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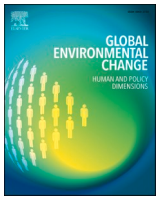

The financialization of rivers: Clean Development Mechanism (CDM) subsidized hydropower in the Mekong Region's basins at risk

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ABSTRACT

The Kyoto Protocol's Clean Development Mechanism (CDM) is a key carbon offset scheme that underpins the global carbon market. This mechanism leaves out many other non-carbon considerations, including the impacts of the CDM on water governance. The CDM produces credits primarily through energy projects and CDM funded hydropower is one of the most significant outcomes of nearly two decades of carbon financing with funding subsidizing over 1,000 large-scale dams. This research maps these rapidly built infrastructure projects in transboundary river systems, which has shown to have direct links to increasing hydropolitical tensions. The Mekong Region's Irrawaddy, Bei Jiang/Hsi, Red, and Salween rivers are all considered to be amongst the world's river basins considered 'very high risk' for conflict. Our research shows that these 'very high risk' rivers were the top four river basins to receive CDM funded large-scale hydropower. These four basins at 'very high risk' along with the Mekong River were the top five recipient rivers of 274 CDM subsidized large-scale dams. These dams were rapidly financed and constructed in the upstream catchments in the name of carbon reduction claims in China and Europe. This response to climate change enhances power imbalances and raises the risk of hydropolitical tensions as Mekong communities shoulder the costs of increasing insecurities in the name of distant carbon reduction claims in Europe and Beijing.

1. Introduction

The most striking outcome of over two decades of the Kyoto Protocol's Clean Development Mechanism (CDM) is the proliferation of hydropower plants, primarily in ecologically fragile areas such as the Eastern Himalaya (Ahlers et al., 2015). 1,055 large-scale dams have been built with funding from the CDM, largely in Southwest China (UNFCCC, 2022). This offset approach to global climate change relies on extensive hydropower construction and is placing large pressures and unintended consequences on rivers and riverine communities in the Global South (Giuliani et al., 2022).

Some consider the CDM to be a thing of the past and that we have moved onto a Paris era. However, CDM registered hydropower is central to emission reduction claims under Paris. Of the Certified Emissions Reductions (CERs) issued between 2013–2020 that could be counted towards a country's Nationally Determined Contributions (NDCs), hydropower was the largest credit source with over 25 % of the CERs issued (UNEP, 2023). At the time of writing, hydropower projects in the CDM Pipeline that are Paris eligible represent the largest source of potential credits (ibid). Hydropower projects are also the most common type of infrastructure in the CDM pipeline; of the projects that will be carried over under the Paris Agreement, one in five is a dam (Farand et al., 2022). Therefore, understanding climate financed hydropower and the patterns of development it entails is crucial for future climate change policies.

This trend is likely to increase as there are calls to double global hydropower by 2050 (IEA, 2021). Hydropower produces 55 % more energy than nuclear power and more than all other forms of renewable

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energy combined (IEA, 2021). The world's unexploited hydropower potential is estimated at 70 %, mostly located in Asia and Africa (Merme et al., 2014). Over 70 % of the planned projects have a transboundary component (Zarfl et. al., 2015).

Infrastructure development on shared river systems in the name of sustainability or climate security ignore the well-established negative impacts of large scale dams including but not limited to: the impact of hydropower on river fragmentation and biodiversity (Grill et al., 2014; 2019, He et al., 2021), sediment retention and hydrological changes (Kondolf et al., 2018), the consistent over estimation of benefits and under estimation of costs (Ansar et al., 2014), the high quantity of greenhouse gases GHGs these systems produce (Fearnside, 2015; Räsänen et al., 2018), the direct links between hydraulic infrastructure and increased conflict (De Stefano et al,. 2010a, 2017; Wolf et al., 2003b) and the high frequency of repression and violence wrought on indigenous communities and environmental activists with hydropower projects (Del bene et al., 2018).

CDM funded dams are an understudied connection between global climate finance and the hydropower industry. Hydraulic infrastructures are increasingly designed, constructed, and operated primarily as financial vehicles – with social, environmental, or climate change goals becoming secondary or even non-existent (Ahlers, 2020). The connection between global climate finance and the hydropower industry has led to what we refer to as a 'financialization of rivers' phenomenon in the Mekong Region where hundreds of projects fragment river systems in the name of distant value extraction from carbon assets. The 'financialization of rivers' occurs when hydropower dams, which we view as investment vehicles, are deployed in such a way that the intangible financial considerations outweigh the tangible benefits such as energy supply from the clustering of projects. This is exemplified in the Mekong, where hundreds of CDM hydropower projects sit idle, underperform, or experience annual energy grid bottlenecks (Hennig and Harlan, 2018; Liu et al., 2018a) while selling inflated carbon assets into the European market.

Financialization of a ton of carbon renders CO2 to be classified as an asset that can be traded, speculated on and sold (Bridge et al., 2020). A crucial assumption for hydropower produced carbon credit assets is that they can be interchanged and are 'fungible' (Machaqueiro, 2017). Fungibility relies on the presumption that a ton of carbon in one location is the same as a ton of carbon or other GHG elsewhere and can be interchanged. This is a type of carbon 'view from nowhere' where the asset has no context or geography and is presumed to be the same everywhere (Haraway, 1988). This allows CERs to work as offsets, where a ton of carbon emitted in one geography can be offset by a ton of carbon sequestration in another.

In contrast to the carbon 'view from nowhere', water governance is understood as being highly contextual. Water governance outcomes in one river system are very poor indicators of expected water governance outcomes in another (Pahl-Wostl et al., 2012). Even within the same river system, constructing two identical dams will produce vastly different outcomes depending on where they are sited, even if the plants are minting the same amount of CERs for the European market. Water that is shared by multiple groups or states dramatically increases the complexity of governance (Dore et al., 2012). Hydraulic infrastructure sites are highly contested and the location of each project impacts the shared water, but also crucially the surrounding land, making these decisions of where projects are located very political (Hirsch 2016; Matthews, 2012; Rousseau 2020).

Prior to the CDM funding hydropower in these basins, the Irrawaddy, Mekong, Red, and Salween were identified as 'basins at risk' for future conflict (Wolf et al., 2003b). This heightened political risk is the case in rivers where "the rate of change within a basin exceeds the institutional capacity to absorb that change" (Wolf et al., 2003p. 43). A later follow up systematic review of basins at risk of hydropolitical tension by De Stefano et al., (2017) found only 22 of the world's 310 shared basins (McCracken and Wolf, 2019) to be at 'very high risk' for hydropolitical tension, with the Bei Jiang/Hsi (China, Viet Nam) being added to the 'very high risk' basins, while the Mekong basin was reduced from the 'very high risk' rating. The top four rivers where the CDM funded large-scale hydropower are river basins categorized as 'very high risk' for hydropolitical conflict, followed by the Mekong river which received the fifth highest number of large-scale dam investments.

The Mekong Region's transboundary rivers are thus both high risk for hydropolitical tensions, while being home to the largest number of dam projects in the CDM portfolio. The implications of the CDM's hydropower investments across the three geographies of Europe, China, and the Mekong Region will be explored using the telecoupling framework. In this globalized approach to the CDM's hydropower investments, the research questions driving this project are: Where are CDM large-scale hydropower projects being sited in transboundary river basins and what are the hydropolitical implications of these patterns of hydropower subsidies?

2. Telecoupling framework

The telecoupling framework is a theoretical tool designed to analyze distant geographies and complex socioeconomic and environmental systems at various scales, making it well suited to assess the complexities of the CDM's hydropower investments (Liu et al., 2013). In a globalized world, telecoupling is used to link both socio-economic and environmental exchanges between two or more systems. The telecoupling framework consists of five major components – systems, flows, agents, causes, and effects (ibid). The systems are defined as a sending, receiving, and spillover systems based on their relation to each other and the travel of flows between them (ibid). For this analysis, Europe and Annex I countries in the Kyoto Protocol are sending capital flows from the CDM to hydropower projects in the Mekong Region, primarily in upstream China. China's southwest region is the receiving system of hydropower subsidies in the upstream of the basins, and the Mekong Region's transboundary rivers are the spillover system. See (Fig. 1).

Telecoupling has proven useful to study complex environmental and water governance issues over large geographies, notably in China (Kapsar et al., 2019). The framework has been applied to study Beijing's urban water systems (Deines et al., 2016; Yang et al., 2016), the South-North Water Transfer Project (Liu et al., 2016; Quan et al., 2016; Su and Chen, 2021; Su et al., 2022), ecotourism in Qinghai's Sanjiangyuan (three rivers) National Park (Chung et al., 2018) and watersheds in China (Zhang et al., 2021; Zhang and Zhang, 2021). This study will apply the telecoupling framework to study five major transboundary rivers (Irrawaddy, Bei/Hsi, Mekong, Red, and Salween) that China shares with its neighbors in the Mekong Region.

While telecoupling research focuses on the sending and receiving systems, often between trade partners, little research has been done on spillover geographies which remain hidden and overlooked (Liu et al., 2018b). Similarly, CDM research follows this trend, focusing typically on EU and host country relationships. For the sending and receiving geographies their relationship is based around carbon accounting that facilitates the flows of finances and credits. Even though these flows are mediated through hydraulic infrastructure construction, the systems are water blind. The Mekong Region's transboundary rivers and water governance considerations are absent and the telecoupling analysis aims to uncover some of these hidden or less visible costs for the transboundary rivers as a spillover system (Liu, 2014).

CDM hydropower projects are approved and counted at a national scale, despite having international sustainability implications. With regards to transboundary rivers this creates an ill fit governance regime where national agents are approving hydropower projects domestically, to allow for the financing of contested infrastructure projects on rivers that are international. This study foregrounds the Mekong Region's international rivers and hydropolitical risk as a spillover system of the CDM's hydropower portfolio.

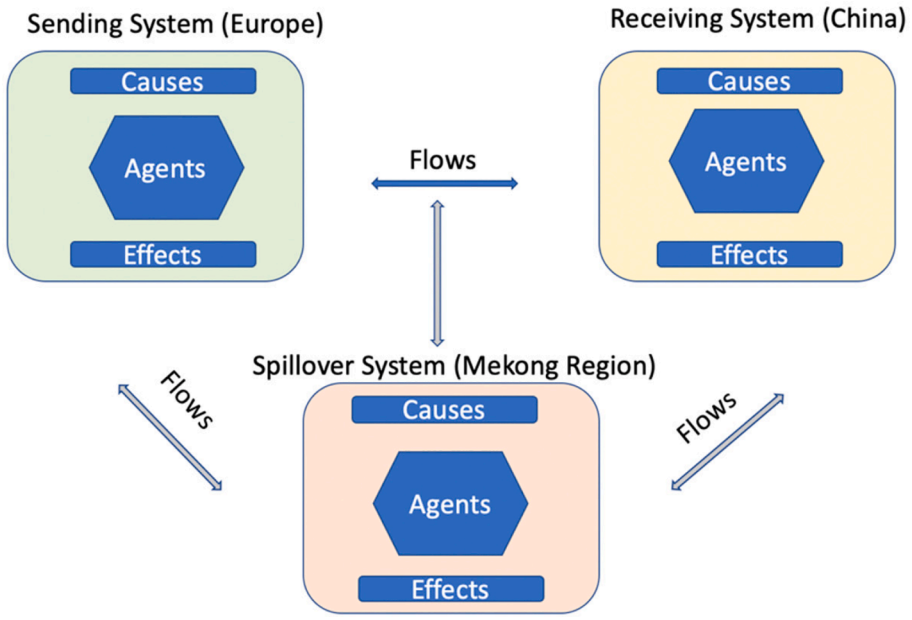

Fig. 1. Telecoupling framework (adapted form Liu et al.,2013).

2.1. Systems

The telecoupling framework utilizes a few key concepts; systems, flows, and agents – as well as causes and effects of the telecoupled system, which we address below in the discussion section. The telecoupling framing allows for analysis of distant, complex, and interrelated systems that encompass both socioeconomic and environmental interactions (Liu et al., 2013). We utilize the threefold systems approach of sender (Europe) and receiver (China) of carbon finance, and transboundary water governance in the (Mekong Region) as the spillover system to explore implications of the CDM's hydropower investments. Large-scale hydropower is funded by European governments or the *sender* of finance in exchange for CERs. China and particularly Chinese hydropower state-owned enterprises (SOEs) are the *recipient* of hydropower subsidies that are used to carry out rapid hydropower construction, particularly in the upper catchments of transboundary rivers. The Mekong Region's riverine communities that heavily rely on these shared rivers are conceived of as the *spillover* location.

2.2. Flows

Flows are the exchange between systems of both tangible items such as traded goods or energy, or intangible flows such as capital or technology transfers, with technology transfer being a stated goal of the CDM (Kaspar et al., 2019). This study will argue that the CDM hydropower rollout is not primarily driven by tangible flows such as energy supply. Instead, the flows that are important to this telecoupled system are the immaterial flows of capital from Europe to Chinese agents in exchange for carbon assets and claims of sustainability. The CDM flows gave incentives to governments and the hydropower industry with the price of a CER reaching over €20/credit in 2008 before settling between €10-13/credit leading up to the price collapse in 2012 (Smits and Middleton, 2014).

2.3. Agents

Agents can be conceived of as individuals or institutions or groups of individuals both human and non (Liu et al., 2013). The CDM hydropower projects engage with numerous and changing agents at multiple scales. The CDM projects are approved between European agents and through national offices for countries selling credits or what is referred to as a 'designated national authority' (DNA). China's National Development and Reform Commission (NDRC), which is one of the most powerful agenda setting agencies in the country, serves as the DNA.

In order to manage the influx of CDM activities after ratifying Kyoto, the China's NDRC established the National Climate Change Coordination Committee (NCCCC). The NCCCC was used to house projects funded by the EU and aimed at creating investment opportunities and profits along the project value chain (Zheng, 2004). Sending system flows from Europe were used to identify cheap energy projects in China and to link and promote the sale of CERs, which are then sold back to European investors (Zheng, 2004).

Zheng (2004) illustrates the complexity and quantity of official agents in this telecoupled system at just the national scale in Beijing (left

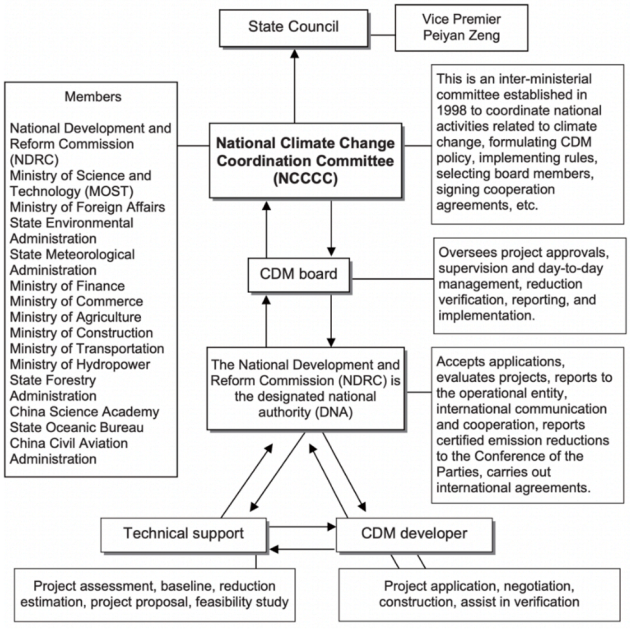

Fig. 2. State agents at China's national scale involved in the CDM system (left) (Zheng 2004).

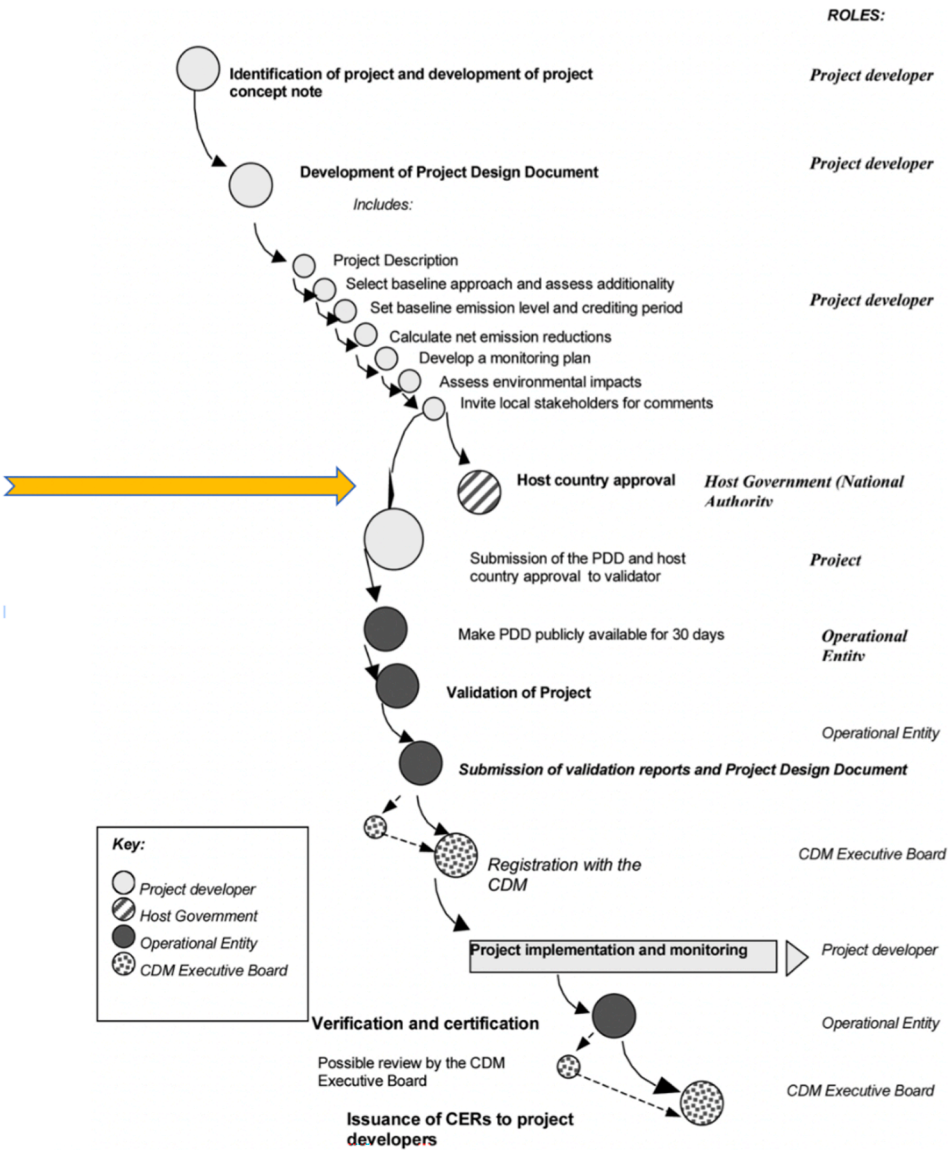

Fig. 3. Simplified CDM project flow (right) (CDM User's Guide, 2015).

Fig. 2). The entirety of the agents in Beijing is represented by a single dot in the overall CDM project flow (right Fig. 3). The immense complexity of agents and CDM investment management domestically renders the process highly technical and often capacity building for national level actors was required as well as the involvement of a third-party consultancy to navigate the process (Smits and Middleton, 2014). This complexity at the national level to approve a project does not incentivize a project proponent to expand the scope of study or agents involved, which makes the side-lining or erasing of spillover effects on international rivers more conceivable.

3. Methods

The CGIAR's Water, Land, and Ecosystem's (WLE) Greater Mekong Dam Observatory database was crucial in assembling hydraulic infrastructure in the Mekong Region as a spillover case study (Dataset on the Dams of the Greater Mekong, MERFI 2024). The observatory was cross referenced with national project data from the UNFCCC's CDM Registry for Cambodia, China, Lao PDR, Myanmar, Thailand, and Vietnam (UNFCCC, 2022). To evaluate the uniqueness of the rapid CDM hydropower construction in the Mekong, the study used the UNFCCC's CDM project registry to build a database of all 1,055 registered large-scale hydropower (>15 MW) infrastructure projects globally (ibid).

GIS was used to map the over 1,000 large scale hydropower dams funded through the UNFCCC's CDM project registry from 2005 to 2022 onto the Transboundary Freshwater Disputes Database (TFDD, 2018). The TFDD database monitors the world's 310 transboundary river basins, which is synonymous with catchment and watershed (McCracken and Wolf, 2019). Project design documents for each of the large-scale hydropower projects were used to extract the proposed project coordinates.

Each project's Project Design Document was individually screened for sub-projects, units of hydropower infrastructures and coordinates. During the screening process, some information about the units of infrastructure and/or their coordinates were found to be incorrect or missing. This potential deviation of the mapped infrastructure especially matters in cases where hydropower infrastructure was sited near international borders, and coordinates were rechecked and cross referenced with company websites.

Additionally, we observed an uncoordinated and often interchangeable use of the term "run-of-river", taking on many meanings ranging from use, non-use or construction of reservoirs, dams, weirs or barrages. This research, therefore, includes any large-scale CDM hydropower projects which involve any form of river capturing or

alteration. The database was subsequently analyzed and visualized (Fig. 4) in QGIS by adding a layer of transboundary water basins from the Transboundary Fresh Water Disputes Database (TFDD, 2018) to the collected coordinates of the CDM large-scale hydropower infrastructures. This was done by ascertaining the quantity of large-scale hydropower infrastructure in each transboundary river basin and finally extracting the information in the form of a table (Table 1). Transboundary rivers that did not receive CDM project approvals were excluded. Basins at 'very high risk' of hydropolitical tensions are highlighted in the results with a full table in the annex. We then selected a large-scale project across different high risk basins in different country contexts Myanmar, Yunnan-China, and Viet Nam, for which data was publicly available, to illustrate outcomes of this telecoupled process on hydropolitical tensions. Cambodia and Thailand have large-scale CDM dams that were excluded as they were not sited in transboundary basins, and Lao PDR lacked sufficient publicly available information.

4. Results

The mapping of 1,055 large scale hydropower projects that received CDM funding illustrates that siting contested infrastructure in transboundary river basins is common. 484 large-scale dams were funded in transboundary rivers, with a majority being constructed in the Mekong Region. The top five transboundary rivers to receive CDM funded hydropower are all in the Mekong Region. The Mekong Region's Salween, Irrawaddy, Red, and Bei Jiang/Hsi rivers are all considered to be amongst the top 22 river basins at 'very high risk' of conflict. These 'very high risk' rivers were the top four river basins to receive CDM funded hydropower.

4.1. Illustrations of the Mekong Region as a spillover system

In the Mekong Region, over 200 large scale CDM projects have significantly restructured the transboundary rivers (Hecht et al., 2019). Hydropower development is done so on a project-by-project basis that does not take into account basin-scale impacts, nor does it consider the cumulative impacts of numerous dams (Schmitt et al., 2019; Winemiller et al., 2016). Hydropower was found to have more significant influence on changes in the river system compared to climate change (Ngo et al., 2018; Hoang et al., 2019; Ziv et al., 2012). These hydropower impacts are not caused by the CDM, but are being financially and discursively supported by this approach to global climate change policy. In the coming decades the market-based solution the global community is relying on to address climate change is producing environmental problems and uncertainty at a greater rate than the problem of climate change it was aiming to address (Lauri et al., 2012).

This represents a form of carbon cost shifting that transfers the burden of carbon policies from wealthy countries onto poorer communities in the Global South (Böhringer et al., 2018). Less powerful Mekong countries are developing dams domestically and are faced with the complexities of hundreds of large-scale dams built simultaneously on their shared rivers upstream; without robust institutions or agreements in place to manage the changes or grievances caused by these infrastructures. This approach to climate change will impact the health of transboundary river systems with feedback delays into the future (Meadows, 2008). The telecoupled arrangement between hydropower subsidies and the minting of CERs has both short and long term spillover impacts on the Mekong Region's hydropolitical tensions.

4.1.1. Sino-Vietnamese hydropolitical tensions and CDM hydropower

The Red River basin (China (49 %), Laos (1 %), and Viet Nam (50 %)) received the most large-scale CDM projects with 77 constructed (Quynh et al., 2005). The Red River does not have a river basin organization nor an international agreement between the three countries (De Stefano et al., 2010b). There are low levels of cooperation between China and Viet Nam, with an agreement to exchange flow data during the wet season. However, China does not share dry season data, which is crucial and desirable information for downstream Viet Nam.

Additionally, China does not share information on hydropower operations. China is not required to inform Viet Nam when it suddenly releases water from the CDM dams upstream. This includes, but is not limited to, the CDM funded 288 MW Madushan hydropower dam, which was built on the mainstream of the Red River less than 100 km from the recently demarcated border (Rousseau, 2017). Madushan was estimated to receive over $13 million annually from CDM revenues and the mainstream Nansha directly upstream was estimated to increase its annual income by 25 % from CER sales (Rousseau, 2014). The CDM financing a large-scale project on the mainstream in close proximity to an international border means that dam releases directly impact northern Viet Nam. The siting of this project decreases Viet Nam's time

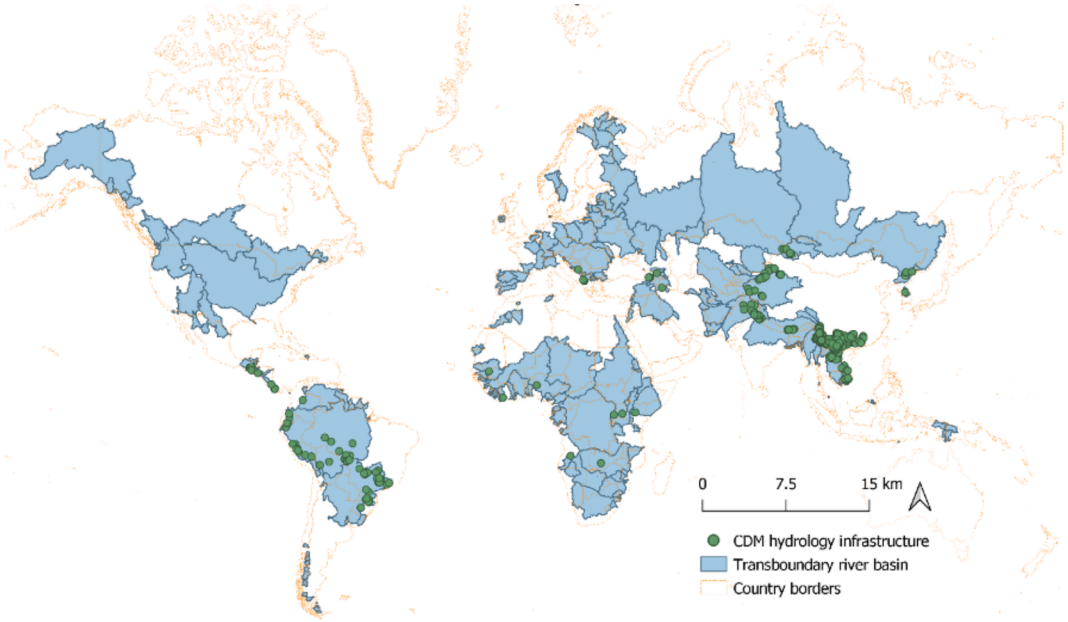

Fig. 4. Map visual of CDM large scale hydropower on Transboundary Freshwater Disputes Database (TFDD 2018).

Table 1
Top transboundary river basins to receive large-scale CDM hydropower projects, basins at 'very high risk' for hydropolitical tension highlighted in red. Complete list of 484 CDM dams in transboundary rivers in the annex.

#	Basin name	Area	Population	Amount countries	CDM projects	Countries' names (UNEP-DHI and UNEP, 2016)
1	Red/Song Hong	140	17,864	3	77	**China**, Lao PDR, Viet Nam
2	Salween	265	7851	3	60	**China**, Myanmar, Thailand
3	Bei Jiang/Hsi	401	77,098	2	56	**China**, Viet Nam
4	Irrawaddy	375	28,583	4	43	Myanmar, **China**, India
5	Mekong	773	58,743	6	38	China, Myanmar, Thailand, Lao PDR, Cambodia, Viet Nam
6	La Plata	2927	88,221	5	33	Argentina, Bolivia, Brazil, Paraguay, Uruguay
7	Amazon	5888	32,164	9	31	Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname
8	Tarim	1098	10,322	7	20	Afghanistan, China, Aksai Chin, Jammu and Kashmir, Kazakhstan, Kyrgyzstan, Tajikistan
9	Indus	856	189,912	7	19	Afghanistan, China, Aksai Chin, Jammu and Kashmir, India, Nepal, Pakistan
10	Ganges-Brahmaputra-Meghna	1652	704,221	7	16	Bangladesh, Bhutan, China, Arunachal Pradesh, India, Myanmar, Nepal

to respond to undisclosed dam releases and heightens hydropolitical tensions.

The border which cuts through the shared Red River basin was not agreed upon until 1999 (Ross, 2021). The Red River basin was the site of previous conflict during the Sino-Vietnamese War, where China as an upstream nuclear power engaged in a land border invasion, sending over 200,000 troops into Vietnam in 1979 (Eisenman, 2019). Diplomatic relations were not reestablished until 1991, after which the border area was extensively cleared of land mines (Le Hong, 2013; Storey, 2012).

The CDM was approving projects and subsidizing hydropower construction in this basin at 'very high risk' of conflict at the height of Sino-Viet tensions, when the threat of armed conflict reemerged around South China Sea disputes (Van Eynde et al., 2013). The diplomatic situation came to a head in 2014 when boats clashed at sea after China parked an oil rig in the disputed waters. Anti-Chinese protests broke out across Viet Nam killing 21 Chinese, injuring thousands more, and causing many to flee the country or be evacuated (Ross, 2021).

Months after the deadly anti-Chinese riots in Vietnam, Chinese and Vietnamese tensions escalated over the CDM funded Thuong Kon Tum hydropower project, located in the Mekong River basin in Viet Nam. The Chinese SOEs PowerChina Huadong Engineering Corporation Ltd. and China Railway Construction Co Ltd. were responsible for the dam. The Thuong Kon Tum project (220 MW) is the largest hydropower project registered to the CDM in Vietnam, claiming a 602,074 ton reduction of carbon credits (UNFCCC, 2022). To put the scale of these approved CERs into perspective, the largest solar project in the entire global CDM portfolio is only 467,318 (ibid). The Thuong Kon Tum was registered in 2012 and was approved to sell carbon credits until 2021 (ibid). See (Table 1).

However, in 2014 as diplomatic relations sank to one of the lowest points since the Sino-Vietnamese War, the Chinese SOE abandoned the Thuong Kon Tum hydropower project site. The Chinese SOEs had suffered both financial and technical setbacks. Viet Nam's state media reported that the companies were requesting an additional $37.65 m than was agreed in the contract, and when they did not receive it they abandoned the project mid construction (Sweet, 2014). It was later announced that the contract with the Chinese SOEs was being terminated by Viet Nam (ibid).

This CDM project contestation has been taking place since 2014 and is still ongoing. The dispute was elevated through multiple courts, with the Vietnamese International Court in Hanoi finally deeming that the Vietnamese companies did not owe compensation to the Chinese SOEs in November 2019 (Minh 2019). Despite being registered to the CDM in 2012, the Thuong Kon Tum was not connected to the national grid until 24 March 2021 (EVN, 2021).

4.1.2. Subnational hydropolitical conflict and civil war at Myanmar's CDM dam site

The only CDM funded hydropower project in Myanmar is the 240 MW Darpein 1 (also known as Dapein 1) hydropower project in Kachin State. It was approved in the CDM by the Netherlands in an area that is highly conflictual. It is located in an area that is contested by the Kachin Independence Organization (KIO) along with its military arm the Kachin Independence Army (KIA) and the Burmese military or Tatmadaw. The uneasy truce was enshrined by a ceasefire signed in 1994, but 17 years later the ceasefire broke down at the CDM's Darpein 1 project site (Hennig, 2016).

The KIO was not pleased about the project arrangements, and Chinese hydropower SOE Datang (Yunnan) United attempted to assuage Kachin concerns with an additional payment of between $2–4 million to the KIO (Kean and Mon, 2019). The payment allowed for Chinese workers to return to the dam site, but they came accompanied by Tatmadaw security forces and fighting between the Tatmadaw and the KIA broke out at the dam site in 2011. It is estimated that at least 50 people died in the initial fighting and thousands fled the area, many over the border into China (Watts, 2011).

The fighting spread and is ongoing to the present day. Datang was forced to cease operations for two years as the region became engulfed in armed conflict (Yeophantong, 2020). The 240 MW registered project with associated carbon credits to match, was found to only have 90 MW of installed capacity available (Kean and Mon, 2019). Despite these losses of life, violence, and severe underperformance, the Darpein 1 project was approved to the UNFCCC's CDM registry in 2013.

Darpein 1 was designed as an energy export project to Yunnan, China and does not have any meaningful grid connectivity to energy poor Myanmar (Hennig, 2016). The project encountered the reality that Yunnan's energy grid is annually overwhelmed due to overbuilt rivers, grid failures, and surplus hydropower energy fueled by CDM subsidies (Hennig, 2016; Liu et al., 2018a). The Darpein 1 began construction in 2008 and CERs are traded in Europe as if the project is operating smoothly, however the lack of energy usage behind the carbon credit reduction claims is creating fake or 'zombie credits' in the system (Reyes, 2011). CDM's Darpein 1 cannot sell energy, so sits idle operating annually at a few percentages of its designed potential (Kean and Mon, 2019). Darpein 1 illustrates how the CDM's hydropower CERs act both as conflict and zombie credits.

4.2. China as a recipient system: Yunnan's zombie credits

The rivers in China's Yunnan Province have become overbuilt, and the rapid construction of hydropower through CDM subsidies has led to large problems of overcapacity and low energy utilization (Cheng et al., 2018). Over 25 % of CDM hydropower in China is located in Yunnan and hundreds of dams sit idle every year due to grid bottlenecks and energy surplus (Hennig and Harlan, 2018; Hennig and Magee, 2021). The poor performance of these projects and grid inefficiencies occurs annually, especially during the monsoon and at a province-wide scale (Liu et al., 2018a; Magee, 2021). With each additional hydropower project – the

problem increases, curtailment of hydropower energy went from 4.4 TWh in 2009, but jumped to over 30 TWh by 2016 and the figure is expected to rise (Liu et al., 2018a; Shuai, 2017).

If all of the installed hydropower were able to run throughout the year, less than half of the dams would be required to meet Yunnan's annual consumption (Cheng et al., 2018). Adding to these inefficiencies of curtailment in the monsoon season, for the past few years Yunnan has experienced drought and hydropower has also underperformed in the dry season due to low water availability (Ji, 2023). The low levels of water in the dam reservoirs during the dry season has forced Yunnan to impose energy consumption restrictions (ibid).

The cheap hydropower energy has spurred energy-intensive industries to migrate to Yunnan to take advantage of the surplus power. This creates a 'second-order effect' in telecoupling where changes in one system impact other systems in a non-linear fashion, sometimes with time lags and legacy effects that outlast the operation of the telecoupling (Liu et al., 2013). Migrating entities such as aluminum smelters and bitcoin mining have moved their extractive industries near Yunnan's dam sites, placing further environmental pressures on the landscape (Deng, 2021).

The rampant bitcoin mining in Southwest China and lack of control over the situation eventually led the Chinese central government to ban bitcoin mining (Global Times, 2021). The ban will create second order effects in new systems as bitcoin mining operations moves abroad, and leads to legacy effects of further energy surplus in Yunnan and incentives to move in more smelting operations or energy intensive industry into the overbuilt rivers. These energy shortcomings challenge not just the CDM's goals of sustainability or technology transfer, but the validity of the millions of CERs themselves.

4.3. Europe as the sending system: Greenwashing with hydropower

CERs from the CDM can be traded across other carbon markets, such as the European Union Emission Trading Scheme (EU ETS). The EU ETS claimed it would operationalize the World Commission on Dams 'gold standard' guidelines for sales of hydropower credits, however when reviewing over 1,000 large-scale dams not a single instance was found where a dam's credit sales were rejected due to not meeting the WCD guidelines (Haya and Parekh, 2011). This allows cheap hydropower credits with little oversight to enter the EU markets, and arguably slow down meaningful energy fossil fuel transition in Europe (Lohmann, 2011). Despite the criticism around the CDM, CERs were extended at COP26 in Glasgow to be allowed to count towards climate commitments until 2030. After these decisions, participants to COP26 could pay a few Euros to 'offset' their plane travel via the UN's aviation offset scheme – CORSIA, which approved the use of old CDM credits (Farand et al., 2022). One in five projects used for offsets until 2030 is a hydropower dam (ibid).

There are currently scant regulations or oversights on corporations using antiquated CDM credits for net zero claims. Rather than usher in sustainability or a solution to climate change, the offset scheme allows corporations in Europe to conduct fossil fueled business as usual, while projecting net zero claims to their consumers. It is unrealistic for consumers to trace how these carbon credits are assembled, from where they originated, or if they are legitimate. This unregulated space will increasingly be wielded as a form of greenwashing on consumers to make them feel better about their 'sustainable' life choices, while the costs of this approach to global climate change policy is shifted onto rivers in the Global South.

5. Discussion

5.1. Causes of the telecoupled system

For both sending and receiving systems the 'financialization of rivers' is convenient and profitable compared to meaningful fossil fuel transitions. There are incentives for both the EU and China to exaggerate the benefits of the telecoupled systems, rather than confront the unsustainable realities of CDM hydropower that are taking place far away from the decision-making centers. Greenwashing these high impact projects and their credits as a solution to climate change occurs in the Mekong Region. "A favorite slogan of Chinese hydropower companies now is that they are 'addressing climate change'. Particularly when they can combine 'addressing climate change' with the conversion of river resources to big money" (Li and Shapiro, 2020, p94).

Many treat the CDM as a thing of the past, focusing on the first commitment period from 2008 to 2012 prior to the crash of the CER price. However, this telecoupled system is active and the CDM is still financing large-scale dams in the Paris era. The Lao PDR had three approved in 2017 alone, Pakistan two in 2021, and Gabon had a project registered as recently as 2022 (UNFCCC, 2022).

The telecoupled system is minting assets for a booming industry, with carbon credits valued at $270 billion globally (Varsani and Gupta, 2022). Offsetting creates new demand and spaces for capital. New financial actors beyond the state and traditional international financial institutions (IFIs) are engaging in carbon asset speculation, such as corporations, private enterprises, pension funds, and creditors (Ahlers, 2020; Rempel and Gupta, 2020; March and Purcell, 2014; Merme et al., 2014; Middleton et al., 2012; Smits and Middleton, 2014). Likewise, China's economy is increasingly financialized leading towards an accumulation through increasing spatial expansion (Harvey and Paik, 2017). This capital accumulation process was carried out in peripheral Yunnan Province through investments in large-scale infrastructure, and in particular energy projects (Su and Lim, 2023).

China is both the largest investor in energy projects globally and the largest recipient of climate change financing under Kyoto domestically (Soanes et al., 2016; Li et al., 2020). China plays an increasingly powerful role in agenda setting in international climate change policy arenas and the Paris Agreement (Hilton and Kerr, 2017). In the Mekong Region, Chinese banks and development initiatives are leading hydropower development prior to receiving EU subsidies (Geheb and Suhardiman, 2019). In Cambodia, while outside of transboundary basins, all four of the country's large-scale CDM hydropower projects have been built by Chinese SOEs and registered for the CDM only after construction was complete, thereby removing any argument of additionality (Baird and Green, 2020). Yunnan Province alone, where most of the dams in transboundary rivers are sited, has as a single province invested over $1 billion in energy projects in all three of the countries it borders (Lao PDR $4.18, Myanmar $1.17, Viet Nam $1.08) (Hess, 2020).

The Chinese hydropower industry was already technologically advanced and financially healthy without the carbon asset from the CDM (McDonald et al., 2009; Siciliano et al., 2017 Warner et al., 2017). China is the leading constructor of hydraulic infrastructure both domestically and abroad (Siciliano et al., 2019; Siciliano et al., 2017; Li et al., 2020). China is building hydropower projects in over 70 countries with the vast majority of these beginning after 2006 when the 'Going Out Policy' 'zou chu qu zhan lüe' (走出去战略) coincided with injections of capital through the launch of Kyoto's CDM funding (McDonald et al., 2009; Siciliano et al., 2019).

Chinese SOEs are now the leading financier, constructor, designer, and operator of dams globally (Tan-Mullins et al., 2017; Urban, 2018; Siciliano et al., 2017; Siciliano et al., 2019). These hydropower corporations are primarily state-owned and do not necessarily need construction projects to be highly profitable to pursue them (Tan-Mullins et al., 2017). SOEs respond to political goals and development objectives set out by the Chinese Communist Party, such as installed renewable energy capacity (Li and Shapiro, 2020). The CDM subsidy renders projects that were already planned or constructed to become more profitable, and to make non-profitable projects more likely to be built. Therefore, the overbuilt nature of rivers in the Mekong Region cannot be separated from global climate change policy and the hydropower subsidies received from the CDM.

5.2. Effects of the telecoupled system: CDM infrastructure in basins at risk

The changes to the transboundary river systems, particularly the downstream implications for the Mekong Region as a spillover system through the rapid roll out of over 200 CDM large-scale dams are not well understood. Dams of this scale often take 5–10 years to construct, so that many of these projects were being built simultaneously and have multidecadal life expectancies. The changes brought by these simultaneous construction projects is complex, exponential, multiscale, and will have lag time effects for decades to come (Rousseau and Habich-Sobiegalla, 2021, Rousseau, 2021).

While these dams would be controversial with or without CDM funding, the CDM's justification for funding projects is 'additionality', so the CDM would argue that these large dams would not be built without their funding. Project proponents have to prove the same idea throughout the application process, that the dam could not be constructed without CDM funding. By this logic of additionality, Darpein 1, Madushan, and Thuong Kon Tum would not be built without the CDM. We have highlighted examples of escalating tensions at just three dam sites, but we believe other forms of contestation would be found at various scales with the other hundreds of large-scale dams.

The Salween, Irrawaddy, Red, and Bei Jiang/Hsi rivers have limited or no international agreements or institutional capacity to jointly manage the rapid changes and long-lasting impacts brought on by the CDM investments, which increases the likelihood of conflict (Petersen-Perlman et al., 2017; Wolf et al., 2003a). The lack of institutional capacity or mechanisms to address the costs of the 'financialization of rivers' phenomenon is problematic as the majority of the projects were constructed in upstream China. Given China's position as an upstream superpower, downstream states of Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam have relatively little political clout to directly redress grievances with China diplomatically, particularly when there is no governance arrangement in place to do so. This is the case in the Salween, where all 60 large-scale CDM projects were built upstream of Myanmar and Thailand. The effects of the CDM hydropower portfolio thus enhances the power imbalances between China and less powerful downstream states.

The hundreds of large-scale CDM dams will increase the complexity of diplomacy and cooperation to manage transboundary rivers in the Mekong Region. We illustrated how a single CDM hydropower project can become entangled in escalating tensions through armed conflict or years of arbitration. In the Mekong, the Thuong Kon Tum project pulled national governments and hydropower SOEs into years of international arbitration during periods of high political tension between China and Viet Nam. In Myanmar's Irrawaddy basin, the CDM's Darpein 1 spurred direct violence and a subsequent military occupation at the disputed project site.

In the Red River, which received the most large-scale funded CDM hydropower with 77, more research is needed on how the grouping of multiple projects impact transboundary hydropolitical dynamics. Unannounced dam releases near international borders creates sudden, short term risks. However, the lack of information on dam operations and construction in upstream China, creates planning uncertainties for Viet Nam in the long term. These infrastructures in combination with a lack of data sharing or institutional capacity exacerbates uncertainties in the Red River basin.

6. Conclusion

We illustrated how global climate change policy is funding large-scale hydropower in basins at 'very high risk' of hydropolitical tension. The patterns of CDM hydropower investments in transboundary rivers are not dispersed, but instead concentrated in the Mekong Region. Hundreds of contested projects received subsidies, primarily going into Chinese SOEs with distant value extraction taking place in Europe from carbon asset markets. With each additional CDM dam constructed, the risk for hydropolitical tensions was raised and power imbalances between upstream and downstream states were enhanced.

At the same time, as each one of the hundreds of large-scale dams went online in Yunnan, the efficiency of the entire energy grid was reduced, and each carbon credit was rendered further away from justifications of carbon reductions nor sustainability. The extreme pace and density of the hydropower rollout rendered the transboundary rivers to be overbuilt and inefficient. These large-scale infrastructures almost always cause benefits to accrue to a small group of elites, while socializing the costs onto millions of Mekong citizens (Middleton, 2022; Rousseau et al., 2017; Soukhaphon et al., 2021). The costs from these projects will extend well past the CDM and challenge the sustainability of carbon markets in relation to the long-term tradeoffs of infrastructure on international rivers.

This bond between global climate finance and the hydropower industry has led to a 'financialization of rivers' phenomenon in the Mekong Region. 'Financialization of rivers' occurs when hydropower investment vehicles are deployed in a manner so that the tangible benefits from things like energy production, are outweighed by intangible financial considerations. Overbuilt rivers, energy surplus bottlenecks, and credit registration at unbuilt or conflictual project sites illustrate this dynamic. The efforts to profit from the world's rivers should not be understood as financing sustainable development, but instead developing sustainable finance (Motta and Matthews, 2017).

Carbon credits represent another source of value creation from dams that primarily perform as investment vehicles (Ahlers and Merme, 2016; Ahlers, 2020). The global market mechanisms to address climate change joining forces with an already profitable hydropower industry presents a severe threat to the world's rivers and riverine communities. Despite all of these issues with hydropower, the urgency of climate change risks has supercharged investments in hydraulic infrastructure projects, streamlining finances and approvals while sidelining opposition and contestation over these development interventions (Fox and Sneddon, 2019; Li and Shapiro, 2020). This sidelining of opposition is occurring domestically while international considerations are nonexistent. This is particularly problematic for the future of carbon markets where accounting and approvals occur at a national level for projects that have international environmental implications and globalized financial flows.

As of 2023, CDM hydropower represents the largest potential type of carbon credit that is Paris eligible (UNEP, 2023). This trend of hydropower bolstered carbon reduction claims is likely to accelerate as new carbon markets come online, the increase in voluntary carbon credits, and the push from the financial sector for corporations to offset their carbon production within financial portfolios. We expect more hydropower projects would be certified if the CER market price had not slumped in 2012 and that this 'financialization of rivers' process could be more pronounced if carbon credit values increase. Through the CDM and currently under Paris, hydropower has proven to make up a significant source of carbon credit production in the portfolio.

This raises serious questions of the role of carbon offsets in global climate change policy and hydropower's place within Paris Article 6.4. Our research demonstrates the problems with addressing climate change through a carbon only approach at a national level, that inherently has shared international water implications. While the CDM did not cause any given project to be conflictual, hydropolitics and attention to the conflict risks associated with infrastructure construction in transboundary rivers was absent in the CDM. Transboundary water governance is highly contextual and where infrastructure is being constructed in shared rivers has severe implications for hydropolitical outcomes. Rather than a domestic, carbon only approach to global climate change policy, water and hydropolitical risk in shared rivers should be a central feature of global environmental governance considerations.

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CRediT authorship contribution statement

Stew Motta: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Isabella Böck:** Visualization, Methodology, Investigation, Data curation. **Johanna Koehler:** Writing – review & editing, Supervision. **Aaron T. Wolf:** Writing – review & editing, Supervision, Methodology. **Philipp Pattberg:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annex 1. . CDM hydropower projects in global transboundary river basins, basins at 'very high risk' for hydropolitical tension highlighted in red

#	Basin name	Area	Population	Amount countries	CDM projects	Countries' names(UNEP-DHI and UNEP, 2016)
1	Red/Song Hong	140	17,864	3	77	**China**, Lao PDR, Viet Nam
2	Salween	265	7851	3	60	**China**, Myanmar, Thailand
3	Bei Jiang/Hsi	401	77,098	2	56	**China**, Viet Nam
4	Irrawaddy	375	28,583	4	43	Myanmar, **China**, India
5	Mekong	773	58,743	6	38	China, Myanmar, Thailand, Lao PDR, Cambodia, Viet Nam
6	La Plata	2927	88,221	5	33	Argentina, Bolivia, Brazil, Paraguay, Uruguay
7	Amazon	5888	32,164	9	31	Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname
8	Tarim	1098	10,322	7	20	Afghanistan, China, Aksai Chin, Jammu and Kashmir, Kazakhstan, Kyrgyzstan, Tajikistan
9	Indus	856	189,912	7	19	Afghanistan, China, Aksai Chin, Jammu and Kashmir, India, Nepal, Pakistan
10	Ganges-Brahmaputra-Meghna	1652	704,221	7	16	Bangladesh, Bhutan, China, Arunachal Pradesh, India, Myanmar, Nepal
11	Ili/Kunes He	415	5184	3	13	China, Kazakhstan, Kyrgyzstan
12	Ca/Song-Koi	27	2741	2	13	Lao PDR, Viet Nam
13	Saigon	30	10,911	2	13	Cambodia, Viet Nam
14	Ma	30	2985	2	7	Lao PDR, Viet Nam
15	Ob	3042	30,697	4	6	China, Kazakhstan, Mongolia, Russian Federation
16	Grijalva	126	8302	3	6	Belize, Guatemala, Mexico
17	Chiriqui	1	90	2	5	Costa Rica, Panama
18	Amur	2093	65,217	4	3	China, Mongolia, Dem. People's Rep of Korea, Russian Federation
19	Lake Prespa	8	601	3	3	Albania, Greece, The former Yugoslav Republic of Macedonia
20	Coruh	22	789	2	3	Georgia, Turkey
21	Nile	2933	174,365	14	2	Burundi, Central African Republic, Egypt, Hala'ib triangle, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Abyei, South Sudan, United Republic of Tanzania, Uganda, Dem. Republic of the Congo
22	Mira	10	625	2	2	Colombia, Ecuador
23	Niger	2111	93,618	12	1	Benin,Burkina Faso,Côte d'Ivoire, Cameroon, Algeria, Guinea, Mali, Mauritania, Niger, Nigeria, Sierra Leone, Chad
24	Zambezi	1373	37,980	9	1	Angola, Botswana, Mozambique, Malawi, Namibia, United Republic of Tanzania, Dem. Republic of the Congo, Zambia, Zimbabwe
25	Kura-Araks	190	14,462	6	1	Armenia, Azerbaijan, Georgia, Iran (Islamic Republic of), Russian Federation, Turkey
26	Orinoco	934	12,165	4	1	Brazil, Colombia, Guyana, Venezuela
27	Senegal	448	7409	4	1	Guinea, Mali, Mauritania, Senegal
28	Juba-Shibeli	792	19,761	3	1	Ethiopia, Kenya, Somalia
29	Tumen	33	2602	3	1	China, Dem. People's Rep of Korea, Russian Federation
30	Lempa	18	4609	3	1	Guatemala, Honduras, El Salvador
31	Han	33	17,758	2	1	Republic of Korea, Dem. People's Rep of Korea
32	Kunene	109	1933	2	1	Angola, Namibia
33	Neretva	7	633	2	1	Bosnia and Herzegovina, Croatia
34	Motaqua	16	3846	2	1	Guatemala, Honduras
35	Sassandra	68	4143	2	1	Côte d'Ivoire, Guinea
36	San Juan	41	3443	2	1	Costa Rica, Nicaragua
37	Terek	43	3939	2	1	Georgia, Russian Federation
	SUM of CDM large-scale hydropower intransboundary river basins				**484**	

Data availability

Data will be made available on request.

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