R&D and jointly funded project IP. In both cases the terms of the licenses are left to the IP owners to be fairly negotiated on commercial terms; however, when licensing to other CERC participants, the terms must be favorable (U.S. Department of Energy et al., 2011).

In addition to the TMP, a contract among the researchers is needed in any situation involving background IP not in the public domain, a need for confidentiality, where any new project IP may be created, and where there are participants from both China and the United States involved (Baird, 2012). Any contracts established under the CERC must comply with the respective national laws of China and the United States, government contracting regulations, and any regulations of the researchers' employers.

The TMP was specifically designed to clarify the joint ownership of IP resulting from joint research activities, and invented jointly by signatories to the CERC protocol from both the U.S. and China. If project IP is invented by signatories from one territory only, then the TMP requires that participants agree to negotiate in good faith terms of a nonexclusive license to the participants from the other territory. There are also provisions in the TMP that encourage the sharing of data and information related to the project work with the public, except when there is a need to preserve confidentiality (Baird, 2012).

If any disputes over IP arise in the context of CERC activities, there are provisions in the TMP for how they are to be resolved. CERC participants with IP-related disputes are first supposed to try to work out a mutually agreeable resolution. If such a resolution cannot be reached, then an arbitral tribunal in accordance with the applicable rules of international law as set by the United Nations Commission on International Trade Law (UNCITRAL) is to be utilized (U.S. Department of Energy et al., 2011). The inclusion of such a provision for dispute resolution is rare among collaborative research efforts, which typically leave any disputes to the individual laws of the relevant countries to resolve.

Table 1
CERC technology mandates.
Source: Marlay (2011).

Technology area	Mandate
Coal	Advance coal technology needed to safely, effectively, and efficiently utilize coal resources in both countries, including the ability to capture, store and utilize emissions from coal use
Vehicles	Contribute to dramatic improvements in vehicle technologies with potential to reduce the dependence on oil and improve fuel efficiency in both countries
Buildings	Build a foundation of knowledge, technologies, human capabilities, and relationships that position the United States and China for a future with very low energy use and highly energy efficient multi-family residential and commercial buildings

3.3. The three CERC consortia

3.3.1. The Advanced Coal Technology Consortium (ACTC)

The ACTC was the first CERC consortium to launch joint demonstration projects, several of which expanded upon existing private sector partnerships that had been in the early stages of development as the CERC was being established and were folded into the CERC portfolio. For example, Huaneng and Duke Energy had begun cooperation related to advanced coal technology and Carbon Capture and Sequestration (CCS) demonstration as part of Huaneng's GreenGen project in Tianjin as the CERC agreement was being negotiated back in 2009 (Spegele, 2011). Also in mid-2009, Duke and Huaneng signed a cooperation agreement that included Huaneng's participation in Duke's Edwardsport IGCC power plant in Indiana that was to include a CCS demonstration project, among other projects (Duke Energy, 2009).

Another U.S.-based ACTC participant, LP Amina, had already begun cooperation with Gemeng International Energy Co. of Shanxi province, following on a successful demonstration of another LP Amina technology process in China with the Zhejiang Energy Group that had since been transferred back to the United States (Latta, 2011; Spegele, 2011). The CERC, along with the U.S.–China Energy Cooperation Program (ECP), provided a platform for LP Amina to sign an MOU with Gemeng to conduct a pilot scale demonstration of LP Amina's Integrated Fractionation Conventional Gasification (IFCG) coal-to-chemical technology at Gemeng's facility in Shanxi (LP Amina, 2011).

Several of the ACTC's projects have led to IP creation; however, none of the IP is jointly held by Chinese and U.S. partners. As of January 2013, ACTC participants had reportedly filed 15 Patents, including 12 from the Clean Coal Conversion Technology project that were filed in China by Chinese ACTC members, and 3 from the CO_2 Utilization project that were filed in the United States by U.S. ACTC members (Fletcher and Zheng, 2013; Friedmann et al., 2013).

3.3.2. The Building Energy Efficiency (BEE) Consortium

The BEE consortium is particularly focused on R&D activities, and as a result has played particular attention to IP creation in its projects. Several BEE participants developed a schematic illustrating which CERC project areas the consortium members expected to have the highest and lowest IP generation potential based on the nature of the technologies involved and the scope of the research plans, and plotted this against their energy or CO_2 reduction potential (Fig. 4).

Several of the BEE consortia members have reported IP development, or development in progress, as a result of CERC research activities. One BEE project focused on liquid flashing technology was developed as part of a BEE project conducted jointly between Dow Chemical, Oak Ridge National Laboratory (ORNL) and Chongqing University. BEE member Dow Chemical has filed for a patent in the United States related to its liquid flashing technology, with additional filings forthcoming, and reported that the IP creation stemmed from Dow and ORNL R&D activities that did not include participation from Chongqing University. As of July 2013 Dow was also in the process of filing for a patent associated with its advanced white roof ("cool roof") coating technology that it developed in collaboration with ORNL and Lawrence Berkeley National Laboratory (LBNL) (Levinson, 2013). Chongqing University was the Chinese partner on the broader BEE project on High Efficiency Roofing Technology, but the task of developing advanced white roof coatings was restricted to the United States in the original CERC project concept document, primarily due to IP protection-related concerns held by the U.S. participants. Several patents have also been filed in China by CERC BEE researchers from MOHURD.

The BEE has yet to undertake any demonstration projects, but MOHURD has announced several efficient building demonstration projects that will be part of the CERC and will likely incorporate U.S. technologies and software.

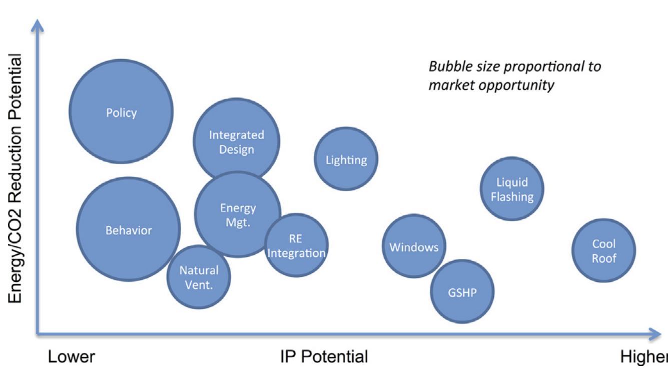

Fig. 4. IP creation potential in the building energy efficiency consortium. *Notes:* GSHP = Ground Source Heat Pump.
Source: Adapted with permission from Zhou and Liu (2013).

3.3.3. The Clean Vehicles Consortium (CVC)

The CVC has been one of the most active consortia in terms of inventions. As of January 2013, participants in the CERC CVC had filed 12 patents in China and 11 in United States, as well as 20 disclosures in the United States. While all of the patents filed in China were filed by Chinese participants, the 11 patents filed in the United States were filed by Chinese participants, and were related to patents that had first been filed in China (Huei and Ouyang, 2013; U.S. Department of Energy, 2013). However, none of the patents were filed jointly both U.S. and Chinese CERC participants.[1]

Two members of the CVC, Tsinghua University and the University of Michigan, are the only CERC members that have developed their own amendment to the TMP, which both sides signed in December 2012. The amendment designates national institutional leads for managing newly created and jointly developed IP among the institutions in each country. The national intuitional leads also coordinate the sharing of expenses related to filing for joint IP and allocating revenue based on licensing of IP, as well as negotiate non-exclusive licenses with third parties. Even though each side had a lead institution, all partners still jointly are to decide IP strategy and cost sharing arrangements.

3.4. Cross-consortia differences

The three CERC consortia have had differing experiences in IP creation, with the reported inventions resulting from CERC R&D activities as described above listed in Table 2. While each of the CERC consortia are expected to report to their respective government funding agencies on the creation of IP under the CERC research program, all of the topics being researched as part of the CERC are closely related to other ongoing research initiatives in almost all of the participating organizations. As a result, it is difficult to truly discern whether the IP that CERC participants report to have been invented through CERC research activities was actually invented in the context of the CERC research programs or in closely related research programs. In addition, there are different cultures of transparency in reporting such patent data across the various CERC organizations, as well as time lags. While the patents and disclosures reported in this table are as up to date as possible at the time of writing, new filings are occurring all the time.

[1] The specific patent and disclosure numbers for the CVC inventions are listed in Huei and Ouyang (2013).

Table 2
Reported inventions resulting from CERC research and development activities.
Sources: Fletcher and Zheng (2013), Zhou and Liu (2013), Huei and Ouyang (2013); interviews with CERC participants.

CERC Consortium	Patents filed in China by Chinese participants	Patents filed in the US by Chinese participants	Patents filed in the US by US participants	Patents filed in China by US participants
ACTC	12	0	3	0
BEE	10	0	2[a]	0
CVC	12	11	20[a]	0
Subtotals	*34*	*11*	*25*	*0*

Notes:
[a] Includes invention disclosures. Due to discrepancies in data as reported across multiple sources, patent reports should be treated as estimates. Data collected through October 2013.

During the IP training workshops intended to familiarize CERC researchers with topics related to IP protection, few researchers from either the United States or China were willing to raise questions about specific IP concerns in the context of ongoing CERC research projects. However, in one-on-one discussions with several CERC participants, a variety concerns about IP protection in the context of the CERC were raised. While few had reservations about specific CERC members, many had run into problems in prior collaborations and did not want to be bothered with time-consuming IP negotiations. Others noted frustration with their own institutes′ IP management offices in responding to their IP-related concerns. It is perhaps not surprising that research scientists, most of which have little experience in IP law, should choose to navigate around potential IP related issues rather than face them head on in the way that the TMP encourages. In contrast, the CERC participants from the private sector were far more confident in navigating IP related issues, primarily due to their access to legal teams with extensive IP expertise.

4. Discussion

The mandate of the CERC includes innovation and invention of new clean energy technologies and applications, and several CERC projects include R&D activities (Appendix B). The attention given to the TMP within the context of the CERC reflects the expectations of policy makers that the CERC generate new IP. However, a question remains as to whether this type of international clean energy collaboration that involves so many geographically dispersed participants with such diverse interests, combined with the existing challenges that many U.S. researchers and businesses perceive with respect to IP development in China, can realistically lead to IP creation. In addition, there is the question of whether the TMP is serving as an effective tool in providing confidence to researchers that their IP will be protected should a disagreement arise.

Four years into the CERC, there are yet to be any disputes over IP elevated to one of the designated dispute resolution systems. While this result could be taken to signal the effectiveness of the TMP, the reality is that as the first phase of the CERC nears completion, much of the IP being created under the CERC does not involve direct collaboration between U.S. and Chinese participants. IP is indeed being created in both China and the United States, however all of the IPR is fully held by either the U.S. or the Chinese side. The degree of collaboration between the Chinese and U.S. sides varies by CERC consortium, but none of the consortia have jointly filed for IP protection. While the CVC has had Chinese participants filing for patents in both China and the United States, none of these inventions were jointly developed with both Chinese and U.S. CERC participants. To date no U.S. CERC participants have filed for patent protection in China.

IP is clearly still a sensitive issue within the CERC, despite the TMP, and to date most CERC participants have opted to avoid IP-related issues all together by designing their research programs such that less sensitive research topics are conducted collaboratively, and more sensitive topics are restricted to in-country partners. As a result, few CERC members have opted to test the efficacy or enforceability of the TMP.

The protection of IPR has been frequently cited as a crucial factor in promoting innovation. In recent years, China has made strides in upgrading its national system for IP protection, including the legal procedures for protecting IPR and for addressing violations. Concerns over sharing IP rights have been frequently identified as a barrier to tangible and fruitful collaborations in the past, and IPR infringement is a particular concern among international researchers working with Chinese researchers – whether or not such concerns are justified. Different forms of international collaborations include varied strategies to deal with IPR protection, but providing clarity in rights allocations and rules has been shown to be crucial from the outset in any technology partnership.

The TMP was designed to provide this clarity. However, it does not seem to have significantly changed the behavior of CERC participants with regards to their willingness to share IP or co-develop IP with Chinese participants. This is likely due to the fact that although the TMP provides IP protection on paper, in practice there is still much skepticism about its enforceability. Particular concerns have been raised by CERC participants about protecting "easy IP," or IP that is relatively easy to copy, as well as trade secrets, which may be harder to enforce since they are not disclosed like patents (Lewis, 2013). There are several key differences in how the relevant legal regimes are structured in the United States and China that create complications for undertaking joint R&D efforts which could lead to patentable information created by scientists from both countries (Lewis, 2012b).

In addition to complications resulting from the handling of newly created IP, there are additional complications related to the handling of preexisting IP: IP that was owned by one of the CERC participants that needs to be shared with other participants while still maintaining the necessary protections over ownership. The owner could license the use of this existing IP to the other partners, but then arrangements also have to be made for how any improvements on this licensed technology will be handled. While the original owner might want to maintain ownership of any inventions related to improvements to his or her IP, if these improvements were made in China, Chinese contract law does not allow for the licensee to be prohibited from further developing new technologies based on the licensed technologies (Mak, 2012). So while contracts can be used to work out issues among researchers working on collaboration, these contracts may not be enforceable if they violate the laws of the country in which the research is being conducted.

As previously noted, many large corporations that had initially joined the CERC back in 2009 and 2010 have since withdrawn (Appendix A). There appear to be a variety of reasons for this, including persisting IP protection concerns, a lack of willingness to help subsidize the program operations, or a cost-benefit calculation that neither of these costs were worth the potential political

capital that involvement in a high-level, government sanctioned collaboration could provide.

Several of the CERC consortia have advanced collaborative R&D among their participants, but these collaborations have not sufficiently crossed borders. Many of the truly collaborative and international projects under the CERC do not deal with true R&D activities, but rather less sensitive research areas such as technology modeling and policy analysis. Several of the CERC consortia have promoted R&D partnerships between U.S. industry and U.S. national laboratories, or between Chinese industry and Chinese universities and research laboratories, and such partnerships have indeed developed new IP. The lack of jointly developed IP from U.S. and Chinese CERC participants most certainly reflects persisting concerns about IP protection.

While not the primary focus of this paper, initial inquiries appear to reveal that the promotion of cross-border collaboration in CERC projects has been more successful at the technology demonstration phase than at the technology R&D phase. For example, in the ACTC, several U.S. companies, in collaboration with U.S. national labs and universities, are demonstrating advanced coal technologies in China, and several Chinese companies are involved in demonstration projects in the United States. The BEE, led by MOHURD, is currently developing several demonstration projects in China, utilizing technologies developed by both Chinese and U.S. consortium members. One of the most important outcomes of joint demonstration projects as identified by CERC researchers was relatively simple data sharing related to project operation, made possible by the improved environment for transparency created by the CERC. There are many examples of innovations from elsewhere being commercialized in China in a variety of sectors, and this development is increasingly evident in clean energy technologies as well. Further investigation of the stages of commercialization across successful CERC research projects, as well as other bilateral cooperation initiatives with China, is a topic of future research and forthcoming studies.

5. Conclusions and policy implications

The CERC begins to shed some light on the question of how IP can be better managed to promote cross-national technology cooperation in the clean energy sector. While the CERC is still in its early stages, the above analysis of the CERC′s IP framework highlights some of the unique characteristics of the model for collaborative clean energy research that it has established, as well as a range of expectations about what the CERC can and will achieve. Many CERC participants reported that they had initially joined the initiative because they believed the IP framework could be beneficial to their continued work in China, although they did not expect that the TMP would solve all of their IP challenges. Several private companies involved in the CERC mentioned tangible results from their participation, including new business ventures, and new IP. By mid-2013, all of the CERC consortia had reported inventions and IP resulting from CERC R&D initiatives.

Almost all of the U.S. commercial participants across the three consortia mentioned that one of the biggest advantages of participating in the CERC was to gain leverage for technology demonstration projects (Spegele, 2011). Many have invested their own money in the collaborations taking place under the CERC far in excess of government support because government involvement provided leverage for project approvals, and many CERC collaborations were perceived to have current or future commercial value. On the Chinese side, there has been a discernable focus on producing tangible metrics with potential commercial value such as patents, reflecting the incentives put in place by the government agencies running the CERC. This is likely reflected in the large number of patents that have been filed by Chinese CERC participants in contrast with filings by U.S. participants.

While it is too early to comprehensively assess the efforts of the CERC, it is increasingly evident that the CERC provides a model for collaborative clean energy research, development and demonstration (RD&D) that is unique in the history of U.S.–China collaborations in this area. Spanning the public and private sectors and involving top researchers from universities and national laboratories in both countries, the CERC has also been credited with propelling numerous other clean energy collaborations, including some with potentially large commercial value. The scale of the CERC is extremely impressive, and it is clearly building important clean energy-focused research partnerships between China and the United States.

Where the CERC is falling short, however, is in providing a model for Sino-U.S. R&D collaboration that generates truly collaborative inventions. Despite the innovative model of IP management encompassed in the CERC′s TMP, the TMP has not yet proven to provide sufficient assurance to CERC participants to alleviate all of their concerns related to IP protection concerns. While the CERC is indeed producing inventions, many of which are jointly developed among CERC consortia members from academia, research institutes and industry, and is in some cases encouraging the co-filing of patents in both China and the United States, it is not yet producing inventions that were jointly developed by U.S. and Chinese participants, or IP rights that are jointly held by entities in both the United States and China. It is evident from all three CERC consortia that collaboration is easier in the basic research stage and in the demonstration stage than in the R&D stage at which IP is frequently generated.

Even if the CERC is not yet meeting all of its expectations with respect to IP creation, as the first U.S.–China program targeting clean energy R&D, it may ultimately play an important role in building trust among the consortia participants, which could lead to even more constructive collaborations in the future. IP concerns are diverse and complex, and are often based on perceptions of risk which may or may not reflect actual risk. Only when both actual and perceived risks are understood and mitigated can a constructive environment for collaboration be achieved. As a result, it is important that both governments continue to support the CERC′s collaborative research programs, even as IP concerns persist. Without sustained support, and continued attention to IP concerns, it will be even harder for China and the United States to make progress towards developing true cross-national research collaborations which ultimately could produce considerable global benefits, particularly in the clean energy field.

The CERC experience provides some useful insight about improvements that are still needed in order to effectively navigate IP concerns specific to U.S.–China collaborations. There is still clearly a need to better alleviate the concerns of the participants related to IP protections, as well as to better educate researchers about how to use legal tools like the TMP to better facilitate collaborative research endeavors. Rather than attempt to navigate complicated IP issues, researchers not trained in IP law are more likely to avoid IP negotiations, even at the expense of potentially valuable cross-border collaborations, unless they are confident that they have institutional support.

The CERC case can also serve as a model for changing the way in which researchers are trained to understand the risks and benefits associated with collaborative research. While most research institutions have legal teams and technology transfer offices, the majority of researchers interact with these offices only when absolutely necessary, and often when it is too late – for example when an IP violation has already occurred. An approach like the one that has been adopted by the CERC through its TMP and IP training activities that both educates researchers and technology

transfer offices about the benefits of cross-border research collaborations as well as the associated legal procedures, may help to encourage a more constructive and proactive relationship among researchers and begin to create an environment in which international research collaborations can succeed.

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Appendix A. Supporting information

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