



Technology transfer in the hydropower industry: An analysis of Chinese dam developers' undertakings in Europe and Latin America[☆]

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ABSTRACT

Technology transfer is essential for transitioning to a low carbon economy which can include hydropower. Chinese dam developers allegedly dominate the global hydropower industry. Studies have been carried out on technology transfer in their undertakings in Africa and Asia. However, such work is lacking for Europe and Latin America. The aim of this paper is to identify the extent, drivers and inhibitors of technology transfer of Chinese dam developers' undertakings in Europe and Latin America. We find relatively few Chinese undertakings and thus limited evidence for technology transfer both in Europe and Latin America. Transfers identified are frequently mutual with the Chinese player transferring technology to the host country and vice versa. This transfer is driven by business considerations in Europe (costs, capacities) and Latin America (costs, lacking access to finance), but also geopolitical ones (Europe: creation of a trading area; Latin America: access to (natural) resources). It is impeded by Chinese dam developers' poor reputation regarding safeguards as well as (only in Latin America) protectionist policies and significant capacities of host country players. Our research provides transparency regarding the European and Latin American hydropower industry, while also highlighting that attempts to influence what kind of technology is transferred by Chinese dam developers may be worthwhile.

1. Introduction

The transition towards a low carbon economy is seen as a major challenge by policy-makers around the world (Bridge et al., 2013; Geels, 2012). Hydropower dams are considered by many as a part of the energy mix of a low carbon economy, particularly for developing countries which have not exploited many economically viable hydropower sites yet (Gernaat et al., 2017; Zarfl et al., 2015). Hydropower already provides 16% of the global electricity and about 85% of global renewable electricity (IEA, 2016). Its role as a renewable electricity source is projected to grow in the coming years due to an unprecedented boom in dam construction currently under way with installed global hydropower capacity expected to increase by 73% until 2040 (Zarfl et al., 2015). Despite this boom, hydropower remains extremely contested due to its vast negative environmental and social impacts (Khagram, 2004; Kirchherr et al., 2016a; McCully, 2001; WCD, 2000). Some have even questioned if hydropower is an appropriate

technology to use because of these impacts (Ansar et al., 2014; Kirchherr, 2017a; Warner et al., 2017).

Mitigating hydropower dams' negative environmental and social impacts is a challenge, as is their construction from an engineering standpoint, particularly for many energy-hungry developing countries (Biswas, 2012; Hensengerth, 2015a). Traditionally, the World Bank as the largest international donor linked to hydropower facilitated technology transfer (term defined in Section 3) to enable developing countries to exploit their hydropower resources (Kirchherr et al., 2017; Park, 2010). However, a funding gap opened when World Bank decided to opt out of hydropower dam financing in the early 2000s due to the massive public protests.¹ This funding gap helped to prepare the ground for the rise of Chinese players in the global hydropower industry (Biswas, 2012; International Rivers, 2012; Kirchherr, 2017b; McDonald et al., 2009). It coincided with the Chinese government's 2001 Going Out Strategy which encouraged SOEs to expand abroad to continue their growth and increase Chinese influence (Chen et al., 2017; Motta

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¹ The World Bank has engaged again in hydropower financing again around 2010 (Kirchherr et al., 2017; Park, 2010).

and Matthews, 2017).

Chinese hydropower dam developers² are said to dominate the global dam industry nowadays (Urban et al., 2015a, p. 577 ff.; Verhoeven, 2015, p. 178 ff.). Yet a comprehensive and up-to-date public database on dam projects with Chinese involvement around the world is not available (Kirchherr, 2017b). Most scholars, e. g. Urban et al. (2013) and Kirchherr et al. (2017b), seeking data on such involvement rely on the database developed by International Rivers, an NGO mostly advocating against large dams (Eichert, 2014), which was last updated in November 2014 (International Rivers, 2014). However, the industry is dynamic and much has changed since 2014 (Tan-Mullins et al., 2017).

Sinohydro is believed to be the largest dam developer in the world allegedly constructing every second dam globally (Mang, 2012, p. 2; Verhoeven, 2015, p. 124). The second major Chinese dam developer is China Three Gorges Corporation (CTGC) which built the infamous China Three Gorges Dam (Wilmsen and Webber, 2016; Xu et al., 2011). Other major Chinese dam developers are China International Water and Electric Corporation (CWE) and China Gezhouba Group (International Rivers, 2015; Mang, 2012; Urban et al., 2015b). All of these companies are state-owned enterprises (SOEs) (McDonald et al., 2009).

Numerous scholars have studied Chinese dam developers' engagement overseas in recent years. Two observations stand out when examining this body of literature. First, only a single study, Urban et al. (2015b), considers Chinese dam developer' involvement from the perspective of technology transfer despite hydropower dams' alleged role as a (challenging to develop) source of renewable electricity for developing countries aiming to transition to a low carbon economy. Second, current studies focus on dam projects with Chinese involvement in Asia (e. g. Matthews and Motta, 2015, Hensengerth (2015a, 2015b), Chan, 2017, Lamb and Dao, 2017) and Africa (e. g. Hensengerth, 2012, Kirchherr et al., 2016b, Yankson et al., 2017) or both Asia and Africa (e. g. Tan-Mullins et al., 2017, Siciliano and Urban, 2017, Urban et al., 2015a), while neglecting other parts of the world.³

The regional focus of this study is Europe and Latin America (we consider those countries to be part of Europe respectively Latin America that have been outlined as such by WHO (2017a, 2017b). Europe and Latin American may be regions of specific interest for at least two reasons. First, both regions are viewed as regions declining in power (Edwards, 2009; Webber and Douglas, 2016) with rising powers such as China possibly exploiting this decline (Christensen, 2015). Second, Europe and Latin America appear as notable markets for Chinese hydropower players with every tenth dam with Chinese involvement being constructed in Europe and Latin America, according to International Rivers (2014).

This paper aims to advance the literature on Chinese dam developers by providing a helicopter view on technology transfer in Chinese dam developers' undertakings in Europe and Latin America.⁴ This is the first study that specifically examines Chinese undertakings in Europe and Latin America and thus also technology transfer in Chinese dam developers' undertakings in these parts of the world, as far as we are aware. We examine the extent, drivers and inhibitors of technology

² We usually abbreviate 'Chinese hydropower dam developers' with 'Chinese developers' throughout this study to enhance readability. We note that a 'Chinese hydropower dam developer' can also be a firm that merely provides elements of the hydropower dam, e. g. turbines.

³ Two exceptions regarding the second observation are acknowledged. First, McDonald et al. (2009) provide a global overview regarding Chinese dam developers' undertakings. Second, Nordensvard et al. (2015) examine Sinohydro's policy documents. Yet both of these studies lack specific discussions regarding relevant undertakings in selected regions such as Europe and Latin America. We further note that information regarding technology transfer in undertakings involving Chinese dam developers can be retrieved from studies mentioned in this paragraph beyond Urban et al. (2015b), whereas technology transfer is not the theoretical framing of these studies.

⁴ We do not examine European and Latin American dam developers' undertakings in China via this work.

transfer in Chinese dam developers' undertakings in Europe and Latin America. To do so, we have carried out more than 40 semi-structured interviews with relevant industry players in 2015, 2016 and 2017 including interviews with several Chinese dam developers such as CTGC and CWE. These interviews are complemented by document analysis. Overall, we find relatively few undertakings of Chinese dam developers both in Europe and Latin American and thus limited evidence for technology transfer. The technology transfer identified is frequently mutual with the Chinese dam developer transferring technology to the host country and vice versa. It is driven both by business and geopolitical considerations. Meanwhile, it is inhibited by Chinese dam developers' dismal reputation regarding safeguards and (only in Latin American) protectionist policies and significant capacities of host country players.

The remainder of this paper is organized as follows. Section 2 provides background regarding the hydropower industry in Europe and Latin America. Section 3 outlines technology transfer as the theoretical framing for this study. Section 4 presents our methods. Meanwhile, Section 5 analyzes the technology transfer and its drivers and inhibitors for Chinese dam developers' undertakings in Europe and Latin America. We summarize our argument and outline policy implications of this work in Section 6.

2. Background

While Europe as a global power may be declining, electric power consumption per capita in Europe remains among the greatest in the world (World Bank, 2017a). Hydropower provides around one-third of this electricity (World Bank, 2015). Countries such as Norway gain more than 95% of their electricity from hydropower (World Bank, 2015). Yet hydropower development in Europe is stagnating since the most lucrative sites have already been developed in the first half of the 20th century (Biswas, 2012). The exception are selected countries in Eastern Europe which can still hold large unexploited and economically viable hydropower potential (IHA, 2017; World Energy Council, 2016a). Interviewees noted that the general stagnation of hydropower development in Europe has led to a decay of hydropower capacities among many European players (further information on interviewees in Section 4). "The Chinese outcompete us on [technical] capacities to construct large dams", a European dam developer said. This resonates with Kirchherr et al. (2016b) who writes that Chinese developers would be known for delivering "large dam projects with relatively few overruns in either the schedule or budget".

Interviewees shared the impression that Chinese dam developers are extremely active in Europe and even felt threatened by them at times. For instance, a policy-maker at the European Investment Bank (EIB) complained that "the Chinese are trying to steal our projects", whereas he acknowledged that EIB does not systematically scan Chinese dam developers' undertakings in Europe. However, the extent of Chinese undertakings in Europe is limited, according to our study. A total of 15 Chinese undertakings were identified via our work (Table 4). This accounts for a maximum of one-tenth of total undertakings in Europe, according to estimates from our interviews. The identified undertakings are concentrated in Eastern Europe. Most (three) are in Russia, followed by Macedonia and Georgie (two each). Of the identified undertakings, five are proposed, one under-construction, seven are completed and one is suspended.⁵

While electricity consumption in Europe is significant, the opposite is true in Latin America. Only Africa consumes less electricity per capita than Latin America. Much of Latin America's energy stems from hydropower, with the region accounting for over 20% of global hydropower production (IHA, 2017; Rubio and Tafunell, 2014). Excluding China, Latin America has experienced the fastest hydropower growth in

⁵ We could not determine the status of one undertaking.

the world over the last 30 years (IHA, 2017; Rubio and Tafunell, 2014). The rapid rise of hydropower across the region was primarily an outcome of the oil crisis of the 1970s, as the region was largely dependent on oil for energy production and rapidly had to diversify its energy mix. Hydropower development further accelerated from the 1980s onwards as technology and expertise in the region became more cost-effective and enhanced (Rubio and Tafunell, 2014). Latin American hydropower dam developers are infamous for their ability to develop extremely complex mega projects since the completion of the Itaipu HPP in 1984 (built by Unicon, a Brazilian player, and Conempa, a Paraguayan player (Itaipu Binacional, 2017)); the Itaipu HPP is the largest operational hydroelectric energy producer in the world until today (PT, 2017a).

Our interviews revealed that a common perception among observers of the Latin American dam industry is that, like Europe, Chinese dam developers are extremely active on this continent. However, when examining the data in more detail we found that “there is much less [going on] than perceived”, as a consultant of a Chinese dam developer also claimed. Overall, 29 undertakings and thus almost twice as many as in Europe were identified (Table 5). No estimate was attainable as to how this number compares to the total number of relevant undertakings in Latin America; accessing data on Latin American endeavours was more difficult for us than for the European case. We suspect that the undertakings with Chinese involvement in Latin America also account for no more than one-tenth of all relevant undertakings in this region. Chinese dam developers’ engagement in Latin America would then need to be considered as limited. Most undertakings (ten) are in Ecuador, followed by Honduras (four). Of these undertakings, eight are proposed, eleven are under-construction, nine are complete and one is suspended.

3. Theoretical framing

Lacking access to technology is seen as a major bottleneck for developing countries aiming to transition towards a low carbon economy (Li, 2016; van der Gaast et al., 2009). Technology transfer emerged as a possible response to this bottleneck in the early 1990s (Bell, 1990; Schnepf et al., 1990); it is considered as “a cornerstone” (Lema and Lema, 2012, p. 24) of the transition towards a low carbon economy since the Intergovernmental Panel for Climate Change (IPCC) featured it prominently in its 2000 report (IPCC, 2000). Technology transfer is defined as the movement of technology from the site of origin (in our case: China) to the site of use (in our case: Europe respectively Latin America) (Ahmed, 2009, p. 3). This definition implies that even if a technology is already in use in a recipient country, further transfer of this technology to this country can still occur. While the technology transfer concept has been hyped, a lack of progress is to be reported in achieving technology transfer in practice. This may have induced a broader conceptualization of the term in recent years (Ockwell et al., 2010; Pueyo et al., 2011).

We consider *dimensions*, *channels* and *types* of technology transfer throughout this study. Hardware and software are the main *dimensions* of technology transfer, a conceptualization introduced by Bell (1990) and further refined by Bell (2009) and Ockwell et al. (2010). Early literature on the topic mostly conceptualized technology transfer as hardware transfer (Lema et al., 2015; Pueyo et al., 2011). Hardware refers to all technology needed to create the physical facilities (in our case: a hydropower dam) envisaged by the technology transfer recipient. It thus comprises capital goods and equipment (e. g. turbines) as well as services such as engineering services to produce the dam design or consultancy services to develop an environmental and social impact assessment (ESIA). Any dam project built outside of China by a Chinese dam developer is thus an instance of hardware transfer. This even includes a hydropower dam built by a Chinese player without any participation of the host country which is then handed over to operators from the host country once completed.

Meanwhile, software refers to skills needed upon the completion of

the physical facilities at question. Software transfer is now considered as essential for successful technology transfer. A successful technology transfer is one that does not only provide hardware, but that also enables the recipient country to operate/maintain, replicate and innovate the received hardware (Ockwell and Mallett, 2012; Pueyo et al., 2011). Software can be differentiated in know-how and know-why skills. Know-how skills are the skills enabling the operation and maintenance of the physical facilities at question. For instance, these can include know-how regarding sedimentation management for a hydropower dam (Dai and Liu, 2013; McCully, 2001). A minimum level of expertise is usually needed for the recipient country to be able to (learn to) operate a technology (Hensengerth, 2015b; Omar et al., 2011).⁶

Know-why skills refer to the ability to understand the principles of how the physical facilities at question work. These know-why skills are thus essential for the replication of the work via another project and for further innovation of facilities (Bell, 2009; Lema and Lema, 2012). Let us assume that a project was completed by a Chinese developer with this developer using a novel technique for underground works during the project.⁷ If this novel technique was not explained to those in the recipient country throughout or upon completion of the project, no know-why skills have been transferred. The country would thus not be better off in carrying out a specific task (in this case: constructing a dam) despite this task having been carried out within the country's borders. The transfer of know-why skills may be facilitated if a local partner participates in a project (Urban et al., 2015b). Since we found no evidence of know-why transfer in this study, we do not list it in the key tables of this paper, Tables 3–5.

While international donors such as the World Bank played a major role in enabling technology transfer initially, as indicated in the introduction, the main source for technology transfer these days is the private sector (e. g. argued by IPCC, 2000, Kulkarni, 2003 and Schneider et al., 2008). The *channels* of private sector technology transfer considered in this study are trade and foreign direct investment (FDI) (Niederberger and Saner, 2005; Schneider et al., 2008) with the former being the far more common one (Schneider et al., 2008, p. 2931 ff.).⁸ The combination of trade and FDI are called ‘undertakings’ throughout this paper. Technology transfer via trade occurs through provision of hardware and/or software (e. g. for the construction of a hydropower dam) to the recipient country. Meanwhile, technology transfer via FDI occurs through investments made by foreign entities (e. g. a Chinese dam developer) in local entities (e. g. a European dam developer or a specific Latin American dam project), which enables the investor to exchange hardware and software with the (partly) purchased entity.

We find and thus distinguish two *types* of technology transfer in this study (Lema et al., 2015; Winstead, 2014; World Bank, 2017b). North-South technology transfer (NSTT) and South-South technology transfer (SSTT). NSTT is technology transfer from developed to developing countries; it is the type of technology transfer considered most frequently in the scholarly literature (Lema and Lema, 2012; Urban et al., 2015b, 2015c). SSTT is technology transfer from developing to developing countries. The latter type of technology transfer has only been considered very recently by scholars (Norasingh et al., 2015; Urban

⁶ Build-Operate-Transfer (BOT) contracts offer some solution for countries lacking this minimum level of expertise. Projects under BOT contracts are not only designed, financed and constructed by a dam developer, but then also operated by this developer (International Rivers, 2012). An example of this is Cambodia's Kamchay Dam which will be operated by Sinohydro for 44 years. This allows Cambodia to benefit from this technology, although it may be unable to operate it (Hensengerth, 2015a; Siciliano et al., 2016).

⁷ This example was provided by a reviewer of this paper.

⁸ Schneider et al. (2008) also lists a third channel of technology transfer which is licensing, defined as the “purchase of production and distribution rights and the underlying technical information and know-how to exploit them” (Schneider et al., 2008, p. 2931). However, licensing is not practiced in the hydropower industry, as far as we are aware, and thus not considered in this study.

Table 1
Case studies.

Main case studies	Sinohydro China Three Gorges Corporation (CTGC)
Additional case studies	China Gezhouba China Harbin Electric International China Huadian Engineering China International Water and Electric Corporation (CWE) China National Electric Equipment Corporation (CNEEP) Dongfang Electric Corporation Guizhou Wujiang Hydropower Development Huaneng Langcang River Hydropower Hydro China Hyalancang International Energy Norinco International State Grid Yangtze Power

et al., 2015c). Admittedly, developing countries consist “of a diverse set of countries from emerging economies to low-income countries” (Lema et al., 2015, p. 184). We define those countries as developing countries that are denoted by the World Bank as low income (LI), lower middle income (LMI) or upper middle income (UMI) (with the latter category comprising countries such as Belarus and China), while developed countries are those denoted as high income (HI) (Lema et al., 2015; Winstead, 2014; World Bank, 2017b).

We acknowledge that some readers may disagree with the categorization of China as a player of the South, given China's already discussed (alleged) dominance in the global hydropower industry as well as its rise as a global power (Pan and Tin-Yau Lo, 2017; Zhang, 2016). The conceptualization of China as a player of the South is common in the relevant scholarly literature, though (Urban et al., 2015b, 2015c) and also consistent with our operationalization in the previous paragraph. We have therefore retained this conceptualization, while acknowledging that China may need to be re-categorized soon.

Drivers of technology transfer have been frequently discussed in the scholarly literature. We distinguish between business and geopolitical drivers throughout this study, a distinction inspired by Kirchherr (2017b). The business driver regarding technology transfer is the need of a stakeholder in the recipient country for a technology that either cannot be provided or cannot be provided cost-competitively domestically. The larger and thus more complex an envisaged project is (with thus only few companies having the relevant hardware and software), the more likely it is that technology transfer will occur and novel technology may be introduced to a country via this technology transfer (Gandenberger et al., 2016; Weitzel et al., 2015). Countries with comparatively low levels of development can be particularly susceptible for the transfer of capital goods, with other hardware such as equipment or engineering services being available domestically in principle once capital goods are secured (Gandenberger et al., 2016; World Bank, 2017b).

The scholarly literature further highlights that technology transfer can be facilitated, e. g. via preferential loans, if the provider maintains an interest to secure access to the market of the (potential) recipient and/or natural resources in the country at question (Foster et al., 2008; Prato and Nepelski, 2013). We call this latter driver a geopolitical driver. This driver can be of particular relevance if companies involved are SOEs (as is the case with Chinese dam developers, as outlined previously) which thus may particularly entangle business and geopolitical considerations. Our methods to gather empirical findings for the theoretical framing introduced in this section are discussed next.

Table 2
Interviewee overview.

#	Interviewee	Organization	Type of Organization
1	Professor	Tsinghua University	Academia
2	Professor	Chinese university	Academia
3	Researcher	Chinese university	Academia
4	Staff	International Finance Corporation (IFC)	International donor
5	Staff	European Investment Bank (EIB)	International donor
6	Staff	European Bank for Reconstruction and Development (EBRD)	International donor
7	Staff	Inter-American Development Bank	International donor
8	Staff	European development aid agency	International donor
9	Staff	Large international NGO	NGO
10	Staff	Large international NGO	NGO
11	Staff	Nature Conservancy	NGO
12	Staff	Regional NGO (Latin America)	NGO
13	Staff	Large international NGO	NGO
14	Staff	International Rivers	NGO
15	Managing director	Think tank	NGO
16	Staff	International NGO	NGO
17	Staff (Latin America)	Large international NGO	NGO
18	Staff (Latin America)	Large international NGO	NGO
19	Staff	World Wildlife Fund (WWF)	NGO
20	Staff	International NGO	NGO
21	Staff	China International Water & Electric Corporation (CWE)	Private sector
22	Staff	China Three Gorges Corporation (CTGC)	Private sector
23	Staff	Chinese dam developer	Private sector
24	Staff	Chinese dam developer	Private sector
25	Senior staff	Chinese dam developer	Private sector
26	Staff	European dam developer	Private sector
27	Staff	International Commission on Large Dams (ICOLD)	Private sector
28	Staff	International Hydropower Association (IHA)	Private sector
29	Senior engineer	European dam developer	Private sector
30	Chief executive officer (CEO)	Equipment supplier for hydropower dams	Private sector
31	Social impact assessment (SIA) consultant	Major European environmental and social impact assessment consultancy	Private sector
32	Project manager (Latin America)	ESIA consultancy	Private sector
33	Consultant (sub-contracted by Sinohydro)	ESIA consultancy	Private sector
34	Partner	Large strategy consultancy	Private sector
35	(Former) consultant	ESIA consultancy	Private sector
36	Consultant	ESIA consultancy	Private sector
37	Consultant	Major consultancy	Private sector
38	Consultant	Boutique hydropower consultancy	Private sector
39	Staff	Large law firm	Private sector
40	Director	Hydropower consultancy	Private sector
41	Director	Financier	Private sector

4. Methods

The chosen unit of analysis for this study and thus our case studies for this work are Chinese hydropower dam developers. This implies the exclusion of other players, e. g. those only constructing irrigation dams. We particularly focus on Sinohydro and CTGC, the largest Chinese dam developers, as outlined in Section 1, while also considering additional Chinese dam developers if relevant undertakings by these players are identified in Europe and/or Latin America. The different dam developers analyzed in this study are depicted in Table 1. We note these developers usually construct large dams with all HPPs considered in this study being large dams.⁹ We further note that some of the Chinese

Table 3
Summary of core findings.

		Europe	Latin America
Key Chinese Players		<ul style="list-style-type: none"> ● CNEEP ● CTGC ● CWE ● Norinco International ● Sinohydro ● State Grid ● Yangtze Power 	<ul style="list-style-type: none"> ● China Gezhouba ● China Harbin Electric International ● China Machinery Engineering Corporation ● CNEEP ● CTGC ● CWE ● Dongfang Electric Corporation ● Hydro China ● Sinohydro ● Hardware
Technology Transfer	<i>Dimension</i>	<ul style="list-style-type: none"> ● Hardware ● Software 	
	<i>Channel</i>	<ul style="list-style-type: none"> ● Trade ● FDI 	<ul style="list-style-type: none"> ● Trade ● FDI
	<i>Type</i>	<ul style="list-style-type: none"> ● SSTT ● NSTT 	<ul style="list-style-type: none"> ● SSTT
Drivers	<i>Business</i>	<ul style="list-style-type: none"> ● Costs ● Capacities 	<ul style="list-style-type: none"> ● Costs ● Lacking access to finance
	<i>Geopolitical</i>	<ul style="list-style-type: none"> ● Creation of trading area 	<ul style="list-style-type: none"> ● Access to (natural) resources
Inhibitors		<ul style="list-style-type: none"> ● Dismal reputation regarding safeguards 	<ul style="list-style-type: none"> ● Dismal reputation regarding safeguards ● Protectionist policies ● Significant capacities of host country players

dam developers considered are part of a conglomerate that constructs assets beyond hydropower dams. For instance, CTGC also has an installed capacity of 3.7 GW of wind and solar power (Li, 2015). For reasons of scope, we only focus on the parts of such conglomerates that relate to hydropower dam construction.

The choice to focus on Chinese dam developers reflects that the main source of technology transfer is the private sector, as outlined in the previous section. However, additional private sector players, most notably funders such as China Development Bank (CDB) or China Exim Bank (CEB), could have been chosen as a focus unit of analysis as well. While their perspective is of relevance to this study, we were largely unable to access them and thus decided not to focus on them; the empirical grounding of any in-depth discussion of their role would have been too thin.¹⁰

We attempt to generalize findings regarding Chinese dam developers' undertakings throughout this study since we are most interested in a "more general understanding of generic processes that occur across cases" (Miles and Huberman, 1994, p. 172). However, we acknowledge that "one [dam developer] can be very different to the other", as noted by NGO staff we interviewed, and that our attempt to generalize can thus induce misinterpretation and superficiality. Hence, we also attempt to differentiate as much as possible between the different Chinese dam developers throughout this study. We note that this latter attempt is exacerbated by the anonymity ensured to our interviewees.

Data for this study was collected via expert interviews. These were conducted in 2015, 2016 and 2017. Overall, 41 relevant interviews have been carried out (Table 2). We were particularly interested in interviewees with an overview regarding the hydropower industry, given that this study attempts to provide a helicopter perspective regarding Chinese dam developers' undertakings in Europe and Latin America. Most interviews were loosely structured. We ensured anonymity since we believe that this approach helped us to build trust and thus gain additional insights, as also argued by Berry (2002). We

⁹ A large dam is defined as any dam above 15 m in height (measured from the lowest point of foundation to top of dam) or any dam between 10 and 15 m in height which meets at least one of the following conditions: a) the crest length is not less than 500 m; b) the capacity of the reservoir formed by the dam is not less than one million cubic meters; c) the maximum flood discharge dealt with by the dam is not less than 2 000 m³ per second (ICOLD, 2015).

¹⁰ We also briefly considered to include the Asian Infrastructure Investment Bank (AIIB) as one of our case studies. However, we then found that AIIB does not sponsor hydropower dam projects, although it plans to do so in the near future (AIIB, 2017).

provide selected details regarding interviewees whenever possible. Information which is not referenced in Section 5 is derived from expert interviews, mirroring Urban et al. (2015c).

In addition to expert interview, document analysis (with documents considered being peer-reviewed articles, newspapers pieces and relevant industry reports) was carried out. We particularly undertook document analysis to update the list of dam projects with Chinese involvement in Europa and Latin America that has been provided by International Rivers (2014). For this purpose, we searched websites of Chinese dam developers regarding dam projects and also consulted the Environmental Justice Atlas (EJA, 2017). Furthermore, we undertook Google News Archive searches with a variety of different keyword combinations (e. g. 'CTGC' and 'Brazil') (we also asked interviewees regarding dam projects with Chinese involvement in Europe and Latin America). We identified a total of eight dam projects that are not listed in the database by International Rivers (2014) and complemented most of the entries in this database with up-to-date information. The relevant lists of dam projects are provided in Tables 4 and 5. These provide the most comprehensive overviews of dam projects with Chinese involvement in Europe and Latin America that is currently publicly available, as far as we are aware.

5. Results and discussion

This section starts by summarizing our core findings regarding technology transfer in Chinese dam developers' undertakings in Europe and Latin America. The two succeeding sub-sections are then structured as follows. First, we provide accounts of Sinohydro's, CTGC's and additional Chinese dam developers' undertakings in Europe respectively Latin America. We then discuss drivers and inhibitors of identified technology transfer. The core findings of this section are summarized in Table 3.

A dimension of technology transfer in Chinese dam developers' undertakings in Europe was found in nine instances.¹¹ All involve the transfer of hardware, but only three the transfer of software which reflects Urban et al. (2015b) who found evidence for the transfer of hardware in the case of Cambodia's Kamchay Dam, constructed by Sinohydro, but only limited software transfer. We further note, also

¹¹ Four of the identified undertakings are only proposed and thus no dimension of technology transfer has occurred for them yet. Meanwhile, insufficient information was gathered for two other undertakings.

Table 4
Hydropower industry undertakings with Chinese involvement in Europe.

Undertaking	Country	Height (m)	Size (MW)	Costs	Status	Start	Completion	Financier(s)	Dam builder(s)	Technology transfer		
										Dimension		
										Hardware	Software	Trade FDI
1 Bushat	Albania	N/A	40	150	Completed	2001	2008	CEB	CWE	✓	✓	SSTT
2 Dabar	Bosnia and Herzegovina	N/A	160	N/A	Under construction	2013	Ongoing	N/A	CWE	✓	✓	SSTT
3 Kaniv Pump Storage	Ukraine	74	1440	1400	Proposed	N/A	N/A	Chinese development bank	SinoHydro, UkrHydroEnerg	✓	✓	SSTT
4 Khadori	Georgia	N/A	24	33	Completed	N/A	2006	State Grid	State Grid	✓	✓	SSTT
5 Komarnica River	Montenegro	176	232	222	Proposed	N/A	N/A	N/A	SinoHydro, Norinco International	✓	✓	SSTT
6 Kozjak	Macedonia	130	82	N/A	Completed	1994	2002	N/A	CWE	✓	✓	SSTT
7 Neskra	Georgia	135	280	1000	Suspended	N/A	N/A	N/A	SinoHydro	✓	✓	SSTT
8 Nizhne Angarskaya	Russia	N/A	1100	N/A	Proposed	N/A	N/A	N/A	Yangtze Power, EuroSibEnerg	✓	✓	SSTT
9 Nizhne-Bureyskaya	Russia	47	320	408	Completed	2010	2016	N/A	CTGC, RusHydro	✓	✓	SSTT
10 Purchase of stake in EDP	Portugal	N/A	N/A	2700	Completed	2011	2011	CTGC	CTGC	✓	✓	NSTT
11 Tarnita-Lapustesti Pump Storage	Romania	N/A	1000	N/A	Proposed	N/A	N/A	N/A	Bids from two Chinese consortia ^a	✓	✓	SSTT
12 Trans-Sibirskaya	Russia	N/A	650	N/A	Proposed	N/A	N/A	N/A	Yangtze Power, EuroSibEnerg	✓	✓	SSTT
13 Ulog	Serbia	53	17.5	60	Completed	2012	2016	GDB	SinoHydro, EFT Group	✓	✓	SSTT
14 Vardar Valley ^b	Macedonia	N/A	N/A	1500	N/A	N/A	N/A	GDB	SinoHydro	✓	✓	SSTT
15 Vitebsk	Belarus	N/A	40	230	Completed	2011	2016	GDB	CNEEP	✓	✓	SSTT

^a First Chinese consortia: China Huadian Engineering with Guizhou Wujiang Hydropower Development, second Chinese consortia: Huaneng Langcang River Hydropower with HydroLancang International Energy.

^b Would comprise the construction of 12 HPPs.

Table 5
Hydropower industry undertakings with Chinese involvement in Latin America.

#	Undertaking	Country	Height (m)	Size (MW)	Costs	Status	Start	Completion	Financier(s)	Dam builder(s)	Technology transfer			Type
											Dimension		Channel	
											Hardware	Software		
1	Amatila Falls	Guyana	25	165	164	Suspended	2013	N/A	IADB, CDB, Low Carbon Development Strategy Fund, China Railway First Group, Norwegian Government	N/A	✓	✓	✓	SSTT
2	Aqua Zarca	Honduras	N/A	22	N/A	Under construction	2013	Ongoing	DESA	Sinohydro	✓	✓	✓	SSTT
3	Barinas	Venezuela	N/A	100	50	Under construction	2011	N/A	Sinohydro	Sinohydro	✓	✓	✓	SSTT
4	Capulin San Pablo	Costa Rica	51	50	N/A	Completed	2013	2017	N/A	Hydro China	✓	✓	✓	SSTT
5	Chaglla	Peru	202	462	1200	Completed	N/A	N/A	IADB	CTGC	✓	✓	✓	SSTT
6	Chalillo	Belize	45	7	30	Completed	2003	2005	Canadian International Development Agency	Sinohydro	✓	✓	✓	SSTT
7	Chucas	Costa Rica	63	50	N/A	Completed	2011	2016	N/A	Sinohydro	✓	✓	✓	SSTT
8	Coca Codo Sinclair	Ecuador	31	1500	1980	Completed	2010	2016	CEB	Sinohydro	✓	✓	✓	SSTT
9	Delisitanisagua	Ecuador	35	115	230	Under construction	2013	Ongoing	CDB	Hidronova, Hydro China	✓	✓	✓	SSTT
10	El Reventador	Ecuador	N/A	520	2690	Proposed	N/A	N/A	CEB	China Machinery Engineering Corporation, Sinohydro	✓	✓	✓	SSTT
11	Jupia/Ilha Solteira	Brazil	53/76	4950	1480	Completed	N/A	N/A	CTGC	N/A	✓	✓	✓	SSTT
12	Magdalena River	Colombia	30–150	N/A	N/A	Proposed	N/A	N/A	CDB	Hydro China, Cormagdalena	✓	✓	✓	SSTT
13	Mazar-Dudas	Ecuador	N/A	21	51	Completed	2011	2017	CDB	CNEEP	✓	✓	✓	SSTT
14	Mians Jobones	Ecuador	N/A	335	552	Proposed	N/A	N/A	Bank of China, IADB, Andean Development Corporation, Ecuador Government	N/A	✓	✓	✓	SSTT
15	Mimas San Francisco	Ecuador	78	276	477	Under construction	2014	2017	CDB, CEB	China Harbin Electric International, Sinohydro, Cardno	✓	✓	✓	SSTT
16	Néstor Kirchner/Jorge Cepernic	Argentina	75/43	1740	4000	Under construction	2015	Ongoing	CDB, Bank of Communications	China Gezhouba, Electroingenieria, Hydrocuyo	✓	✓	✓	SSTT
17	Ocana	Ecuador	N/A	26	37	Under construction	2008	N/A	Bank of China, IADB, Andean Development Corporation, Ecuador Government	Alstom Hydro Espana	✓	✓	✓	SSTT
18	Patuca II	Honduras	105	270	N/A	Proposed	N/A	N/A	N/A	Sinohydro	✓	✓	✓	SSTT
19	Patuca IIA	Honduras	N/A	150	N/A	Proposed	N/A	N/A	N/A	Sinohydro	✓	✓	✓	SSTT
20	Patuca III	Honduras	55	105	350	Under construction	2011	Ongoing	Industrial and Commercial Bank of China	Sinohydro, Dongfang Electric Corporation	✓	✓	✓	SSTT
21	Quijos	Ecuador	144	50	N/A	Under construction	N/A	Ongoing	CDB, CEB	CNEEP	✓	✓	✓	SSTT
22	Reventazon	Costa Rica	130	306	1400	Completed	2010	2016	IFC, IADB, EIB, Costa Rican Government, CEB	Andritz, Sinohydro	✓	✓	✓	SSTT
23	San Gaban III	Peru	N/A	260	438	Proposed	N/A	N/A	N/A	CTGC/EDP	✓	✓	✓	SSTT
24	Santa Maria	Peru	137	750	1600	Proposed	N/A	2020	N/A	China Gezhouba, Energia Azul	✓	✓	✓	SSTT
25	Santo Antonio	Brazil	14	3150	N/A	Completed	2008	2012	State Power Investment Corporation	Consortium of Brazilian players	✓	✓	✓	SSTT
26	Sao Luiz de Tapajos	Brazil	53	8040	5800	Proposed	N/A	N/A	N/A	CTGC	✓	✓	✓	SSTT
27	Sopladora	Ecuador	N/A	487	755	Completed	2011	2016	CEB	China Gezhouba	✓	✓	✓	SSTT
28	Toachi Platon	Ecuador	60	253	589	Under construction	2010	N/A	Rosximbank, Bank of the Ecuadorian Institute of Social Security	CWE, Inter PAO UES	✓	✓	✓	SSTT
29	Vaca	Belize	N/A	18	39	Completed	2007	2010	N/A	Sinohydro	✓	✓	✓	SSTT

echoing Urban et al. (2015b), that we did not find evidence for the transfer of know-why skills as a sub-dimension of software in any of the undertakings. Technology transfer occurred via fourteen dam projects and one merger. This indicates that trade may indeed be a much more common channel of technology transfer than FDI, as already outlined by Schneider et al. (2008). Seven of the 15 undertakings (47%) include Chinese financing. Meanwhile, six of the 14 dam projects (43%) comprise a collaboration of a Chinese dam developer with a domestic player. The technology transfer undertakings identified are cases of (mostly) mutual SSTT except for one (a case of NSTT; further discussed below) which indicates that players in developed countries are apparently largely not considered as a necessity to carry out large HPPs.

Meanwhile, a dimension of technology transfer in Chinese dam developers' undertakings in Latin America was found in 17 instances.¹² All relate to the transfer of hardware, but no instance of software transfer, with hardware transfer thus being even more dominant than software transfer in Latin America than in Europe. Consequently, no instances of know-why transfer were identified. Furthermore, 21 instances of dam construction by a Chinese company and thus trade were identified as well as three cases of Chinese dam developers purchasing an existing hydropower asset which is an example of FDI (Schneider et al., 2008). 17 of the 29 undertakings (59%) include Chinese financing, a share more than 10% higher than in Europe. Meanwhile, 8 of the 29 dam projects (28%) comprise a collaboration of a Chinese dam developer with a domestic player. The type of technology transfer is (frequently mutual) SSTT for the identified undertakings, according to our research.

5.1. Technology transfer in Chinese dam Developers' undertakings in Europe

5.1.1. Sinohydro

Sinohydro is involved in more undertakings in Europe (five) than any other Chinese dam developer which indicates that it may be the largest Chinese dam developer, as already argued by Urban et al. (2015a) and Verhoeven (2015). Only limited evidence was found regarding dimensions of technology transfer in these projects. The only dimension of technology transfer identified is hardware transfer via trade that is Chinese-led SSTT. It relates to the construction of the 17.5 MW Ulog HPP in Serbia which is also the only project of Sinohydro in Europe that is listed on the company's website (Sinohydro, 2017a). Sinohydro was subcontracted for this project by EFT Group, a European energy trading and investment group, via an engineering, procurement and construction (EPC) contract¹³ with EFT Group now operating the HPP for 30 years (EFT Group, 2017; Yankson et al., 2017). The set-up of this project resembles the 400 MW Bui HPP in Ghana, also constructed by Sinohydro, which is now operated by the Ghanaian Bui Power Authority (BPA) (Hensengerth, 2012; Kirchherr et al., 2016b).

5.1.2. CTGC

CTGC features two undertakings in Europe, according to our research. This is surprising given that CTGC's (2015) annual report, its last annual report that is available online, states that developing small and medium HPPs in Europe is a strategic priority for CTGC (CTGC, 2015). Both undertakings, unlike Sinhydro's Ulog HPP (which merely focused on design of, procurement for and construction of the project),

¹² Eight of the identified undertakings are only proposed and thus no dimension of technology transfer has occurred for them yet. Meanwhile, insufficient information was gathered for four undertakings.

¹³ Under an EPC contract (also called 'turnkey contract'), the contractor has the duty to design, procure and construct the entire project. This arrangement thus places the responsibility for the entire project in the hands of the contractor. A fixed pricing method is usually used for these types of contracts. The EPC contractor does not operate the project once completed (unlike the BOT contractor) (Chen and Landry, 2016; International Rivers, 2012).

feature hardware as well as software transfer. The identified instance of trade that is mutual SSTT is the 320 MW Nizhne-Bureyskaya HPP in Russia. The project was constructed in a joint venture with RusHydro, a Russian dam developer, with both companies now also responsible for the operation of the HPP (and CTGC carrying out some training regarding operation for RusHydro) (PT, 2017b). Meanwhile, CTGC's most notable activity in Europe in recent years (in 2011) was its purchase of a 21% stake in EDP, a Portuguese dam developer (Bugge, 2011). Our interviews suggest that this FDI may be best understood as evidence for NSTT from the Portuguese player to CTGC.

5.1.3. Additional Chinese dam developers

The Chinese dam developer most active in Europe after Sinohydro is CWE with three identified undertakings. These involved the transfer of hardware. For instance, State Grid, the second largest company in the world by revenue, has constructed and is now also operating since 2006 the 24 MW Khadori HPP, the first foreign-funded power station in Georgia, an instance of trade that is SSTT (Xinhua, 2017). Evidence for the transfer of software beyond the CTGC instance was found in the 40 MW Vitebsk HPP in Belarus which is carried out by CNEEC, another instance of trade that is Chinese-led SSTT, according to our research. The firm was not only hired to commission the HPP, but also to provide maintenance during the warranty period, and train domestic personnel which is supposed to operate the HPP upon completion of this training (Belarus.by, 2015).

5.1.4. Drivers

An important driver of technology transfer in the European market are business considerations. The cost-competitiveness of Chinese bids is a key driver (Kirchherr et al., 2017) with some bids being 25% cheaper than the second cheapest (non-Chinese) bidder. Furthermore, Chinese and European dam developers are both keen to learn from each other. For instance, CTGC was onboarded in the Nizhne-Bureyskaya project since the Russian dam developer was keen to gain both hardware and software via CTGC's involvement. Meanwhile, CTGC was and is keen to enter the European and Latin American market, but potential customers believed it would lack the needed ability to implement internationally recognized safeguards. These safeguards constitute a hardware which CTGC hoped to acquire via the purchase of the EDP stake – the only identified instance of NSTT in our study. This indicates that safeguards may be the only remaining hardware part of HPP technology where players from the North still have an edge over Southern players. "China Three Gorges Corporation tried to enter [the European and Latin American] market for decades. They just couldn't do it alone", a consultant who advised EDP told us.

Interviewees also noted that Chinese players need local engineers for dam construction despite their vast experiences with dam construction gained in China (McDonald et al., 2009). One consultant explained that the Chinese "don't know our rocks here, our soil, the topography. You need local knowledge for this which only our engineers have". Chinese developers interviewed acknowledged this and also outlined that they would be keen to learn from their European partners in projects beyond contextual aspects of dam construction. "We [...] need more exchange [...] in terms of what is the newest technology available and what could be the most sustainable technology", a Chinese dam developer said.

The described business drivers must also be seen in the context of geopolitical drivers. These are formalized for Europe via the One Belt One Road Initiative (OBOR), a Chinese-led strategy. Its aim is to increase cooperation between Eurasian countries with the intention of creating a trading area that can rival the transatlantic one which is dominated by the United States (Du, 2016; Lee and Lye, 2016). This initiative covers more than half of the world's population, 75% of its energy resources and 40% of its GDP (Shepard, 2016). For instance, China's political leadership has pledged to invest in Georgia's hydropower sector as part of OBOR (Xinhua, 2016). Similarly, the Vitebsk

HPP in Belarus has been explicitly framed by the Chinese political leadership as a project that needs to be seen as part of this initiative (Belarus News, 2016). We note that none of the undertakings we examined in Europe seem to be driven by Chinese attempts to securing access to natural resources. Belarus is even known as a country with very limited natural resources (Rapoza, 2017).

5.1.5. Inhibitors

Chinese players' reputation regarding the non-adherence to safeguards acts as the main inhibitor regarding Chinese-led undertakings in Europe, according to our research. This connects to McNally et al. (2009) as well as a recent study by Kirchherr et al. (2017) that outlined that 57% of those involved in the hydropower industry in Myanmar, Laos and Cambodia find Chinese dam developers' performance regarding social safeguards to be poor. A case in point for reputation issues in Europe is Sinohydro. Overall, our research indicates that Sinohydro has had difficulties in entering the European market. For instance, we found that the dam developer aimed to provide, via trade, Chinese-led SSTT in countries such as Georgia and Montenegro. However, its contract for the construction of the 280 MW Neskra HPP in Georgia was terminated (despite the outlined Chinese pledge on developing Georgia's hydropower industry) with the HPP now taken over by a consortium that includes the European Bank for Reconstruction and Development (EBRD). Meanwhile Sinohydro initially expressed interest in developing Montenegro's Komarnica River, but eventually did not submit a bid, allegedly because it deemed the site to have too grave geological problems. Interviewees suggested, though, that it was indicated to Sinohydro that it would be unable to win the respective bid due to its reputation not to uphold international safeguards. CTGC's inability to carry out more dam projects in the European market despite its explicit positioning towards Europe also indicates that its reputation regarding safeguards acts as an inhibitor of technology transfer. Overall, the limited involvement of Chinese dam developers in Europe suggests that the identified problematic reputation regarding safeguards as an inhibitor outweighs the outlined drivers at this moment. More NSTT regarding safeguards may be needed to change this.

5.2. Technology transfer in Chinese dam developers' undertakings in Latin America

5.2.1. Sinohydro

Sinohydro is involved in more undertakings (twelve) than any other Chinese dam developer, according to our research. Thus, it is likely the most dominant Chinese dam developer in the Latin American market. Evidence for Sinohydro-led hardware transfer was found in nine of these instances with Sinohydro usually acting as an EPC contractor in these projects. One example of a recently completed EPC project is the 1500 MW Coca Codo Sinclair HPP in Ecuador, the largest energy project in the country's history which now supplies 44% of Ecuador's electricity needs (PT, 2017c). This project is now operated by Empresa Pública Estratégica Hidroeléctrica, an Ecuadorian player (Sinohydro, 2017b).

5.2.2. CTGC

CTGC features three undertakings in Latin America, according to our research. This number is surprisingly small, given CTGC's purchase of a part of EDP to significantly expand in the Latin American market, as discussed earlier. The only undertaking of an instance of trade identified that resulted from this purchase is the 260 MW San Gaban III in Peru which was won by Hydro Global Peru which, in turn, is composed of CTGC and EDP (Ingram, 2016). Meanwhile, CTGC acquired the operational HPPs in Brazil, the Jupia and Ilha Solteira HPPs with a joint capacity of 4950 MW (Li, 2015), while it also just acquired the operational 462 MW Chaglla HPP (Weinman, 2017), two instances of FDI. We believe these investments can be seen as efforts to gain a foothold in the Latin American market.

5.2.3. Additional Chinese dam developers

The only Chinese dam developer that is comparably active to Sinohydro and CTGC in Latin America is China Gezhouba with three undertakings. These all involve hardware transfer via trade. The different HPPs are usually carried out in a collaboration of a Chinese dam developer and additional non-Chinese players. For instance, the 750 MW Santa Maria HPP in Peru is carried out by China Gezhouba and Energia Azul, a Peruvian utility (HydroWorld.com, 2012). Meanwhile, the Argentinian 1740 MW Néstor-Kirchner-Jorge Cepernic HPP is built by a consortium that entails China Gezhouba as well as the Argentinian players Electroingenieria and Hydrocuvo (Xinhua, 2015). We found that hardware transfer in Latin America does not only entail EPC contracts, but only the provision of selected items, e. g. turbines. For instance, Dongfang Electric Corporation only provides turbines for the construction of the 105 MW Patuca III HPP in Honduras (Lagos, 2017). The only instance of FDI beyond those by CTGC is the attempt by State Power Investment Corporation to purchase the Brazilian 3150 MW Santo Antonio HPP (Petroleumworld, 2017), identified as an attempt to gain a presence in this market.

5.2.4. Drivers

Business considerations are an important driver in the Latin American market. First, technology transfer from Chinese to Latin American players is enabled by the cost-efficient provision of this technology by the Chinese, e. g. the case of the purchase of turbines for the 105 MW Patuca III HPP in Honduras. One consultant claimed that "the Chinese are 30% cheaper than domestic players on average". The winning offer for Argentina's Néstor Kirchner-Jorge Cepernic HPP, led by a consortium around CTGC, was 17% cheaper than the second-placed offer (Xinhua, 2015).

Another key driver is the lack of access to hydropower financing. This explains the higher share of Chinese financing in Latin America when compared to Europe (59% versus 47%). This also particularly explains why Ecuador features the most undertakings with Chinese involvement. With Ecuador cut off from Western investments in late 2008 when the country declared its national debt to be illegitimate, Ecuador had very limited financing options. Most of the USD 10 billion of loans provided to Ecuador since 2009 by China have been dedicated to hydropower development (EIU, 2016). This contrasts significantly with China's investment in the country in 2007 which amounted to just USD 7 million (Briones Hidrovo et al., 2017; EIU, 2016). Interviewees pointed out that projects such as the 1500 MW Coca Codo Sinclair HPP in Ecuador would not have been possible without Chinese financing. As one interviewee said: "This project was something the [Ecuadorian] government had wanted to build for a long time, but it was unable to raise the capital to do so."

Chinese financing is even attractive for Latin American countries with access to Western investments since this financing usually comes with none of the policy requirements imposed by Western lenders (Grugel et al., 2008; Matthews and Motta, 2015). It would be erroneous to state, though, that Chinese financing is entirely unconditional. The conditionality is more business-oriented. For instance, the USD 300 million loan provided by CEB for the construction of the Reventazón HPP was tied to allowing Sinohydro to participate in the project (CAD, 2011).

Geopolitical considerations also drive Chinese engagement and thus technology transfer in Latin American undertakings. Access to (natural) resources is the geopolitical driver that was identified in Latin America. A case in point is CTGC's involvement in the 8040 MW Sao Luiz de Patajos HPP. This dam would not just provide electricity, but also reduce the cost of food exports from Brazil to China via the Tapajós-Teles Pires waterway by linking remote industrial farms in Mato Grosso state with the Amazon River and the seaport of Belem (Blocksom and Locatelli, 2016). Meanwhile, China's main geopolitical benefit of assisting Ecuador is access to oil, including oil pre-sales to PetroChina, a Chinese state-owned oil and gas company, with the Ecuadorian

government receiving payments in advance in exchange for guaranteed future oil shipments (Alvaro, 2011; EIU, 2016). This resonates with Odoom (2015) who also found that the attempt to access oil has driven Chinese dam developers' engagement in Africa. Meanwhile, Mohan and Power, p. 30 ff.) (2008) write that securing energy resources has been a core driver of much Chinese engagement overseas since the 1990s. Indeed, "individual projects do not necessarily need to be profitable to be approved [as long as they] contribute to grander [...] goals [regarding] political and economic strategies" (Matthews and Motta, 2015, p. 6275).

5.2.5. Inhibitors

Three main inhibitors were identified via our research on Latin America. The first inhibitor was particularly mentioned by NGOs. It relates to the reputation of Chinese dam developers regarding safeguards and thus mirrors the situation in Europe. Particularly wealthier countries in Latin America such as Brazil and Chile have strict environmental and social safeguards regulations and Chinese dam developers are not believed to be able and/or willing to adhere to them. Indeed, there are numerous examples of Chinese dam developers violating environmental and social safeguards in Latin American HPPs. One case in point is Sinohydro's involvement in the 22 MW Aqua Zarca HPP in Honduras. The firm had to terminate this engagement in 2013 due to local protests that were grounded in the allegedly insufficient mitigation of the HPP's negative social impacts by Sinohydro (Banal-Estañol et al., 2017; Brautigam, 2016; Ellis, 2014). Chinese dam developers' reputation may be slowly improving, though. An example are the HPPs to be constructed on the Magdalena River in Colombia. While Sinohydro was originally disqualified from even bidding for these HPP contracts, the Colombian government is now seemingly keen to engage Sinohydro, after the Brazilian player Odebrecht was forced to quit the project due to corruption charges (Acosta, 2017).

Strict safeguards can also be used as tools to implement protectionism. As one interviewee working for an international NGO stated: "China has repeatedly tried to be more involved in Brazilian hydropower, but the government is quite protectionist and has not allowed much participation from Chinese firms." Indeed, policies in numerous Latin American countries are designed to favour local firms which impedes Chinese engagement and thus technology transfer in this market. A country with allegedly particularly protectionist policies is Venezuela, according to our research, which may explain why only a single Chinese undertaking was identified here (the country has only exploited one-third of its economically viable hydropower potential so far (World Energy Council, 2016b)).

The third inhibitor relates to the significant expertise regarding dam construction in Latin America which was already outlined in Section 2. As one industry interviewee stated: "Latin American capacity is very high. The region has world-class engineers". The Latin American expertise in dam construction thus explains why no instances of software transfer were identified on this continent; Latin American players can operate even large facilities without external training and the relevant know-why is also present. Significant capacities also explain why there is less collaboration between Chinese dam developers and domestic players in Latin American projects than in European ones (28% versus 43%) since these collaborations can be seen facilitating Chinese-led software transfer. Overall, the limited involvement of Chinese dam developers in Latin America currently suggests that the identified inhibitors outweigh, like in Europe, the outlined drivers.

6. Conclusions and policy implications

Many in the hydropower industry indicated in the past three years that there is much interest in this analysis. While a common perception within the industry is that Chinese players are increasingly active both in Europe and Latin America, two regions declining in power, no international donor, NGO or private sector player that we talked to

maintains a systematic and up-to-date overview regarding Chinese undertakings in the hydropower industry in Europe and Latin America. Similarly, scholars have not studied Chinese dam developers' undertakings in Europe and Latin America from an industry perspective. The aim of this study was to start closing this research gap. We did this by examining the extent, drivers and inhibitors of technology transfer in Chinese dam developers' undertakings in Europe and Latin America.

Our work finds relatively few undertakings of Chinese dam developers and thus limited evidence for technology transfer both in Europe and Latin America. The undertakings identified are usually cases of mutual South-South technology transfer with Chinese players transferring technology to the host country and vice versa. Technology transfer includes the transfer of hardware and software in Europe, but only the transfer of hardware in Latin America. The most common channel of technology transfer both in Europe and Latin America is trade, whereas a few instances of FDI were also identified. The only instance of North-South technology transfer found in our study was CTGC's purchase of a stake in EDP with the safeguards technology gained via this purchase aimed to help CTGC to enter the Latin American market – an aim that has not yet materialized. The lack of NSTT indicates that players in developed countries are apparently largely not considered as necessary to carry out large HPPs (with the exception of safeguards).

Technology transfer in Europe and Latin America is driven by both business and geopolitical considerations. The cost-efficient provision of technology by Chinese players is an important driver of technology transfer both in Europe and Latin America with Chinese players offering services up to 30% cheaper than competitors. Furthermore, limited hydropower capacities in selected European countries such as Belarus drive Chinese-led technology transfer on this continent. Meanwhile, lacking access to hydropower financing that is non-Chinese is a major driver of technology transfer in Latin America. Technology transfer both in Europe and in Latin America is impeded by Chinese dam developers' dismal reputation regarding safeguards. Protectionist policies as well as the excellent capacities of Latin American players further inhibit technology transfer in the Latin American market. Overall, the identified inhibitors outweigh the identified drivers and thus explain why there are only relatively few undertakings in both Europe and Latin America.

The finding of our study that bears the greatest policy relevance may be that

Chinese players frequently collaborate with domestic ones (Europe: 43% of undertakings; Latin America: 28% of undertakings). This indicates that technology transfer to Chinese players is feasible and thus reach-outs to these players may be worthwhile. For instance, NGOs as well as donors may carry out trainings for Chinese players regarding best practice safeguards policies which could then impact the safeguards implemented in HPPs with Chinese involvement. Such efforts could potentially enhance the sustainability of the hydropower sector. This is desirable for those promoting hydropower as part of the energy mix of low carbon development as well as for those who believe that there must be more environmentally-responsible and socially-just alternatives to hydropower at least in the medium-term.

Major data collection efforts were undertaken for three years to conduct this study. However, players in the dam industry proved to be extremely secretive, and thus many of our efforts turned out to be futile. For instance, numerous reach-outs to relevant Chinese funders yielded no replies, as outlined in Section 4. Hence, we neither claim that the interview data presented in this study is representative nor that the data gathered via desk research is exhaustive and/or contains no errors. We only present an initial narrative regarding Chinese dam developers' undertakings in Europe and Latin America that is tentative. We decided to seek the publication of this narrative since we believe that it can serve as a starting point for future research and thus contributes the cumulative knowledge development on this topic.

Future research may attempt to replicate our work. It may also focus

on Chinese engagement in specific countries and/or specific undertakings in Europe and Latin America to validate and further nuance our findings. Particularly smaller dam projects tend to be neglected by scholars. An analysis of the engagement of non-Chinese dam developers' undertakings, e. g. European ones (including a comparison of these undertakings to Chinese dam developers), would also be of great interest. This work could also examine if there is a presence of non-Chinese hydropower players in China. Overall, much scholarly work remains to be done regarding the hydropower industry. We hope that this study proves to be instructive for this work.

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