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South–South Technology Transfer of Low-Carbon Innovation: Large Chinese Hydropower Dams in Cambodia

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ABSTRACT
Large dams have been controversially debated for decades due to their large-scale and often irreversible social and environmental impacts. In the pursuit of low-carbon energy and climate change mitigation, hydropower is experiencing a new renaissance. At the forefront of this renaissance are Chinese actors as the world's largest hydropower dam-builders. This paper aims to discuss the role of South–South technology transfer of low-carbon energy innovation and its opportunities and barriers by using a case study of the first large Chinese-funded and Chinese-built dam in Cambodia. Using the Kamchay Dam as an example, the paper finds that technology transfer can only be fully successful when host governments and organizations have the capacity to absorb new technologies. The paper also finds that technology transfer in the dam sector needs to go beyond hardware and focus more on the transfer of expertise, skills and knowledge to enable long-term sustainable development. © 2016 The Authors Sustainable Development published by ERP Environment and John Wiley & Sons, Ltd

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Introduction

POOR COUNTRIES SUCH AS CAMBODIA DEPEND ON TECHNOLOGY TRANSFER FOR OBTAINING ACCESS TO STATE-OF-THE-ART low-carbon technology such as large hydropower dams.

Large dams[I] have been controversially debated for several decades due to their large-scale and often irreversible social and environmental impacts (WCD, 2000). In the pursuit of low-carbon energy and climate

[I]A brief disclaimer has to be made about the 'low-carbon' or 'low-emission' label of large dams. Compared with the pre-dam natural river flow, the dam reservoir usually creates deeper water and slower water flow speeds, which can lead to an increase in methane and CO_2 emissions (Chang *et al.*, 2009). Other greenhouse gas emissions are methane and nitrous oxide from the bacterial decomposition of organic material underwater (such as rotting trees) and the greenhouse emissions from the production phase of hydropower dams, particularly CO_2 emissions from cement production for the dam-building (Fearnside, 2002; Rosa *et al.*, 2004; Ruiz-Suarez *et al.*, 2003). Nevertheless, calculated over the entire lifetime of the hydropower plants, the greenhouse gas emissions are far less than for fossil-fuel power plants and are comparable to those of other renewable energy technologies (Urban *et al.*, 2013), and are therefore considered an option for achieving sustainable development.

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change mitigation, hydropower is experiencing a new renaissance in many parts of the world, despite its vulnerability to climate change and the emissions of greenhouse gases from its reservoirs and during dam construction (IPCC, 2011).

Chinese actors, such as Sinohydro, a Chinese state-owned enterprise (SOE), are the world's largest dam-builders. While China has a long history of domestic dam-building and water management (Bai and Imura, 2001), recent developments have led to Chinese-funded and Chinese-built overseas dams, particularly in low- and middle-income countries in Asia and Africa (Bosshard, 2009; McDonald *et al.*, 2009; International Rivers, 2012). Chinese 'going out strategy' encourages overseas investments to access natural resources such as energy and water resources (Mohan and Power, 2008, McNally *et al.*, 2009; Wu and Flynn, 1995), including for electricity imports and to power overseas industries (Urban *et al.*, 2013).

There are currently more than 330 Chinese-funded and Chinese-built overseas dams, most of them in Southeast Asia (38%) and Africa (26%). The large majority of these are large dams that have been built since 2000 (International Rivers, 2014), at a time when other dam-building nations and organizations, particularly those from the OECD, withdrew from the dam-building industry.

For poor countries such as Cambodia in Southeast Asia, large dams from Chinese investors are a welcome opportunity to obtain modern energy technology that can help reduce energy poverty, power the economy and lead to sustainable development. In a country with an electrification rate of 34% in 2011, poor grid infrastructure and large electricity imports (IEA, 2014), large dams are seen as a symbol of modernity and a prospect for a brighter, more prosperous future. While OECD investors tend to shy away from investing in Cambodia's sub-par energy sector, South–South technology transfer from Chinese dam-builders offers rarely seen opportunities. The Kamchay Dam, which is Cambodia's first large dam, demonstrates however that Cambodia has also relatively little capacity to absorb the new large-scale technology and to sustainably manage its environmental and social implications. While the absorptive capacity for hydropower innovation is low, both production capabilities and innovation capabilities are largely absent. In the specific case of the Kamchay Dam, technology transfer of hardware has occurred successfully; nevertheless, the transfer of the 'software', such as the knowledge, skills, expertise and experience of how to plan for, build, manage and operate the dam sustainably, is lagging behind. This is also partly due to the limited sustainability of the practices of the technology-transferring country. We therefore suggest that successful technology transfer for sustainable development needs to involve improved practices on both the recipient and the technology-transferring sides.

Against this background, the paper aims to discuss the role of South–South technology transfer of low-carbon energy innovation by using the Kamchay Dam, the first large Chinese-funded and built hydropower dam in Cambodia, as a case study. The *research question* for this paper is as follows: what are the opportunities, barriers and implications of the technology transfer deal between China and Cambodia for the Kamchay Hydropower Dam and what does this mean for sustainable development? Key literature in the field of technology transfer discusses the need for North–South technology transfer and cooperation for enabling access to low-carbon innovation in low- and middle-income countries (Ockwell and Mallett, 2012; Watson *et al.*, 2014; Bell, 2009; Brewer, 2008; Pietrobelli, 2000; Able-Thomas, 1996; Bell, 1990). It is suggested that a comprehensive change is needed from technology transfer to socio-technical transformations (Byrne *et al.*, 2011, 2012). While there is a large body of literature on North–South technology transfer, there is far less literature on South–South technology transfer. Empirical research on South–South technology transfer of low-carbon innovation is rare. This paper aims to add to the understanding of this as yet under-explored, but highly timely and relevant, field of literature.

The analysis is based on extensive research and fieldwork in Cambodia and China funded by the Economic and Social Research Council's (ESRC's) Rising Powers programme for the 'China goes global' project (ESRC reference ES/J01320X/1). It draws on 61 semi-structured in-depth interviews with local communities, local and national governments, dam-builders and financiers as well as 10 focus group discussions. In addition, we conducted a multi-level stakeholder mapping, used quantitative supplementary data from the International Rivers' dams database and conducted an analysis of firm strategies, environmental impact assessment (EIA) documentation and national legislations.

The following section discusses Chinese-funded and Chinese-built overseas dams and their role in Cambodia, the next section presents the conceptual framework and methodology, the fourth section elaborates the findings and the last section discusses the findings and concludes the paper.

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Chinese-Funded and Chinese-Built Overseas Dams and their Role in Cambodia

Chinese-Funded and Chinese-Built Overseas Dams

The World Bank stopped funding large dams between the mid-1990s and 2010 due to their severe negative environmental and social impacts, just to start funding them again in 2011. During this gap of more than a decade, Chinese dam-builders became the global dam leaders by providing funding, engineering expertise and technological innovation for large dams. Still, the controversies around dams have not gone away; in fact, the standards and the sustainability of dams are still rather low with regard to the social and environmental impacts.

Chinese dam-builders are directly involved in the construction of more than 330 overseas dams around the world (International Rivers, 2014). The majority of the dams are located in Asia (57%, mainly in Southeast Asia (38%)), followed by Africa (26%), Latin America (8%), Europe (7%, mainly Eastern Europe), the Middle East and the Pacific (1% each).

The Chinese are involved in overseas dam investments with different roles. They can act as financiers, developers and builders as well as sub-contractors only or acting as a combination of these roles. Usually they are involved in at least two of the above tasks (Urban *et al.*, 2013). Looking particularly at Chinese financiers, they act as investors in 115 overseas dam projects. The main Chinese financiers are state-owned banks (SOBs), mainly China Export Import (Exim) Bank and China Development Bank, and in only a few cases state-owned enterprises, private enterprises or development funds. For the majority of the investments (66%), China acts as the sole financier. In 22% of the cases national host governments participate in the investment, for the remaining 13% of the cases international investors also participate together with Chinese dam-builders, and in few cases the investors are national financiers, such as the governments of host countries (International Rivers, 2014).

Sinohydro is the Chinese SOE most involved in the construction of overseas dams, as both builder and subcontractor as Figure 1 shows. Sinohydro is leading the global hydropower sector as the world's largest dam company in terms of number and size of dams built, investment sums and global coverage. It is followed by China International Water and Electric Corp. (CWE), China Gezhouba Group Company Limited and China Three Gorges Corporation (International Rivers, 2014). In general, almost all of the Chinese companies involved in the construction of overseas dams are state owned. The role of the Chinese government is therefore crucial in influencing the overseas strategy of the country in terms of investments, as well as technical support, especially for large infrastructural projects such as dams.

Energy Poverty and Dams in Cambodia

About nine million people in Cambodia still lack energy access. The electrification rate in urban areas is high, at 97%; however, in rural areas the rate is considerably lower, accounting for only 18% (IEA, 2014). Electricity production in Cambodia is 90% reliant on oil products such as kerosene and diesel. Cambodia's electricity production is far below the country's needs, and imports (1644 GW h) exceed by far the domestic production (1053 GW h) (IEA,

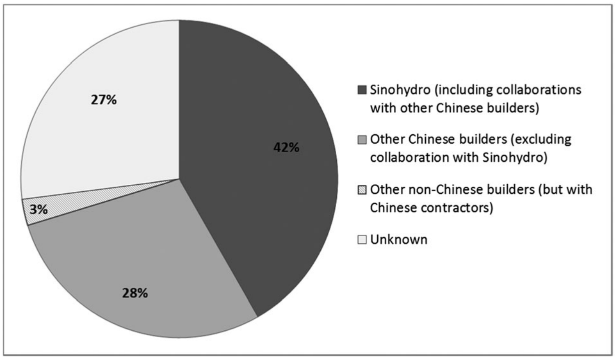

Figure 1. Chinese dam-builders involved in overseas dam projects. Data source: International Rivers (2014)

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2014). Cambodia therefore relies heavily on imported oil for the production of electricity, as well as on electricity imports, mainly from neighbouring countries, primarily Vietnam and Thailand. Overall, Cambodia has some of the highest electricity costs in the world due to the above-mentioned issues, despite being a low-income country (IEA, 2014).

According to the National Strategic Development Plan 2009–2013 (NSDP), energy is central to sustainable growth and poverty reduction in Cambodia. Improving the power sector is one of the government's key priorities in ensuring a reliable, secure electricity supply at affordable prices (RGC, 2010). Hydropower development represents the first energy priority: it is expected to substantially replace fossil fuel consumption for electricity generation. Currently, there are seven hydropower dams in operation, and more than 70 further hydropower projects were in the process of planning, under study and under construction in Cambodia in late 2014.

The government adopted the National Policy on Green Development and the National Strategic Plan on Green Development 2013–2030, which includes hydropower targets (RGC, 2013a, 2013b). In the long term, Cambodia hopes to export some of its electricity to neighbouring countries to gain revenue. Cambodia's Minister of Public Works and Transport, Khy Tainglim, reported this vision: ''Water is our oil [...] and we should use our water to export and get foreign currency to develop the country' (cited by Goh, 2004, p. 7).

However, activists and environmentalists have expressed their concerns for the social and environmental consequences of such projects. For instance, experts have warned that the construction of dams in some places such as Koh Kong and Kratié Provinces could greatly affect the rivers' fish populations, thereby impacting people's food security, and threaten the only remaining habitats of endangered species such as the freshwater Irrawaddy dolphin and the Siamese crocodile (Heng, 2012).

Good leadership and accountable governance with a long-term vision of achieving sustainable development are needed in order to ensure that Cambodian–Chinese cooperation will ultimately bring positive outcomes (Heng, 2012). This will also need to be transparent and include the disclosure of relevant information, as well as promoting a participatory and inclusive development approach by engaging relevant stakeholders, minimizing any potential negative impacts on the environmental and socio-economic conditions, and making sure that the benefits are shared among all parties involved, particularly the local communities (Heng, 2012).

Conceptual Framework and Methodology

Conceptual Framework

The paper draws on the theories of international *technology transfer* for low-carbon innovation (Ockwell and Mallett, 2012; Bell, 1990; Brewer, 2008). *Innovation* is here defined as creating something new or developing a new product, service or idea (Rogers, 2003). *Low-carbon innovation* is crucial to achieve low-carbon energy transitions and to mitigate climate change. The diffusion of low-carbon innovation, including hydropower, is a complex process, which includes research, development, demonstration and deployment. It is not only a technological process, but also depends on the existence of appropriate incentives for firms and other organizations to engage in technology development for the creation of markets for technologies, and it requires skilled labour (Ockwell and Mallett, 2013; Saviotti, 2005). Poor countries, such as Cambodia, are notoriously weak in developing indigenous innovation in the large-scale energy sector. This puts them at a strategic disadvantage, as energy innovation is important for ensuring energy security and reducing energy poverty as well as for developing a sustainable, climate-friendly energy sector that minimizes external dependence. Brewer (2007) therefore refers to the need for a facilitation of innovation and diffusion through *international technology transfer* – North–South, South–North and South–South – under the 'technology transfer paradigm'.

The IPCC's Special Report on Methodological and Technological Issues in Technology Transfer defines 'technology transfer' as a 'broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change [...] The broad and inclusive term 'transfer' encompasses diffusion of technologies and technology cooperation across and within countries. It comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions and integrate it with

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indigenous technologies' (Hedger McKenzie *et al.*, 2000, 1.4). This definition thus includes both technology transfer and technology cooperation. The understanding of technology transfer and cooperation has broadened in recent years, moving away from pure 'hardware thinking' and the classical North–South model to embed four distinct flows of know-how, information, experience and equipment: (1) from North to South (such as from the EU to China and India), usually through foreign direct investment (FDI) and/or overseas development assistance (ODA), joint ventures and licencing, (2) from South to North (such as from China and India to the EU), such as through joint ventures and other forms of technology cooperation, (3) from South to South (such as from China and India to other low- and middle-income countries such as Cambodia), often through FDI and/or ODA, and (4) from North to North (such as from the EU to the US or vice versa), such as through joint ventures and other forms of technology cooperation.

Three flows can be distinguished within the process of technology transfer and technology cooperation: (1) capital goods and equipment, (2) skills and know-how for operation and maintenance and (3) knowledge and expertise for innovation (Ockwell *et al.*, 2007, 2010; Ockwell and Mallett, 2012, 2013). Technology transfer and technology cooperation can be between firms, hence horizontal, and/or include advances in technology development, hence vertical, e.g. from R&D to commercialization. The nature of technology transfer is in reality diverse and could mean short- or long-term transfer, transfers within a larger corporation, joint venture or the selling of the technology. It can span between formal agreements and more informal means such as personnel movement, networks and publications (Ockwell and Mallett, 2013). Going beyond traditional technology transfer, which often focusses on FDI or ODA, involves broader *international technology cooperation*, which refers to a wide range of co-operative approaches between firms and/or countries, including joint ventures, licencing agreements, mergers and acquisitions.

South–South technology transfer and technology cooperation is a rather new, as yet under-researched phenomenon. Most of the literature on technology transfer is limited to North–South technology transfer from richer, developed countries to poorer, developing countries. The rise of China (and other emerging economies) as a new political, economic and technological power however challenges the pre-conceptions about technology transfer and shifts the focus towards South–South technology transfer and cooperation.

These technology transfer theories will be analysed from a sustainable development perspective. 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs' (WCED, 1987, p. 43). The environmental, social and economic perspectives of sustainable development will be discussed as well as political and technological considerations with regard to the Kamchay Dam's technology transfer deal between China and Cambodia.

Methodology

To discuss the role of South–South technology transfer of low-carbon energy innovation, and its opportunities and barriers, we selected the Kamchay Dam in Cambodia, Southeast Asia. Southeast Asia has the highest number of Chinese-funded and Chinese-built overseas dams, and the Kamchay Dam is the first large dam in Cambodia. The case study approach is based on the work of Yin (2009).

The paper builds on 24 semi-structured in-depth interviews with local communities directly affected by the dam through changes to livelihoods, 10 focus group discussions with the same affected communities, 19 interviews with institutional actors from the national and local governments and NGOs in Cambodia and 18 interviews with Chinese actors such as dam-builder Sinohydro, regulators and financiers. This makes a total of 61 interviews and 10 focus group discussions that we draw on for this paper. See Table 1 for details.

The interviews and focus group discussions aimed to assess the implications of the dam from social, environmental, economic, political and technological perspectives. Local communities were asked about the impacts of the dam on their lives and livelihoods as well as on the local environment. Cambodian and Chinese authorities were asked about the implications of the dam, particularly taking into account the technological, economic and political impacts as well as addressing legislative and contractual issues related to the technology transfer deal. Major issues

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Targets	Methods	No of interviews	Further details
Local communities affected by Kamchay Dam project (Bat Kbal Damrey, Moat Peam, Ou Touch, Snam Prampir, Tvi Khan Cheung)	focus groups	10 focus group discussions (5–10 people each; about 75 people in total)	50% women; 50% men
Affected individuals from local communities	semi-structured	24	
Institutional actors	semi-structured interviews	19	national/local government, NGOs
Chinese actors	semi-structured interviews	18	Sinohydro, regulators and financiers

Table 1. Interview setup

such as type of contract, legislative requirements for dam construction, including EIAs, and issues around the transfer of technology, expertise and knowledge were discussed.

We also used quantitative secondary data from International Rivers' extensive database, which includes comprehensive up-to-date data about each of China's hydropower projects worldwide and its technology (e.g. contractor, developer, financier, type of hydropower project, costs, size, location, environmental and social implications). We also compiled secondary data to assess the environmental impacts of dams by examining the EIA report of the dam and relevant national legislation. We further analysed dam project documentation and firm strategies, including Sinohydro's environmental and social guidelines.

We coded and analysed the interview and focus group consultation data using the NVivo 10 software and narrative analysis, which allows us to compare several interviews to be able to draw parallels from similar findings and flag up any differences (Yin, 2009). More specifically, all 61 interviews were coded according to themes and sub-themes. The broad themes were divided into social, environmental, economic, political and technological perspectives. Under each of these broad themes we coded very specific sub-themes that were based on the fieldwork information (e.g. EIA procedures, cost of dam, local employment etc.). Each response of the interviewees was coded in this way and relevant sentences were grouped in the coded sub-themes. This resulted in 3661 coded references within the 61 interviews, thus enabling us to see a pattern and understand the most important issues of this fieldwork. While we could include many quotes from the fieldwork in this paper, we decided to summarize the key findings due to the low word limit.

Findings

The Kamchay Dam

The Kamchay Dam has a generating capacity of nearly 200 MW. The dam cost an estimated US$280 million and is financed by China Exim Bank as part of a US$600 million aid package to Cambodia. The dam is based on a concessional loan from Exim Bank that has to be re-paid with 6% interest rates (International Rivers, 2014). The builders, developers and contractors are Sinohydro. There are a range of reported environmental and social issues related to declines and loss of livelihoods by the local population, dam construction in a National Park and late EIA approvals (International Rivers, 2014). See Table 2 for the technical details of the dam.

Sinohydro started building the Kamchay Dam in Kampot Province, Southern Cambodia, in 2006. The dam started operation in late 2011. The Kamchay Dam is the first large hydropower dam in Cambodia and its generating capacity is much needed in the energy-poor country. The Department of Environment in Kampot province claims that the dam can supply up to 60% of Cambodia's energy demand, at least in the wet season. The expected annual

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Type of dam	hydropower plant: rolling compacted concrete gravity dam
Reservoir capacity (hundred million m^3)	0.98
Reservoir surface area (km^2)	20
Purpose	power generation (electricity)
Generating capacity (MW)	193.2
Height (m)	114
Length (m)	568
Cost (million US$)	311(IR database); 280 (GEO)
Workforce	construction (2006–2011): 3000–4000 Cambodian workers (low-skilled labor workers); 1200 Chinese workers operation and maintenance (2006–2050): 50–60 Chinese workers (mainly engineers and technicians)
Average annual electricity generation capacity (GW h)	4.98
Configuration of powerhouses (the powerhouse includes turbines, generators and transformers)	three powerhouses of 180 MW, 10.1 MW and 4 MW
Electricity supply	supplies electricity to Kampot, Phnom Penh and Preah Sihanouk Province
Water flow rate through turbines (m^3 s^{-1})	163.5
Turbines	three turbines of capacity of 60 (MW); model, Francis HL-LJ-240; hydraulic head (m), 122

Table 2. Technical details of the Kamchay Dam. Data from Sinohydro (2014), GEO (2014) and International Rivers (2014)

output is 498 GW h; however, in the dry season the generating capacity may be as low as 60 MW, which is less than a third of the nameplate capacity of 200 MW (NGO Forum, 2013).

The dam is located on the Kamchay River in Bokor National Park, which is the habitat of endemic and rare species. It is reported that the dam and the reservoir have led to the flooding of 2015 ha of protected forest (NGO Forum, 2013). The overall affected area is 2291 ha, including roads and infrastructure. The next section discusses the type of technology transfer deal for the Kamchay Dam.

Type of Technology Transfer

There are various forms of technology transfer: technology transfer that is based on FDI and/or ODA, technology transfer that involves licencing, technology cooperation that involves joint ventures, and more ‘advanced’ technology cooperation that includes mergers and acquisitions. This indicates the process from rather simple forms of technology transfer to more advanced, neo-liberal means of technology cooperation between two countries. The Kamchay Dam is part of technology transfer arrangements based on FDI and a large aid deal.

There are also different flows of technology transfer and cooperation: (1) capital goods and equipment, (2) skills and know-how for operation and maintenance and (3) knowledge and expertise for innovation. Table 3 indicates that in the case of the Kamchay Dam the flow of technology transfer was mainly limited to capital goods and equipment, while very few skills and know-how for operation and maintenance, and little knowledge and expertise for building up domestic production or innovation capabilities, were transferred. Interviews with Cambodian and Chinese institutional stakeholders confirmed that, while about 3000–4000 Cambodian workers helped construct the dam, they were low-skilled labourers. The skilled work force, such as engineers and technicians, was Chinese. Today, as the dam is operating, only Chinese workers are employed to manage, operate and maintain the dam (see also Table 2).

In terms of horizontal versus vertical technology transfer and technology cooperation, for the Kamchay Dam the technology transfer was horizontal only, namely from China’s SOE Sinohydro to the Cambodian government.

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Capital goods and equipment	Skills and know-how for operation and maintenance	Knowledge and expertise for innovation
Yes, transferred from China to Cambodia.	Limited; dam operated and maintained by Chinese Sinohydro for 44 years with Chinese engineers at the site. Some Cambodians were trained.	Limited; some training, but overall limited build-up of indigenous knowledge and expertise for large dam innovation.

Table 3. Flow of technology transfer, based on the work of Ockwell and Mallett (2013)

Interesting, however, is that this is a case of 'delayed' technology transfer, where the ownership of the dam will only be transferred 44 years after the construction started, namely in 2050. Vertical technology transfer, involving advances in technology development for Cambodian actors, has not happened in this case.

At the Recipient End of Technology Transfer

Our fieldwork in the Kamchay Dam example revealed that, while hardware has been successfully transferred from China to Cambodia, there is very limited absorptive capability to be able to operate and manage the dam by Cambodians and there is very limited production and innovative capability to move from technology transfer to indigenous innovation. Bell (1990) divides the technology transfer process into three elements: suppliers, flows and importers. Bell suggests that flows of capital equipment, and the skills and knowledge for operation, contribute to production capacity. Flows of knowledge for generating and managing technical change – also called 'know-why' (Ockwell and Mallett, 2013) – contribute to the accumulation of innovation capabilities. Neither has happened in the case of the Kamchay Dam, as the dam is built, repaired, operated and managed by Sinohydro, without passing on the skills and knowledge for operation to Cambodian individuals, firms or authorities. At the same time there is no build-up of innovation capabilities at this stage, as long-term training of locals is missing from the technology transfer arrangement. See Table 4 for details. In addition to the limited build-up of local technical and innovative capacity, the Cambodian recipient also has limited capacity to deal with the environmental and social impacts of the dam, as Sinohydro remains the main powerful, albeit laggard, actor in this regard.

The next section discusses the wider implications of the Kamchay Dam technology transfer deal.

Wider Implications of the Kamchay Dam Technology Transfer

Urban *et al.* (2013) suggest that the wider implications of technology transfer for dam-building and more generally the social and environmental sustainability of Chinese overseas dams depend on three factors: (1) the type of contract issued between the dam-builder and the host country, (2) the role Chinese dam-builders play and (3) the national and local legislative setting of the host country.

Technology suppliers – China	Technology transfer	Technology importers – Cambodia
Sinohydro's engineering, managerial and other technological capabilities – made available to Cambodia for the Kamchay Dam construction and operation for 44 years	• capital goods, engineering services, managerial services, product design (*hardware*): transferred to Cambodia • skills and knowledge for operation and maintenance (*know-how*): limited transfer to Cambodia • knowledge, expertise and experience for generating and managing technical change (*know-why*): limited transfer to Cambodia	creation of new production capability and accumulation of innovation capability: very limited in Cambodia

Table 4. Process of technology transfer for Kamchay Dam, based on the work of Bell (1990) and Ockwell and Mallett (2013)

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First, the Kamchay Dam is based on a build–operate–transfer (BOT) contract, which in this specific case means that the dam was built by Sinohydro from 2006 onwards, then operated and managed for 44 years by Sinohydro, before the ownership is transferred to the Cambodian government in 2050. This is much longer than the standard BOT time length of 20–30 years. This is in contrast to engineering procurement and construction (EPC) contracts, which are turnkey contracts, meaning that the dam-builder hands over the dam for operation immediately once construction is completed.

BOT contracts generally place the dam-builder in a much more powerful position than EPC contracts and often tend to be used in poorer countries where the skills, knowledge and expertise on how to operate and manage a dam are low and where external expertise is needed for innovation and technological development.

Second, dam-builders who are also developers usually have a stronger influence on the type of technology transfer agreement as well as planning, siting, impact assessment and how to deal with environmental and social impacts.

Third, the type of technology transfer as well as the sustainability of the dam-building can be greatly influenced by the national and local setting of the host country, particularly with regard to the availability and enforcement of health, safety, environmental and social regulations and legislation (see also Hensengerth, 2013). In addition, the degree of local expertise and knowledge determines the type of technology transfer. For example, a country that has higher local expertise and knowledge in the dam industry, such as Malaysia, is more likely to have more advanced forms of technology transfer such as joint ventures and involving EPC contracts, while a country with very little local expertise and knowledge in the dam industry, such as Cambodia, depends on FDI, foreign aid and BOT contracts.

For Cambodia's Kamchay Dam, all three factors (i.e. BOT type contract; the legislative requirements and their enforcement being limited, particularly with regard to the EIA; Sinohydro being the developer and the contractor of the dam) result in a powerful Chinese dam-builder that puts the Cambodian government and the affected people at the receiving and reactive end of technology transfer. Hence, this is stimulating both a poor enabling environment for dams in Cambodia and a low capacity to absorb and manage the technology and its impacts.

Table 5 provides an overview of the wider issues related to technology transfer for the Kamchay Dam, including the three factors of type of contract, role of dam-builder and local legislative setting.

To expand on the EIA issue mentioned earlier, by Cambodian law, development projects such as dams are required to have an EIA in place and approved before the construction process begins. Cambodian law also prescribes that the EIA process should be transparent, the decision-making should be accountable and a wide consultation process should involve affected local communities and civil society organizations (Middleton, 2008; NGO Forum, 2013). However, at the Kamchay Dam the EIA process started late and the EIA approval was in fact granted seven months after the inauguration of the dam (International Rivers, 2013; NGO Forum, 2013). According to the interview with Conservation International based in Cambodia, the content of the EIA is of poor quality, as for example it does not assess the impacts of the dam on species and habitats but only lists what species occur in the national park. It is also being reported that so far any mitigation measures included in the Environmental Management Plan (MEP) have not been implemented (NGO Forum, 2013). According to an interview with the Department of Environment at the provincial level in Kampot, Sinohydro has set aside a so-far untouched budget of US$5 million for implementing mitigating measures, which cannot be accessed by Cambodian government authorities. This is due to uncertainties about the state procedure to use the funds and unclear responsibilities for environmental mitigation between Sinohydro and the local government, as well as lack of local expertise on environmental management and impact mitigation.

The consultation processes before the dam construction was patchy and ad hoc with little local participation, as our interviews with institutional actors, such as International Rivers, international experts from universities and the National Disaster Management Committee in Cambodia find and other reports confirm (International Rivers, 2013). Many villagers were not invited to consultation processes and became only aware of the dam once construction started. The local villagers have complained against Sinohydro in various forms (petitions, mass demonstrations, filing individual complaints), for example due to the closure of the bamboo forest area. Nevertheless, they had to follow a strict hierarchy, addressing first the village chief, then the commune authority, then the district authority, then the provincial authority, and from there on the complaints are said to be taken to the appropriate ministries in Phnom Penh (mainly MIME) or the provincial governor, who then establishes communication with Sinohydro. This is despite Sinohydro's offices being based at the dam site, in very close proximity to the affected villages. The flawed EIA and consultation process limits best practice for sustainable development.

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Type of contract	BOT, transfer to the Cambodian government after 44 years
Financial arrangement	Bundled aid and investment as dam is part of US$600 million aid and investment package.
Financier	China Exim Bank.
Dam-builder	Sinohydro; also developer and contractor.
Governance of dam	No dedicated authority in charge of dam. Split responsibilities between Sinohydro and various ministries, most importantly the Ministry of Industry, Mines and Energy (MIME) and the Ministry of Environment (MoE). Hierarchical and partly non-transparent communication and decision-making process between these organizations.
Impact on livelihoods	Negative impacts on livelihoods as about 22 000 people are directly affected by the dam. Those affected the hardest are poor bamboo collectors who cannot enter their original bamboo area due to the dam construction and fruit sellers who are vulnerable due to a sharp decline in tourism following the dam-building. A lack of alternatives and the absence of any assets have driven local villagers to borrowing money from micro-credit institutions and considering becoming migrant workers in Phnom Penh and Thailand. Many villagers still do not have access to electricity.
Resettlements	No resettlement, although 10 families live under power lines and will have to be resettled in the future.
Compensation	Yes, no complaints, but no standardized or formalized process.
Location of dam	In Bokor National Park.
Impact on environment	Loss of forest and bamboo habitats, threats to a wide range of species, including 10 endangered species such as the Asian elephant, the sun bear, the leopard cat and the tiger.
Responsible government authorities	Ministry of Industry, Mines and Energy (MIME), Ministry of Water Resources and Meteorology (MOWRAM), Ministry of Environment (MoE).
Legislation	BOT projects have to be approved by the Council for the Development of Cambodia (CDC). Law on Water Resource Management; all hydropower projects require a water use license from MOWRAM. Law on Environmental Protection and Natural Resource Management, Forestry Law and a complex and as yet underdeveloped Land Law that has to be complied with.
EIA process	Major flaws, EIA process violated Cambodian law, EIA approval received 7 months after the dam was in operation.
Consultation process	Patchy consultation process, many locals were not invited and only knew of dam plans once construction had begun.

Table 5. Wider implications of technology transfer for Kamchay Dam

Discussion and Conclusion

This paper aimed to discuss the opportunities, barriers and implications of the technology transfer deal between China and Cambodia for the Kamchay Hydropower Dam and to elaborate what this means for sustainable development.

Technologically, Chinese dam-builders are at the cutting-edge of dam-building, constructing the largest and most complex dams on Earth. Chinese actors are also the leaders in the field of South–South low-carbon energy technology transfer, most notably in the hydropower sector (International Rivers, 2014). From the outset they offer rare opportunities for enabling sustainable development, economic growth and modernity to low-income countries that are affected by energy poverty.

However, there are a set of barriers: low-income countries such as Cambodia have very little capacity to absorb these technologies and to manage and operate them, let alone to become innovators in hydropower dams themselves. In relation to the Kamchay Dam, Cambodia's first large hydropower dam, the paper finds that, while hardware has successfully been transferred, the skills, knowledge, expertise and experience of how to operate, manage and build dams rest almost entirely with the Chinese dam-builders, most importantly with Sinohydro. The implications are that the engineering, human, managerial, organizational and financial resources are lacking in Cambodia to run the dam and to be able to build dams themselves without foreign help.

This finding is reiterated by other studies. Im (2010) confirms that 'In Cambodia hydropower development depends almost entirely on technical and financial assistance from outside dominated by Chinese firms. The country

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is facing severe lack of local capacity in identifying needs, project planning and operation, not only in hydropower but also in other related fields such as fishery biodiversity, which is expected to be largely affected by hydropower development' (Im, 2010, p. 2).

This situation is understandable, as Cambodia is a low-income country. Attracting investments by Chinese dam-builders has been an effective tool to help overcome energy poverty, power economic growth and strive for sustainable development. However, in the long run the flow of technology transfer needs to move beyond a technical fix on hardware and include the transfer of 'software' such as skills and know-how for operation and maintenance as well as the transfer of knowledge and expertise for innovation. South–South technology transfer arrangements in dam-building should therefore include training options and create opportunities for building up domestic production and innovation capabilities such as promoted by staff exchanges, training, joint R&D, joint ventures etc.

We conclude that, while South–South technology transfer of low-carbon energy innovation can offer opportunities for sustainable development, it can only be fully successful when host governments have the capacity to absorb new technologies. This means that the transfer of technologies needs to go hand in hand with the development of adequate management frameworks, comprehensive social and environmental policies and guidelines, and an inclusive public consultation process. In addition, the long-term sustainability of the practices of the technology-transferring country and firms needs to be improved to ameliorate the capacities for low-carbon technology transfer on both the recipient and the technology-transferring side. This could include training more technicians and engineers from low-income countries in China to help build up the indigenous hydropower capacity in low-income countries, first in terms of productive capabilities, later in the form of innovative capabilities. This requires moving towards more advanced forms of technology cooperation. Byrne *et al.* (2011, 2012) and Ockwell and Mallett (2012) even suggest going one step further by fostering not only technology transfer, but also wide-ranging socio-technical transformations. In the future different forms of technology cooperation may be more conducive for promoting sustainable development for Cambodia. This could include licencing hydropower technology for reverse engineering, joint R&D, joint ventures and acquisitions of parts of small Chinese hydro firms (e.g. R&D bureaus) by Cambodian firms. This is however made more difficult by the scale of large dams. In general, small hydropower might be more suitable for building up absorptive, production and innovative capabilities than large dams for countries with little hydropower experience and limited capacity. This revised approach to South–South technology transfer and cooperation may offer new opportunities for sustainable development for low-income countries.

Further empirical research needs to be conducted on South–South technology transfer and its implications, beyond Cambodia, China and the dam debate. Further research needs to analyse particularly how skills and knowledge for operation and maintenance (know-how) and knowledge, expertise and experience for generating and managing technical change (know-why) for low-carbon energy technology can best be transferred from emerging economies to low-income countries in the long term and how positive impacts can be maximized and negative impacts minimized, particularly in relation to people's lives and livelihoods.

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