Master thesis MSc Environment and Resource Management
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Hydropower in Yunnan, China: Ecologically Unequal Exchange and the Perpetuation of the (Semi) Periphery

Xiaowan Dam, the tallest dam in Yunnan province (292 meters)
Source: Hortle, 2018

Word Count: 11,950

Contents

Abstract

Ecologically unequal exchange (EUE) theory posits that the global political-economic structure, particularly international trade, drives the uneven distribution of environmental costs and benefits. EUE analysis argues that these structures have acted to create and perpetuate inequalities between the Global North and South based on the ability of the Global North to extract energy (often in the form of raw materials) from and utilize environmental sink capacity of the Global South. This paper contributes to the scholarly debate surrounding these ideas by applying them to the context of hydropower development in Yunnan province, China. Through an analysis of the Clean Development Mechanism (CDM) of the Kyoto Protocol and its application in Yunnan province, this thesis demonstrates that CDM funded dams have been built primarily in rural, poor, and ethnic minority areas and that the energy and benefits produced by those dams have gone to industrial corporations, the developed coastal areas of eastern China, and ultimately consumers in the industrial core of the Global North. Simultaneously, the negative ecological and social costs of dam building are primarily felt by the people living near them. This paper adds to the body of scholarly work supporting ecologically unequal exchange as a global structure driving international ecological and developmental inequality.

Keywords: Ecologically unequal exchange, China, carbon finance, hydropower, Clean Development Mechanism

Foreword

This study represents the culmination of my work carried out for the Master in Environment and Resource Management at the Vrije Universiteit Amsterdam and represents the Research Project component required for all students wishing to complete the program. The project was undertaken between March and June of 2021.

I would like to thank Dr. Hennig of the Philipps-Universität Marburg, Dr. Magee of Hobart and William Smith Colleges, Dr. Harlan of Loyola Marymount University, and Dr. Ptak of Texas State University for their comments and advice in the construction of this research project. I would also like to thank Stew Motta for his stimulating discussions and reviews of drafts for this project. Finally, I would like to thank Dr. Dell'Angelo for supervision of this project, as well as his encouraging and motivating comments about where I might go with this research.

List of Abbreviations

APE – Atmospheric pollutant equivalents

CCP – Chinese Communist Party

CDM – Clean Development Mechanism

CER – Certified Emission Reductions

EU – European Union

EUE – Ecologically unequal Exchange

GHG – Greenhouse gas emissions

GIS – Geographic information system

GNI – Gross National Income

GNP – Gross National Product

GW – Gigawatt

HP - Hydropower

KBA – Key biodiversity areas

LHP – Large hydropower

MW – Megawatt

NDRC – National Development and Reform Commission

PA – Protected areas

SDM – Sustainable Development Mechanism

SHP – Small hydropower

SPCC – State Power Corporation of China

TWH – Terrawatt hours

UHVDC – Ultra-high voltage direct current

UNFCCC – United Nations Framework Convention on Climate Change

1. Introduction

The previous decade has been a momentous time for global climate governance. In 2015, in the face of mounting scholarly evidence of both the certainty and severity of climate change and related issues, national leaders of 191 countries representing the majority of global carbon emissions signed the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). As the first universally binding global climate agreement (the Kyoto Protocol adopted in 1997 was also binding, but only for those countries designated as Annex I), the Paris Agreement was seen as a milestone and shift in the international response to climate change.

Building on these efforts, in 2020 Chinese President Xi Jinping pledged that China will become entirely carbon neutral by 2060 (Mallapaty, 2020). Not to be outdone, American President Joe Biden pledged to reduce U.S. greenhouse gas emissions (GHGs) by half by 2030 and has made a green infrastructure overhaul a cornerstone of his presidential policy (Dennis & Eilperin, 2021). In the leadup to a climate summit convened by President Biden, the European Union (EU) also pledged to reduce emissions by 55% by 2030 (Boffey, 2021). Considering that the sum of the EU, USA, and China's domestic carbon emissions constituted over 57% of global emissions in 2019, these pledges are crucial in the fight to keep global warming below 1.5°C (Ritchie & Roser, 2021).

What these pledges do not address, however, is the impact of carbon emissions driven by globalization and international trade. They refer only to production-based emissions (such as local energy production or domestic manufacturing) but do not include consumption of carbon equivalents embedded in imports. This is despite the fact that China, known as "the world's factory", manufactures multitudes of products intended for international consumption. Failing to acknowledge the emissions produced in other regions of the world due to consumption patterns in the Global North fundamentally misrepresents where responsibility for those emissions lie. For example, based on data from 2017, high-income countries[1] represented 39% of production-based CO2 emissions, but over 46% of consumption based emissions (Ritchie & Roser, 2021). Further considering that the population of high-income countries only represents 16% of the global population (Ritchie & Roser, 2021), the distribution of responsibility is clearly uneven.

It is inequality such as this which the theory of ecologically unequal exchange (EUE) seeks to address and explain. Rooted in Wallerstein's world-systems theory (1974) and Bunker's (1985) conceptions of ecological factors as the roots of national and regional underdevelopment in an unequal world system, EUE focuses on international trade as the central pillar of a global political-economic structure that systematically impoverishes the periphery while enriching the core (Givens et al., 2019; Dorninger et al., 2021). It further argues that this structure is fundamentally necessary for the continued ability of the core to accumulate technological capacity and economic growth (Dorninger et al., 2021).

This paper takes the analytical lens provided by EUE theory and applies it to the phenomenon of rapid hydropower development in Yunnan province, China. In 2018, China produced 1,232 TWH of hydropower electricity (28.5% of world total, Brazil was the second largest with 389 TWH) and had the greatest installed hydropower capacity with 352 GW (Brazil was second again, with 105 GW) (IEA, 2020).

[1] Defined by the World Bank as those with a Gross National Income (GNI) per capita of $12,536 or more (World Bank, n.d.).

Approximately 80% of potential hydropower sources in China are concentrated in the Western provinces of Yunnan, Sichuan, and Tibet, and in the previous two decades hundreds of hydropower plants have been built in those regions (Qin, 2017).

After Sichuan and Tibet, Yunnan province has the greatest potential hydropower capacity in China owing to the six major rivers running through the province (Liu et al., 2018). These rivers are the Dulong (Ayeyarwady), Nujiang (Salween), Lancang (Mekong), Jinsha (Upper Yangtze), Honghe (Red), and the Nanpan (Pearl). The terrain is highly varied, with the mountainous northwest reaching as high as 6740m at Meili Snow Mountain, while its lowest point is a mere 76.4m above sea level near the border with Viet Nam in the southeast. Four of these major rivers are transboundary, running into Myanmar to the west, Lao PDR to the south, and Viet Nam to the east. These shared international rivers and their rapid hydropower development have made Yunnan province a focal point for China's diplomacy with its neighbors and environmental governance scholars worldwide. While the potential for large quantities of carbon free, or at least carbon limited, power in a carbon reduction focused world is enticing, hydropower still poses significant ecological, social, and economic challenges (Ansar et al., 2014). Related ecological problems include river fragmentation, disruption of sediment flows, disruption of fish migration, and flooding, among others (Bai et al., 2017; Csiki & Rhoads, 2010; Mekong River Commission, 2018). Further, the materials and infrastructure needed for hydropower development such as steel, concrete, timber, and road building also bear significant costs (Kibler & Tullos, 2013; Moran et al., 2018). The detrimental effects of hydropower development on marginalized communities, particularly in the case of non-inclusive and non-democratic governance, have also been well established (Bakker, 1999; Geheb & Suhardiman, 2019).

Hydropower's challenges need to be considered as the industry is the largest recipient of Kyoto Protocol funding for emission reductions through the Clean Development Mechanism (CDM). The Kyoto Protocol was adopted some 5 years after the Rio Earth Summit in 1992 and came into force in 2005. Based on the principles of the UNFCCC, it created a framework for committing industrialized and developing countries to limiting and reducing the production of anthropogenic GHG emissions. Splitting all signatories into either Annex I (industrialized-Europe, Australia, Japan and New Zealand) or Non-Annex I (all other countries including China), the goal was to create a framework that allowed for reductions to occur in an equitable and sustainable manner (UNFCCC, n.d.-b).

The CDM is a carbon finance mechanism that theoretically contributes to that goal. It functions as a system of salable offsets which allow Annex-I countries to offset domestic GHG emissions by implementing emission-reduction projects in developing countries. The goal is to stimulate sustainable development and emission reductions in the most efficient way possible. GHG reduction costs are typically higher in Annex I countries while Non-Annex I countries have limited access to capital. The CDM was meant to be an innovative bridge around these constraints to produce effective and efficient GHG reduction.

Based on data from the UNFCCC, China registered a full 47.97% of all CDM projects between 2004 and 2020, constituting 58.84% of total Carbon Emission Reductions (CERs)[2] (UNFCCC, n.d.-a). The second largest CDM registrant was India, with a distant 21.43% and 11.73% respectively. Based on searches in the CDM project registry, China registered at least 3876 CDM renewable energy projects between 2004 and

[2] These are the salable credits traded under the CDM. Each credit is valued as a 1 metric tonne reduction in CO2 equivalent. This equivalency is evaluated based on their global-warming potential (GWP) by converting amounts of other gases (such as methane) to the equivalent amount of GWP for CO2. For example, the GWP for methane is 25. This means that 1 million metric tonnes of methane is equivalent to 25 million metric tonnes of CO2.

2020. Of those, filtering by "hydro, "hydropower", or "hydroelectricity" leaves 1,313. Considering that not all projects use these descriptors in their titles, at least 33.9% of all CDM funded projects in China are hydropower related. In light of the multitude of literature detailing hydropower related problems, it is essential to understand where, how, and why these dams are built and funded. These questions are particularly relevant today as the decision on whether or not to extend the functioning of the CDM will be taken at COP26 in Glasgow in November 2021 (Farand, 2020). Even should the CDM cease to operate, the Sustainable Development Mechanism (SDM) of the Paris Agreement is its spiritual successor and must learn from the mistakes of its predecessor if it hopes to succeed.

This paper adds to the scholarly debate surrounding EUE and the discourse around effective climate change prevention by applying EUE's theoretical structure to the context of hydropower development in Yunnan province, China. Through an analysis of the Clean Development Mechanism of the Kyoto Protocol and its application in Yunnan, this paper contributes to the body of scholarly work examining EUE as a global structure driving international environmental and developmental inequality.

With these factors in mind, the goal of this paper is to uncover the logics driving the construction of questionably necessary, or even useful, hydropower dams in China. How have global and domestic power structures influenced the construction of these dams and what are the consequences thereof? What role has the CDM played in their development? Which actor or actors benefit, and which suffer the consequence of their construction? To answer these questions, the paper will be structured as follows. First, I give a brief background as to why Yunnan province was chosen as a case study and what sets it apart from other areas both within China and without. Second, I summarize the theoretical roots of ecologically unequal exchange and its origins along with a discussion of the related world-systems theory conceptions of core, semi-periphery, and periphery and how they are relevant to hydropower in Yunnan. There is also a brief discussion of alternative theoretical perspectives. I then outline the methods used to investigate the role of various factors in the development of hydropower dams in Yunnan province, including the CDM itself as well as domestic and global political structures. Fourth, I detail the results of my analysis of the CDM project registry and some relevant GIS mapping. I continue with a discussion placing this case study in the larger context of the academic debate surrounding EUE and make the case that CDM funded hydropower in Yunnan is indeed a form of EUE. I conclude with a refutation of alternative perspectives introduced in section three and some recommendations for future research.

2. Background

It is important to explain why Yunnan province was chosen as the case study, and not some other province, governmental unit, or even country. As previously mentioned, China has by far the most hydropower dams in the world and Yunnan province has the third greatest capacity after Sichuan and Tibet (Liu et al., 2018). Simultaneously, hydropower infrastructure in China, while already significant, did not begin growing exponentially annually until the first period of the CDM began in 2005 (Liu et al., 2018) (see fig 1 below). While the Kyoto Protocol was not necessarily the sole driving factor in this boom, it nonetheless offers an unparalleled opportunity to analyze carbon finance and the larger international trade system's effect on hydropower development.

The provincial perspective is a useful level of analysis as it allows for internal comparisons of highly divergent regions within a unified governance structure. It further allows for more effective use of Chinese state and Yunnan provincial statistical data, as zooming in further than the provincial level (especially in a remote region like Yunnan) can lead to difficulty obtaining reliable information. Similarly, the CDM as a UN organized and supervised structure gives far greater access to somewhat reliable documentation, in English, about HP development than would otherwise be accessible.

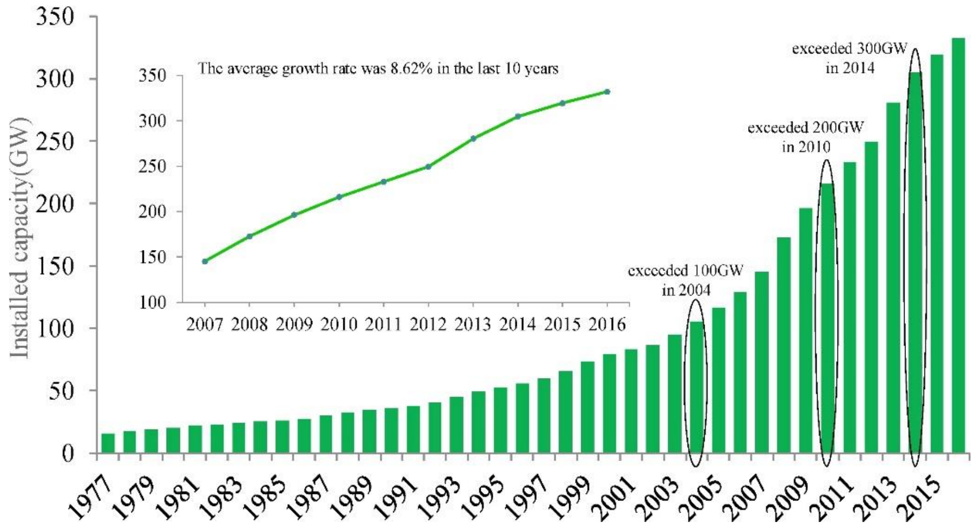

Figure 1: Chinese Hydropower Capacity Growth 1977-2017
Source: Liu et al, 2018

Finally, Yunnan province has the highest installed small hydropower (SHP) capacity in China and is simultaneously the world's largest SHP-producing region (Hennig & Harlan, 2018). This is in conjunction with some of the world's tallest, largest by MW output, and widest dams. This is crucial because it allows us to see how, by whom, and why dams of different capacities and types are built.

An additional emphasis is placed on the development of dams in protected areas and key biodiversity areas. While obviously inherently problematic (dam building is associated with not only damage relating to the dam itself as detailed above, but also with road building and habitat fragmentation (Kibler & Tullos, 2013)) , an analysis of this kind becomes particularly relevant due to the regions wealth of biodiversity. Alternatively known by its nickname the "Wildlife Kingdom", Yunnan has over 18,000 plants, 1,638 vertebrates, and the highest species richness and endemism of all of China's provinces (Clarke, 1999). Yunnan is home to approximately three-quarters of China's protected animals, of which at least 15% are endemic to the province. In this context, it becomes imperative that the forces driving development in ecologically crucial areas are studied and understood.

3. Ecologically Unequal Exchange

3.1 Theoretical Roots

A globalizing world signifies a constantly expanding network of interconnected trade, people, and culture. These connections have given birth to complex systems of production at absolute lowest cost, flows of material wealth made with utmost efficiency in mind. For some lucky few, globalization has assisted in the mass accumulation of wealth, power, and – importantly – a cleaner environment. But every coin has two sides, and by many accounts – and certainly by population size - the dark side of this coin is far larger. Ecologically unequal exchange as a framework analyzes this two-sided coin and links them together through the structures of international trade.

Starting in the 1970's, Wallerstein (1974) takes the historical context of feudal Europe and uses it to explain how both local and global structures influence the developmental paths of nation-states. He discusses how, through the birth of the capitalist world economy, the core regions of northwestern Europe enriched themselves at the expense of peripheral economies through an international trade system constructed in their favor. This imbalance was created and perpetuated through the extraction of raw materials from the periphery and ultimate manufacturing of finished goods in the core. He discusses how this capitalist system was able to restructure both commercial and political power wherever it was able to penetrate. A nation-states' place in the world system, then, is defined by both domestic variables and the influencing power of global structures (Wallerstein, 1974).

Central to this perspective of global inequality is the concept of unequal exchange, which Emmanuel (1972) first articulates. From his perspective, the inequality we see in the world system is a function of wage differentials that are perpetuated by the immobility of labor and the relatively greater mobility of core investment capital, allowing core countries access to an abundance of low paid labor. He argues that this is the basis for unequal exchanges of value, as trade typically occurs between labor intensive, low wage products from the periphery to capital intensive, high wage products from the core. These underlying structures perpetuate inequality as the core captures any excess labor productivity in the periphery in such a way that excess value and infrastructure cannot accrue in the periphery (Emmanuel, 1972; Rice, 2007).

While Emmanuel's unequal exchange and Wallerstein's world systems theory admirably address global inequality, they leave out a key factor in the equation: the ecological underpinnings (Gellert, 2019). This is the gap in the literature that ecologically unequal exchange fills. Stephen Bunker's (1985) work *Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State* takes the structures of world systems theory and unequal exchange, and then roots them in the physical extraction processes under which they function. Combining Marx's labor theory of value, Emmanuel's (1972) wage inequality as the root of unequal exchange, and an ecologically based theory of value, Bunker explains the processes which have led to the regional underdevelopment and environmental degradation of the Amazon on the basis of exploitative international trade from the economic core. A key point is that while local elites benefit from this extraction in the short term, and therefore aid in its facilitation, the processes ultimately deplete the resources upon which their own wealth is based. This could help to explain why today many of the world's billionaires are from "periphery" countries despite overarching growing inequality between core and periphery. For example, since 2000 the number of billionaires found in the Global South has grown at a larger rate than those found in Western countries or Japan (Clelland & Dunaway, 2016). Indeed, China alone is now home to 18.9% of the world's billionaires (Gilchrist, 2020).

Hornborg (1998) attempts to elucidate the empirical drivers of this unequal exchange by demonstrating that in a capitalist system, the greater extent to which a product has been industrially processed and manufactured, the greater value that good creates. As discussed by Georgescu-Roegen (1971), this fact lies in opposition to the entropic law of nature which postulates that the greater extent to which a product has been processed and/or manufactured, the greater its inherent productive potential has been dissipated. This disconnect is created through the capitalist conception of value, or utility, which Hornborg (1998) says uses the "notion of a market price [to conceal] the fact that what is being exchanged are intact resources for products representing resources already spent". (pg. 134) Rice (2007) elaborates upon this point and argues that that unequal transfer of value is hidden through exclusive reference to monetary indicators, which is a "consequence of the neoclassical economics tendency to equate exchange value with utility". (pg. 64) The conundrum for ecological economics (and the point underlying EUE) is therefore twofold. First, market prices are cultural constructions that do not actually measure material flows (which is the point of departure for ecological economics); simultaneously, however, culturally constructed prices have real consequences. The global unequal system is therefore ruled by something which is concurrently "unreal and real at the same time." (Hornborg, 1998, pg. 132)

It is the concealing nature of market prices which necessitates the use of a global, material based approach. As wealth accumulation is based on states' capacity to absorb energy and raw materials and externalize waste products[3], failing to take into account the material products a society absorbs to maintain and grow its own structure leads to a blinkered view of processes of social metabolism (Martinez-Alier, 2009). One aspect of the inequality created is in the form of environmental cost shifting, whereby the extractive nature of relations between states with power and development asymmetries leads to the environmental externalities of high level consumption being pushed onto the weaker subject (Martinez-Alier, 2009). This means that in a finite and material world, consumption of resources in one place by definition means the extraction of resources and degradation of environment in another.

Based on these works and referring to Rice's (2007) delineation of the core components of ecologically unequal exchange, EUE can be defined as follows:

1) *Environmental cost-shifting* whereby the industrial core externalizes and shifts the sociological and ecological costs of extraction of raw material to peripheral states.

2) The uneven and uncompensated utilization of *environmental sink capacity* in the periphery by the core, limiting the ability of the periphery to put that capacity to productive use.

3) Environmental cost shifting and utilization of sink capacity by the core leads to systematic *processes of underdevelopment* in the periphery. This underdevelopment is linked to the reduced ability for peripheral countries to gain benefits from the value inherent in local raw material and sink capacity.

3.2 The Semi-Periphery

One aspect which traditional forms of EUE theory underutilized, and which scholars have more recently usefully borrowed from Wallerstein's world systems theory, is the existence of the semi-periphery (Frame, 2018). As Downes (2009) outlines, the semi-periphery can be "understood as having the [sic] both the consciousness of subordination and the means of resistance-in contrast to the core which may lack the consciousness, or the periphery, which may lack the requisite means." (pg. 114) Alternatively, Lawrence (2009) describes it as a region spatially located between core and periphery regions or a region which has features of both the core and periphery, but in an intermediate way. Taken from Wallerstein (1974) himself, it is a region with an approximate balance between core and peripheral

[3] See Marx's metabolic rift and Prigogine's conception of cities/societies as dissipative structures that absorb order from external sources in order to combat entropic force.

activities. Clearly, these definitions are relatively ambiguous, and first require one to delineate what it means to be either core or peripheral.

Borrowing from the work of Chase-Dunn and Hall (1997), core countries are primarily characterized by highly developed forces of production consisting of high-paid labor, advanced technology, and capital-intensive production. These characteristics stand in contrast to the periphery which typically has low levels of production, frequently focusing on extractive industry, and utilizing high levels of low-paid labor. The semi-periphery has characteristics of both, and most world-systems scholars agree that the semi-periphery is both exploited by the core while simultaneously exploiting the periphery (Clelland & Dunaway, 2016). For the purposes of this paper, I will characterize the semi-periphery according to this last conception.

Some scholars have also noted the existence of internal peripheries, particularly relating to the exploitation of ethnic minorities for low-paid labor for the cause of supporting domestic production for export (Clelland & Dunaway, 2016). Clelland (2014) similarly explores internal peripheries by demonstrating how a transnational capitalist class within China, supported by a Chinese state maintaining monopolistic control, exploits underpaid labor and externalized ecological degradation to sell that labor and associated materials to the core. Since the goods that are manufactured in these peripheries are ultimately sold in the core without accounting for unpaid labor and ecological degradation costs, Clelland argues that this *dark value* is passed onto the core consumer as consumer surplus. As such, the consumer in the core becomes (often unwittingly) a perpetuator of the global hierarchy of states.

These discussions are particularly relevant in relation to Yunnan province as it is not only China's most biodiverse region, but also its most ethnically diverse (Chow, 2005). In China, Autonomous Prefectures are areas where either more than 50% of the population is an ethnic minority or where the area is the historical home of significant minorities. Yunnan province has the largest number of autonomous prefectures of all Chinese provinces with eight of its prefectures being designated as such (out of the province's 16). Even areas which may not be designated as autonomous prefectures by the Chinese government frequently have significant minority populations. For example, Yunnan also has the largest number of autonomous counties (similar to autonomous prefectures but at the county level) of all Chinese provinces with 28 (compared to the second largest, Guangxi, with 12). I will make the argument, therefore, that Yunnan constitutes an internal semi-periphery while China as a whole remains semi-peripheral.

These conceptions of the semi-periphery and internal peripheries are highly relevant in understanding the place of China as an economic superpower that simultaneously gains extremely limited value due to its place in the global commodity chain in comparison to the industrial core (W. Zhang et al., 2018). Indeed, as Arrighi et al. (2003) elaborate, it is not so much the particular mix of economic activities a state partakes in that differentiates between core, semi-periphery, and periphery, but rather its capacity to capture the benefits of the world division of labor. Therefore, despite China's enormous GDP and continued rapid growth, its place along the value chain of production is what places it squarely in semi-peripheral territory.

3.3 Alternative Perspectives

To ensure a nuanced discussion, it is vital to also discuss alternative perspectives. The theories which have been presented until this point focus on the destructive power of capitalism and trade structures which perpetuate international inequality at a material level. There are those, however, who argue that through technology society can decouple economic growth and ecological degradation. There are also those who argue that growth is *necessary* for ecological preservation by way of the environmental Kuznets curve, which posits that society must become sufficiently wealthy before it can focus on protecting the environment (De Mooij & Van Den Bergh, 2002). One of these alternative perspectives is that of ecological modernization theory, which disagrees with the neo-Marxist perspective of EUE that capitalism is inherently incapable of preventing environmental degradation.

While neo-Marxists and ecological modernization theorists agree upon the materiality of the environment and the need to account for it in sociological theories attempting to understand the "human project", ecological modernization theorists argue that a delinking of capitalist growth from environmental degradation is possible (Mol & Spaargaren, 2000). Although going beyond the neoclassical economic tendency of simply talking about "getting the price right" for environmental externalities, ecological modernization theorists still argue that capitalist growth and environmental protection are not antithetical through the "vocabulary of 'rationalizing production and consumption'" (Mol & Spaargaren, 2000, pg. 27). Concepts used to support these assertions include environmental accounting and bookkeeping, green GNP, and environmental efficiency, among others (Spaargaren, 2000). In the context of CDM funded hydropower development in Yunnan, an ecological modernization theorist might argue that any failure to achieve additionality or creation of unaccounted for externalities lie in inadequate ordering of modes of production rather than problems inherent to a capitalist system. To it its critics on the radical left, however, ecological modernization is guilty of technocratic optimism and merely constitutes a "shallow" ecological view. I will detail this refutation of ecological modernization theory as relevant to this paper in section six.

4. Methods

4.1 Data Procurement

Once Yunnan was chosen as the unit of study, the first step towards analyzing the driving factors regarding CDM related hydropower development in the region required a review of existing literature relating to domestic political, economic, and cultural structures. Relevant literature was found by searching for scholarly articles through search engines like Google Scholar, Web of Science, and Science Direct, as well as searches of the Vrije Universiteit Amsterdam University Library. Once prominent articles were identified by sorting by number of citations, further articles were discovered through snowball sampling. Additional literature was found by identifying key authors in the fields of EUE theory or hydropower in China and looking at previous work.

4.2 Project Database

In order to make sense of where CDM projects were built, how they were affecting the province, and by whom they were being funded, I analyzed the registered project activity database of the CDM found at https://cdm.unfccc.int/. This website serves as the publicly available registration and monitoring database of all CDM projects under the auspices of the UNFCCC. Using the "Project Search" function, I narrowed the sectoral scope to "Energy industries (renewable - / non-renewable sources)" and set the host country to China. As previously mentioned, this yielded 3639 search results. As it was not possible to further narrow the search without potentially missing projects (many projects were missing key relevant typology words like "hydro" and region specifiers like "Yunnan"), I went through each individual project to determine those of relevance. After completing this process, I had identified 310 projects of which 298 had ultimately been built (12 were withdrawn or rejected). As the CDM requires all projects to create project documents detailing the exact nature of a project, I then analyzed all 298 sets of project documents to create a separate database detailing

- Date of registration
- Project Title
- Other Parties (governments purchasing related credits through brokers)
- Methodology
- Reductions
- Reference Number
- River Basin and tributary if applicable
- Megawatt (MW) capacity
- Autonomy (country and prefecture)
- Coordinates

Using this database, I undertook some simple descriptive analysis to detail who the largest Annex-I backers of hydropower in Yunnan were and in what river basins the majority of these projects were.

An important distinction to make is that many projects listed under one title in the project database include multiple dams and multiple power stations. As the deleterious effects of damming include the creation of impassable barriers for fish to migrate through and dewatering of river sections, it is crucial to also look at the actual number of dams, weirs, water intakes, and power stations built as opposed to simply the number of projects. In some cases, even if there was only one dam created for hydroelectric purposes, a secondary auxiliary dam would also be built. Consequently, I created a second version of the database where all projects with multiple dams or weirs were divided into separate projects and, unless each separate dam was listed with a specific MW capacity in the project document, MW capacity and total associated carbon reductions were divided evenly between them to prevent accounting errors. For projects with multiple intakes a note was left next to the entry, but the MW capacity and reductions were not divided into separate projects as an intake does not typically create a physical barrier for water flow and fish movement. After dividing projects into their constitutive parts, the 298 projects listed in the CDM registry represented 377 dams and weirs.[4]

Further, some caution must be taken in utilizing project documents from the CDM database. These documents are prepared by those running the project and are often vague and misleading. As such, the geographic coordinates provided in these documents are often incorrect. Based on those coordinates, several of the dams seem to fall outside the borders of Yunnan province or even China itself. Problems with coordinate information included no seconds being provided, coordinates being given as a range, no attached project document, no coordinates listed, coordinates being in another country/province, and coordinates being duplicates of another project. See Table 1 below for an exact count. These numbers

[4] For a full overview of the database, please see the link provided in Appendix A.

represent 28 projects where coordinates given were demonstrably incorrect or inadequate, constituting 9.39% of all projects, or 7.42% when looking at all dams included in bundled projects.[5]

Table 1: Tally of uncertainties with dam coordinates
Source: Own work

Problem with Coordinates	Occurrences
No seconds	14
Given as range	8
No project document	2
Other	4

4.3 Spatial Analysis

As discussed in the introduction, Yunnan has some of the greatest biodiversity in the world. As a result, dam building in the region has particularly strong negative effects for global biodiversity conservation due to its effects on the ability of fish to migrate (Jutagate et al., 2016) and the destruction of downstream habitat through dewatering and upstream habitat through flooding (Kibler & Tullos, 2013; Richter et al., 2010). Therefore, beyond discussions of global inequality and exploitation, inadequate regulation of hydropower development in Yunnan is inherently problematic. In order to analyze to what extent CDM funded dams have been built in particularly fragile and significant regions, I mapped out all dams and cross analyzed their locations with internationally recognized significant conservation areas using QGIS 3.16, an open source desktop GIS system that allows for analysis of geospatial data.

In order to reach an adequate understanding of which areas in Yunnan province are fundamental for conservation, I decided to use both Protected Areas (PAs) and Key Biodiversity Areas (KBAs) as opposed to simply one or the other. This is because while they often overlap, they are not always the same. Protected areas are regions that have been recognized by the Chinese state as serving a particularly important function and can be designated as either nature reserves, world natural and cultural heritage sites, scenic zones, wetland parks, forest parks, geological parks, and water conservancy scenic locations, of which nature reserves account for the largest area (Cao et al., 2015).[6] However, designation of protected areas is as much a political decision as a purely ecological one, and as such designations affect types of industry, development, and settlement allowed. In order to account for the potentially significant areas not protected under Chinese legislation, Key Biodiversity Areas (KBA) as designated by the KBA secretariat (whose members include actors like the IUCN, Conservation International, Birdlife International and the World Wildlife Foundation, among others) were also used.[7] Finally, it should be noted that as some coordinates are listed incorrectly, calculations regarding hydropower projects in PAs and KBAs may vary slightly from reality.

[5] This is only the number of projects where I was able to definitively conclude that the given coordinates were incorrect or inadequate. Without personally visiting each dam, I was unable to determine how many other coordinate sets were incorrect.

[6] Data regarding locations of protected areas in China was found on the Protected Planet website (https://www.protectedplanet.net/en), a United Nations Environment Programme Wildlife Conservation Monitoring Centre (UNEP-WCMC) and International Union for Conservation of Nature (IUCN) biodiversity monitoring platform. The database is updated monthly through submissions by governments, NGOs, and individuals.

[7] More information can be found at http://www.keybiodiversityareas.org/.

4.4 Descriptive Statistical Analysis

In conjunction with the project database and subsequent spatial analysis, I utilized the Chinese Statistical yearbooks available online and a translated copy of the Yunnan Statistical yearbook (National Bureau of Statistics of China, 2019; Statistical Bureau of Yunnan Province, 2019). These statistical data allowed me to analyze where hydropower energy was being produced and consumed, what types of end consumers were using it, and make further deductions about what kind of effects different industries have on GDP, among other information. It is important to note that the data found in these yearbooks was not always internally consistent. These inconsistencies may have occurred for a variety of reasons, including differing accounting standards used by levels of government, changing data collection methodologies, and even human error. Further, Chinese Communist Party government officials are evaluated and promoted in accordance with statistical data in relation to their annual performance; there is therefore plentiful incentive for obfuscation (J.-H. Wang et al., 2015). This was particularly noticeable in regard to population data and energy consumption data. It is similarly possible that inconsistencies only appear to exist in the English version due to incorrect translations of statistical categories and data points. Whenever these inconsistencies existed, I used my best judgement based on surrounding data and (where possible) alternative sources to choose data points to use.

4.5 Limitations

There were a number of limitations for this project, the first of which was the coronavirus pandemic and the subsequent inability to conduct fieldwork. As multiple experts in the field whom I spoke with informed me, it is extremely difficult to get an adequate view of the highly diverse and rapidly changing context in Yunnan without speaking with those who are living it. I tried to overcome these limitations as much as possible by referencing the works of those who *have* been there to conduct fieldwork and by referencing many recent works to ensure the information is still valid.

Second, as I do not speak Mandarin Chinese, I was unable to access primary data in the original language. While some Chinese state documents have publicly available English versions, many do not. Wherever possible, I used the English versions and once again fell back on the work of those who are able to access Chinese language material wherever necessary. A further limitation of translated materials is that occasionally specific contextual meaning is lost in the translation.

5. Results

5.1 Hydropower Governance in Yunnan

The history of hydropower development in Yunnan province is a complex and multilayered story. This is a consequence of a multitude of factors, including the remote nature of Yunnan province, China's governance structure, the rapid development of the Chinese economy and its place in the global hierarchy of nations over time, and (crucially) the socio-economic factors on the ground throughout Yunnan's prefectures. Historically, Yunnan province is also one of the poorest provinces in the country, although this is now changing quite rapidly (National Bureau of Statistics of China, 2019).

Yunnan's, and China's, first hydropower project was built in Shilongba in 1912 with a capacity of just 0.48 MW. Over three decades later, another station was built near Dali with a capacity of 0.4MW (Hennig et al., 2016). Subsequent growth in hydropower capacity in the region can broadly be viewed in three stages. First, hydropower (and at the time particularly small hydropower) was seen as a method of rural electrification. During this initial period, starting in the early 1950's, small hydropower (SHP)[8] was run predominantly by local governments and cooperatives (L. Zhang et al., 2016). Running through the 1980's, the central government also launched initiatives promoting SHP for the purpose of electrification in rural mountainous areas. Second, and in the wake of the social and economic reforms of Deng Xiaoping, SHP became the backbone of industrial development in the relatively impoverished central and western regions (L. Zhang et al., 2016). Finally, in the period Yunnan finds itself today, hydropower is predominantly viewed through the lens of decarbonization[9] and Ecological Civilization[10] (Cheng et al., 2015; Harlan, 2021; Zhou et al., 2009).

It is in this final period where hydropower capacity has seen the most explosive growth, for which the reasons are complex. First was the change in the way the CCP (Chinese Communist Party) and Chinese state govern hydropower development. Beginning in the 1990's, the Chinese state began to reform the electricity generation sector so as to corporatize it and allow it to run more like a company than a government entity (Magee et al., 2006). In 1996, the Ministry of Electric Power was transformed into the State Power Corporation of China (SPCC) with the goals of realigning priorities in terms of the market as opposed to political incentive. This corporatization was carried out even more extensively when in 2002 the SPCC was further broken into five stock carrying power generation companies in which the state maintained a controlling share: namely China Guodian Corporation, China Power Investment Corporation, China Datang Corporation, China Huadian Corporation, and China Huaneng Corporation (Magee et al., 2006). As Magee et al. (2006) discuss, the context of this state energy management reformation is crucial in deconstructing the common conception of the Chinese state as monolithic actor. Despite the fact, then, that the construction of large hydropower projects technically only requires approval from the National Development and Reform Commission (NDRC) and occasionally the Chinese State Council, the five large state power corporations retain significant amounts of political influence in swaying where and how these projects are built (International Rivers, 2016).

[8] It is necessary to distinguish between large and small hydropower in China, as they have different biophysical impacts as well as legal contexts governing their development. Globally, different states and organizations define "small" as ranging between anywhere from up to one megawatt for facilities in Germany and Burundi, and up to 50 MW for Canada, Pakistan, and China. The CDM defines small hydropower as anything under 15MW. For the sake of consistency with statistics taken from the Chinese state and the grounding of this paper's research within China, I will use the definition of less than 50 MW. However, keep in mind that for most, 50 MW is anything but small. Further, there are some scholars who argue that MW capacity creates a false dichotomy between small and large which perpetuates conceptions of small being innocuous. Gleick argues that what really matters is the type of facility (Gleick, 1992). See also Kibler et al. (2013) for the cumulative impacts of small dams and discussion of higher environmental cost per MW output for small dams.

[9] There are certainly arguments to be made that hydropower development, while promoted under the official Chinese Communist Party language of decarbonization, is instead a form of territorialization and extension of state control into previously "under-governed" places. This argument is particularly relevant in the context of Yunnan's highly diverse ethnic population. For an in-depth discussion, see *China Goes Green: Coercive Environmentalism for a Troubled Planet* (2020) or Rousseau's (2020) article on hydropower in China as green grabbing.

[10] Ecological Civilization is one of the Chinese State's organizing political philosophies under Xi Jinping. Made an explicit goal of the CCP under Hu Jintao, it paints the Chinese state as both historical and visionary and grants the state a philosophically grounded mandate to protect the environment at all costs. Unfortunately, that same mandate can often be used to legitimate forced relocation of communities for ecological goals, among other issues (Li & Shapiro, 2020).

An important contributing policy factor is the "China Western Development Strategy", also known as the "Open Up the West Program." Under this program, the CCP has invested heavily in building infrastructure in the Western provinces as part of a "win-win" strategy to alleviate poverty in the resource-rich but economically underdeveloped West and to provide electricity for the highly industrialized East through electricity transfer schemes (Magee et al., 2006). Some of the largest hydropower projects in the province have direct point-to-point ultra-high voltage direct current (UHVDC) transmission lines from power station to energy-hungry Guangdong province (Hennig & Harlan, 2018). As a result of this, despite the extremely rapid buildup of hydropower infrastructure, in 2018 Yunnan more than half of the electricity generated locally (156TWh) (Hennig & Magee, 2021). The exported electricity alone is approximately equivalent to the entire power demand of countries like Thailand and Vietnam.

The story of small dam development runs in tandem with that of large dams. In the 1980's, the definition of SHP was raised to 25MW and by the late 90's to 50MW (Hennig & Harlan, 2018). Because until 2012 small dams could be built without any form of approval or oversight above the prefectural government, all projects under 50MW needed only minimal governmental approval (Hennig & Harlan, 2018; Kibler & Tullos, 2013). Further, in 2005 China passed its Renewable Energy Law which, among other provisions, required all hydropower plants to connect to the national grid and required grid operators to purchase certain amounts of renewable energy (Schuman & Lin, 2012). Since historically impoverished Yunnan had few ways to generate tax revenue and create economic development (by which criteria CCP cadre members are evaluated), SHP development became a highly attractive method to simultaneously develop local economies and follow central government decarbonization and Ecological Civilization discourses (Hennig & Harlan, 2018; J.-H. Wang et al., 2015; L. Zhang et al., 2021).

However, a number of other policies, regulations, and climatic factors have led to SHP development that is chaotic and inefficient. Among others, these include:

- A large number of SHP stations were built between 1950 and 2000 with predominantly rural electrification (whether for domestic or industrial use) in mind. During this period, most SHP was constructed under the county based "3-Self" policy of Self-construction, Self-management, and Self-consumption (Cheng et al., 2015). This policy promoted a highly individualized form of management where the developers of SHP were responsible for, as mentioned above, their own construction, management, and consumption of related electricity. However, in view of the Renewable Energy law and its requirement for all renewables to connect to the central grid, the management of SHP changed fundamentally which led to inefficiencies and oversaturation.
- Approximately 70% of annual rain falls between July and November. Considering that the large majority of SHP is the "run-of-river" variety, meaning there are no reservoirs and thus very limited storage capacity, many SHP owners build dams with water diversion capacities that are higher than the average flow during the rest of the year in order to take advantage of the wet season. This leads to an enormous glut of cheap electricity during the wet season and frequently total dewatering of rivers during the rest of the year (L. Zhang et al., 2021).

5.2 Mapping Out Dams Built

5.2.1 Where are they?

While the entire province has seen CDM funded hydropower development to a certain extent, the majority of dams are concentrated in western, rural, and border areas as shown in Figure 2 below.

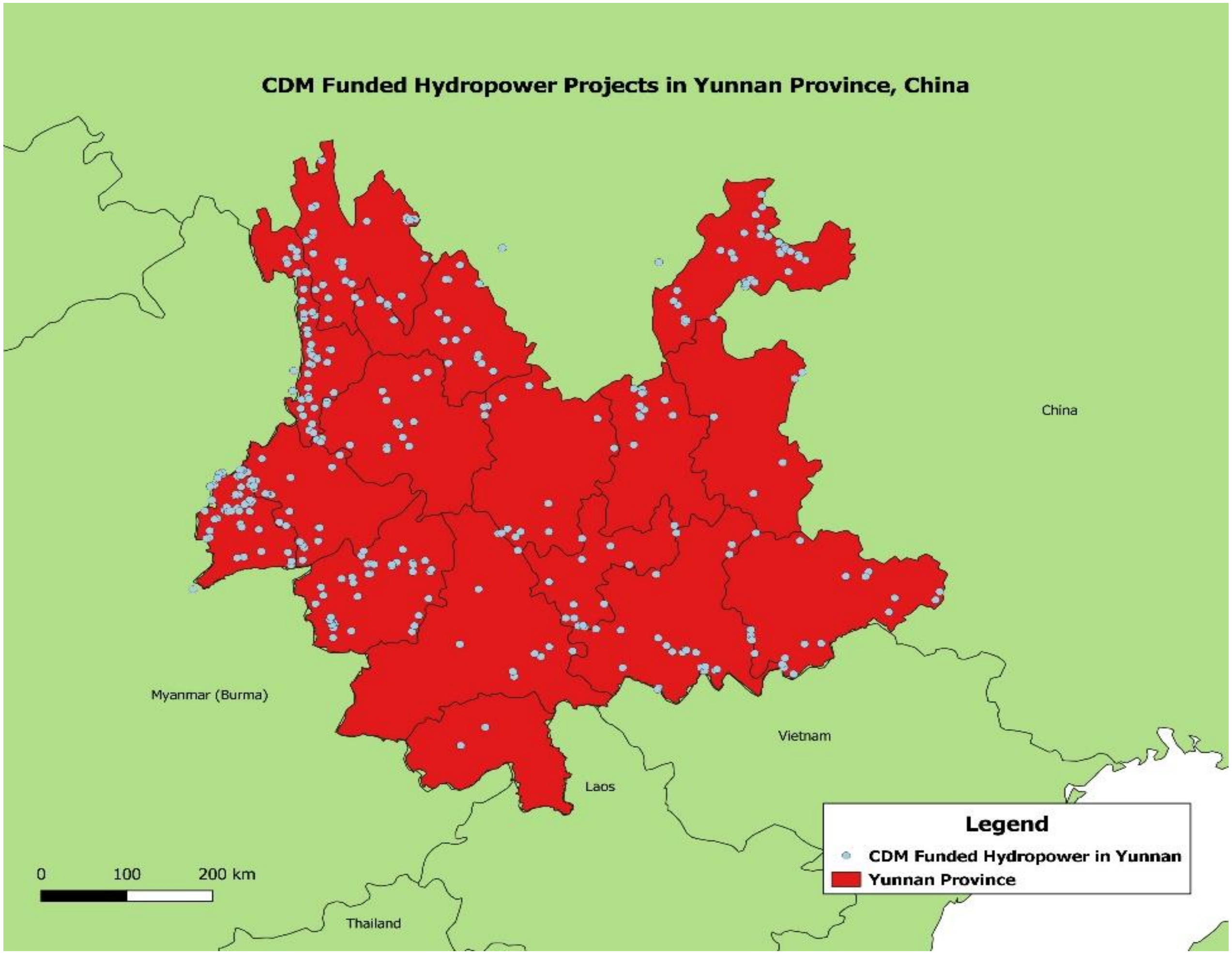

Figure 2: Location of CDM funded dams in Yunnan
Source: Own work

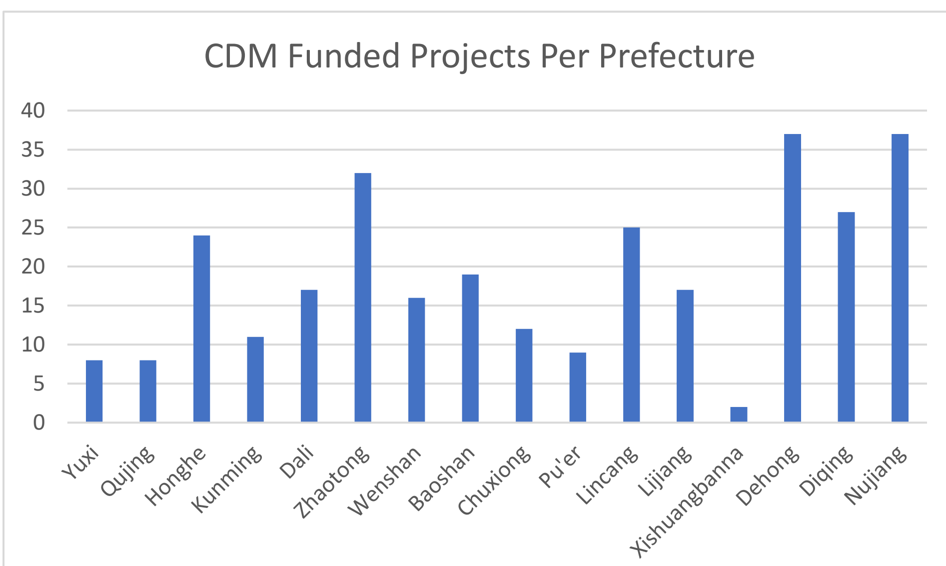

Figure 3: Number of CDM dams per prefecture in Yunnan.
Source: CDM Project Registry

The prefectures of Nujiang, Dehong, and Diqing are three of the four largest recipients of CDM funded hydropower projects, all three of which represent the most western and northern regions of the province. Indeed, 7 out of the 10 largest recipients of CDM funded dams are in the western half of Yunnan province.

Of the 376 separate dams that the CDM has funded in Yunnan province, 55 of these were built within the boundaries of a PA or KBA. However, many projects are built extremely close to the boundaries defined by PAs and KBAs. This is problematic because, despite not being within a designated protected zone, PA and KBA designation takes politically delineated region boundaries into account. In other words, if the Chinese state decides to place a boundary in a particular area because PAs have certain legal rights and environmental defenses, that boundary does not necessarily reflect where the ecologically critical region actually ends.

An excellent example of this is the Three Parallel Rivers Natural Park, which occupies large parts of Nujiang prefecture as well as Lijiang and Diqing in the northwestern corner of the province as seen in Figure 4 above. For this protected area, only the mountains of the region are protected; the river valleys are open to normal development. This runs contrary to the fact that the environmental effects of hydropower development are not exclusively site-specific. For example, building hydropower dams in remote regions requires extensive road network construction and often leads to landslides and earthquakes, among other externalities (Kelly-Richards et al., 2016). As such, I also analyzed the number of projects that were close to PAs and KBAs. When adding a 5km buffer, the number of dams included rises to 98. When creating a 10km buffer, that number rises even further to 137.

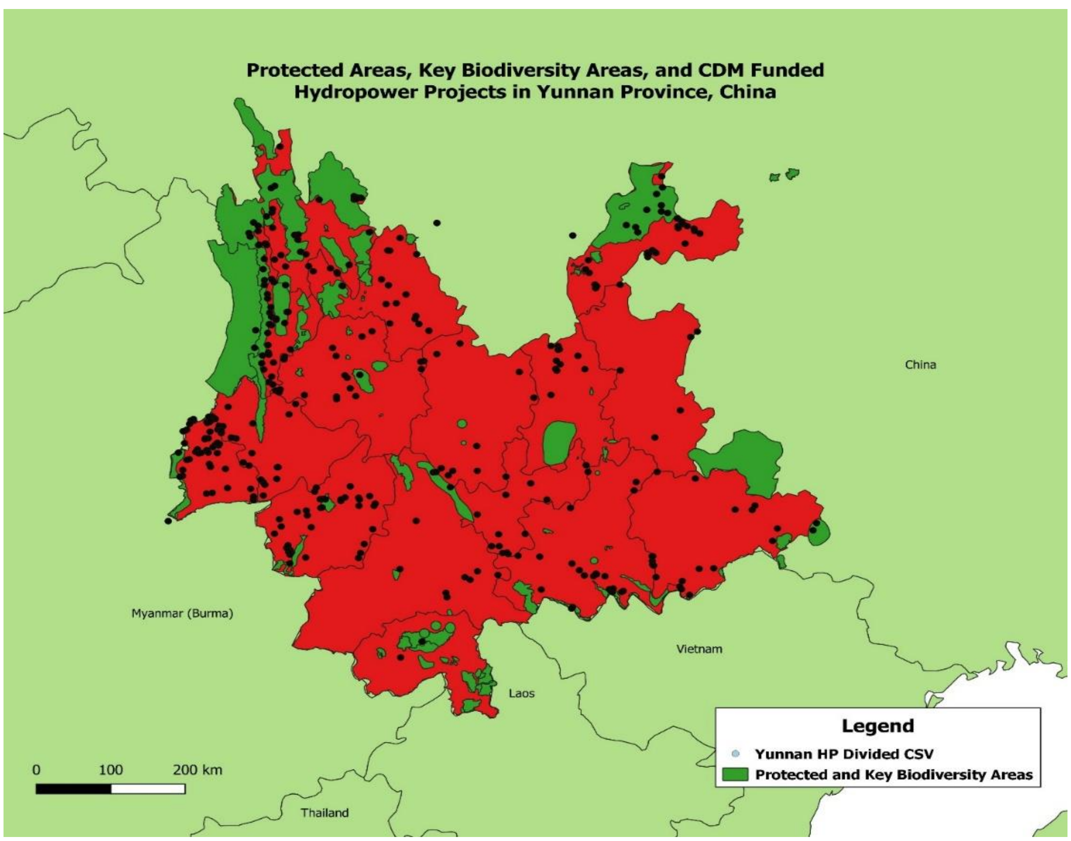

Figure 4: Map of Protected Areas, Key Biodiversity Areas, and CDM dams in Yunnan
Source: Own work

5.2.2 Who funds them?

In terms of who is funding dams in Yunnan through the CDM, there are a few ways to address this question, each with its own implications. Looking purely at who has the most affiliated projects, the United Kingdom immediately stands out as the biggest player with 93 projects since 2005. The Netherlands is a distant second with 59 projects, and Switzerland, Sweden, and Japan round out the top five of countries with the most affiliated projects (see Fig. 5). However, number of dams built does not directly correlate with outcomes or effects of dams on both local peoples and ecologies; the size of the dams built is also of great importance. As the amount of reductions associated with a project tends to go up in tandem with the MW capacity of a dam as well as with the immediate effects on a river and surrounding area[11], charting by associated reductions is also vital in understanding which countries are purchasing the most CERs (see Fig. 6). When doing so, it becomes apparent that the Netherlands has been funding fewer, but far larger projects than the United Kingdom, which carries a different set of consequences. For example, as Kibler and Tullos (2013) demonstrate by analyzing the impacts of SHP and LHP (large HP) per MW of power produced, SHP tends to have greater effects on things like river dewatering and riparian and terrestrial habitat diversity while LHP has greater potential for seismic effects and sediment modification.

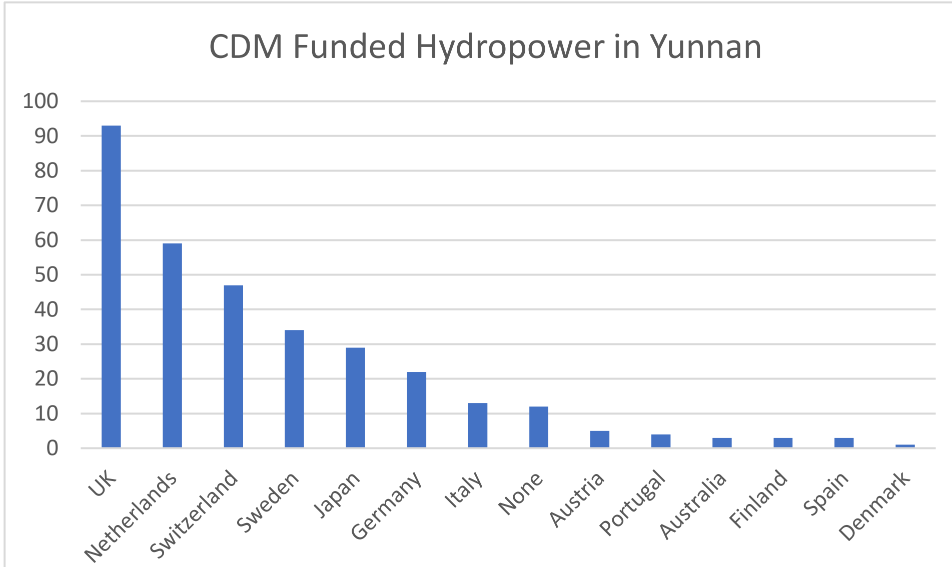

Figure 5: Number of CDM funded hydropower projects per purchasing country.
Source: CDM Project Registry

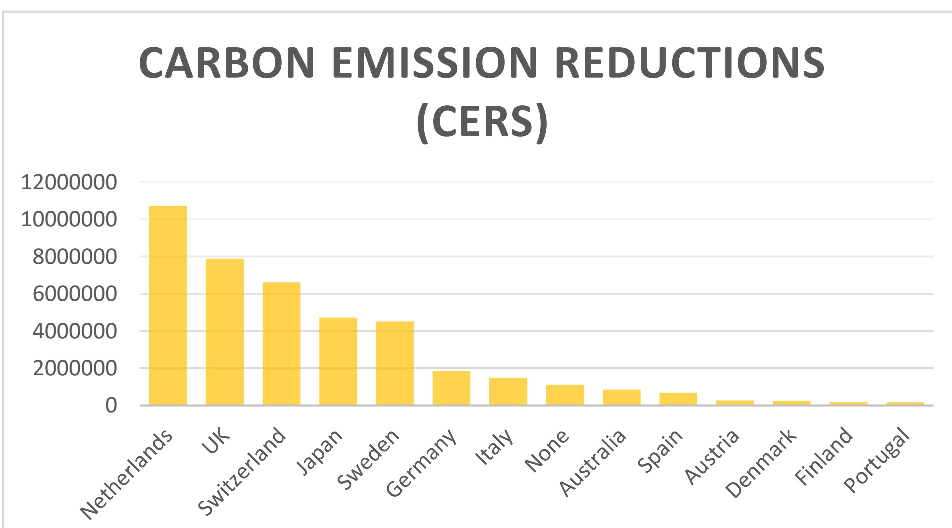

Figure 6: Yunnan based Hydropower CERs purchased per Annex I country in 1-ton carbon equivalents.
Source: CDM Project Registry

[11] This is on a single dam basis, see Kibler et al. (2013) for a discussion of the cumulative impacts of SHP.

5.2.3 Who uses the energy?

As demonstrated above, the majority of CDM funded dams are in the remote rural regions of North and West Yunnan. But where is this energy used? Continuing the trend from 2018 of Yunnan exporting almost half of its energy as demonstrated by Hennig and Harlan (2018) above, in 2019 Yunnan produced 300.77 TWh but consumed only 167.9 TWH (Statistical Bureau of Yunnan Province, 2019). Of the 167.9 TWh consumed locally, only 10.49 TWh were consumed by rural areas. Notably, the three prefectures of Nujiang, Dehong, and Diqing, which represent three of the four most prominent sites for CDM funded dams, also have some of the smallest urban populations (Fig. 7) and smallest rural electricity consumption (Fig. 8).

The implication of these data points is that, despite CDM dams being built in overwhelmingly rural areas, the large majority (96.51%)[12] of CDM dam generated electricity was either exported or used by urban areas. The majority of *that* electricity went to heavy industry. To underscore this discrepancy, the graph below (Fig. 9) compares the total electricity output of each prefecture with that area's rural consumption.

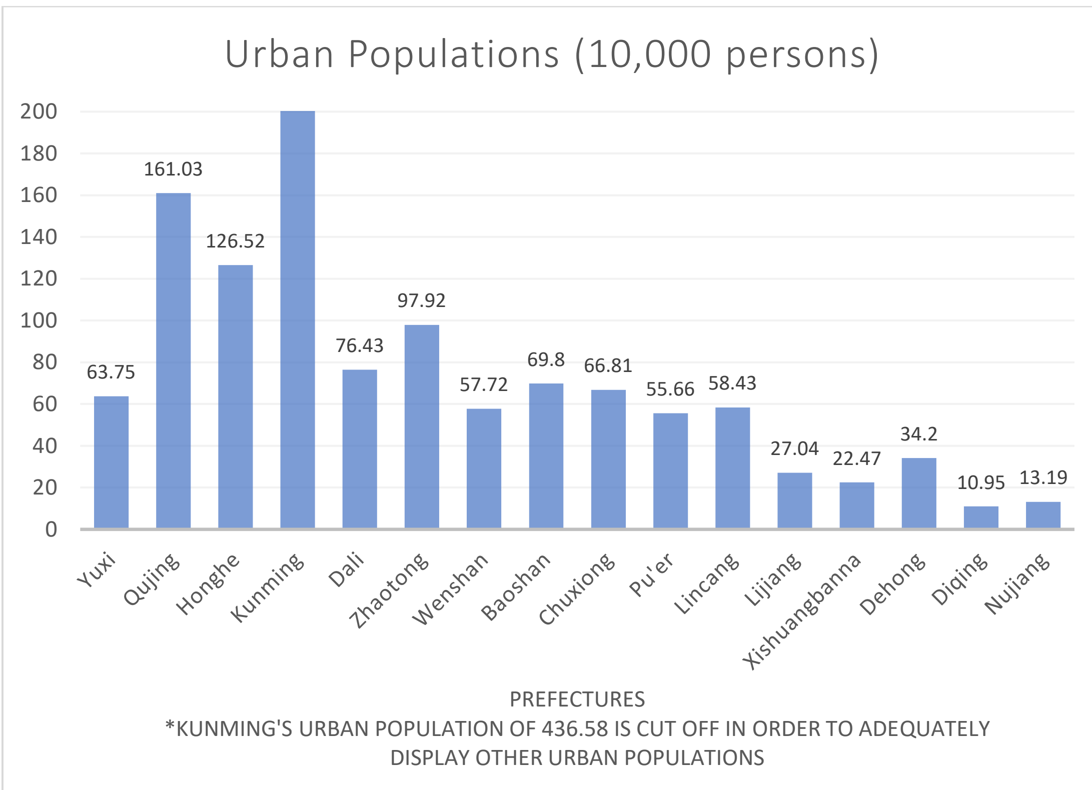

Figure 7: Urban populations of Yunnan's prefectures.
Source: Statistical Bureau of Yunnan Province

[12] This number was derived by taking the total energy production for Yunnan in 2019 (300.77 TWh), subtracting the rural consumption (10.49 TWh), and dividing the remainder (290.28 TWh) by the total generation (300.77 TWh).

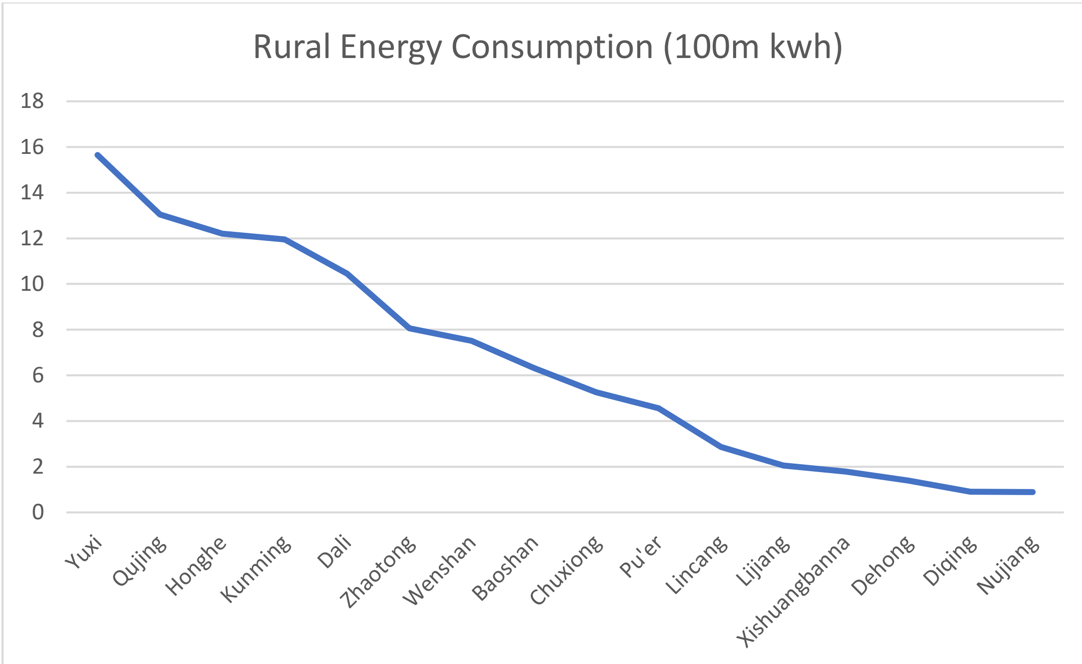

Figure 8: Rural energy consumption by prefecture in Yunnan.
Source: Statistical Bureau of Yunnan Province

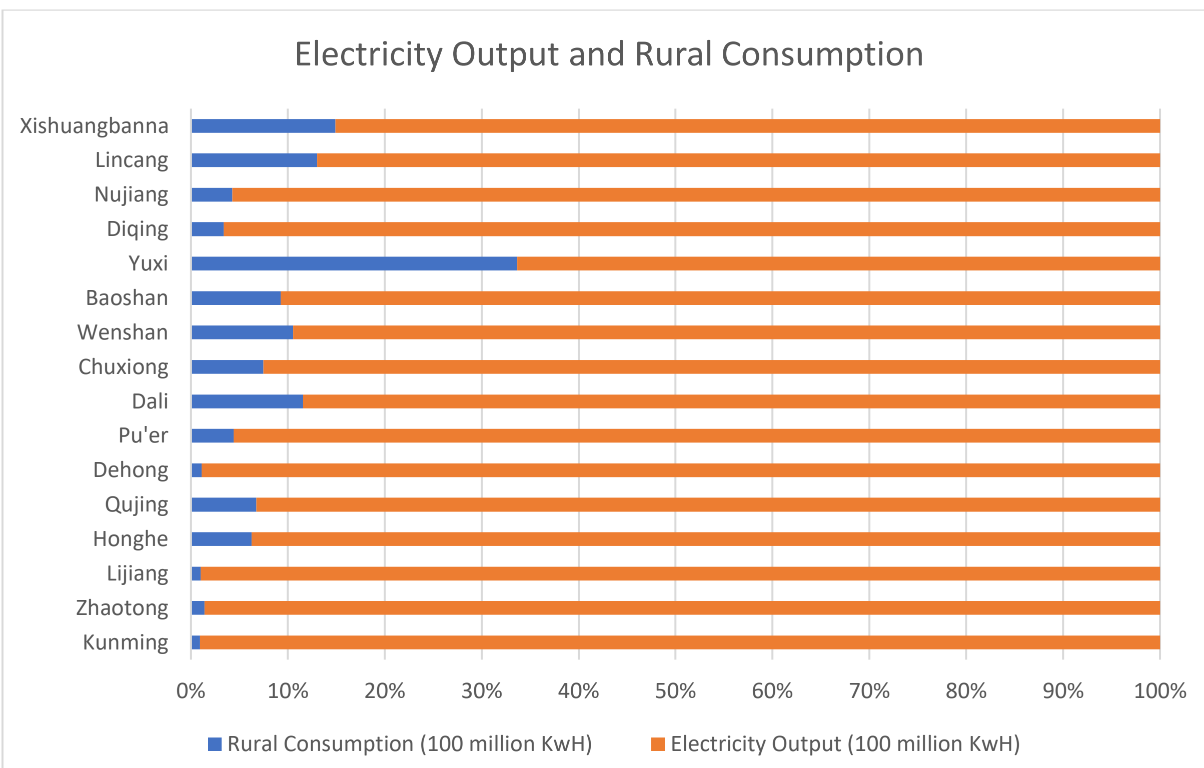

Figure 9: Total electricity generated by Yunnan's prefectures compared to electricity consumption of rural residents in that prefecture.
Source: Statistical Bureau of Yunnan Province

5.2.4 Who benefits and who loses?

This aspect of hydropower development in Yunnan is the hardest to illustrate empirically without undergoing in depth raw material commodity chain analysis and tracing value added for products produced using hydroelectric energy. However, utilizing the statistical data from the Chinese State and Yunnan Provincial Government and the mapping presented earlier, it is still possible to draw some correlations and connections. For example, building off of the previous demonstration of predominantly urban use, and citing Hennig and Magee's (2021) assertion that the industrial sector represents approximately three-quarters of all provincial energy consumption, it is clear that those living near the dams are not the ones benefitting. This is further supported by scholars like Zhang et al. (2021), who discuss how only few local residents are typically able to gain benefits from SHP development. Those who do are either employed by the plant (which frequently is no more than 30 or 40 people per plant) or were previously already wealthy enough to utilize the generated electricity to expand their business and generate income. However, the majority have little opportunity to change occupations or obtain other benefits from SHP development. Worse still, the dewatering associated with many power plants affects agricultural and household water availability during dry seasons (Hennig & Harlan, 2018; L. Zhang et al., 2021). Considering that 48.44% of provincial residents in 2018 worked in the primary industry (which in China includes farming, forestry, animal husbandry, and fishery), SHP construction becomes a serious threat to local livelihoods (Ptak, 2019; Statistical Bureau of Yunnan Province, 2019; L. Zhang et al., 2021).

Table 2: Overview of distribution of wealth by prefecture in comparison to CDM dams built.
Source: (World Bank, 2014; Statistical Bureau of Yunnan Province, 2019)

Prefecture	GDP (100m yuan) (2018)	GDP/Capita (2018)	Poverty Incidence % (2013)	CDM Projects
Nujiang	161.56	29375	51.61	37
Dehong	381.06	29033	13.66	37
Zhaotong	889.54	15987	24.45	32
Diqing	217.52	52669	44.66	27
Honghe	1593.77	33706	25.37	24
Lincang	630.02	24892	18.62	24
Baoshan	738.14	28168	16.63	19
Dali	1122.44	31251	16.49	17
Lijiang	350.76	27128	15.06	17
Wenshan	859.06	23568	13.8	16
Chuxiong	1024.33	37303	13.76	12
Kunming	5206.9	76387	7.75	11
Pu'er	662.48	25170	27.9	9
Yuxi	1493.04	62641	5.53	8
Qujing	2013.36	32798	14.5	7
Xishuangbanna	417.79	35286	11.14	2
Yunnan	17881.12	35335	20.05	299

Similarly, not all residents of Yunnan province are bearing the costs equally. When looking at the six prefectures with more than 20 projects, 4 of those are nationally recognized Autonomous Prefectures. Nujiang, Dehong, and Diqing together are home to 33.7% of Yunnan's CDM funded hydropower dams while representing only 12.7% of the province's land area. The people living in those regions are, respectively, 92.4%, 87.2%, and 52.2% ethnic minorities. And yet the largest consumer of electricity by far, Kunming City, is over 85% Han Chinese (China Daily, 2015).

Looking from the perspective of GDP tells a similar story. The table above (see Table 2) demonstrates GDP per capita for the province in 2018. Except for Kunming, Yuxi, and Diqing, GDP per capita is 38000 yuan per person or lower[13]. Simultaneously, once again with the exception of Diqing, five of the six prefectures with greatest CDM funded dam presence have a below average GDP/capita and four of the six have an above average poverty rate. These numbers indicate that dams are primarily being built in poor and ethnic minority areas while the energy they produce is predominantly used in far wealthier, Han Chinese regions.

6. Discussion and Recommendations

Ecologically unequal exchange is predicated on the idea that a small core of countries systematically impoverishes and underdevelops the periphery to sustain consumption levels that would be impossible without unequal international trade. The development of hydropower in Yunnan seems to fit this description. Locally, this is the case because:

1. Hydropower in the province has been demonstrated to be built primarily for the purposes of private profit (L. Zhang et al., 2021), export to the East and other countries (Hennig & Magee, 2021), and energy-intensive industrial use (Hennig & Harlan, 2018; Hennig & Magee, 2021). Governance structures and the forces of capitalism and international trade underly all of these drivers of development.
2. The well-documented environmental and social impacts of hydropower development are primarily being felt by those who benefit only minimally from the dams themselves (Hennig et al., 2013; Hennig & Harlan, 2018; Kelly-Richards et al., 2016; Kibler & Tullos, 2013; Richter et al., 2010; Ziv et al., 2012). As demonstrated above, and as documented extensively by Hennig and Magee (2021), the large majority of energy is consumed in urban regions and then primarily by industry. In 2018, the secondary sector[14] accounted for 38.9% of GDP despite employing only 13.82% of the population (see Figures 10 and 11 below). Further, considering the generally urban nature of manufacturing, this implies that the majority of the value created by industry is distributed to a

[13] Kunming has an understandably high GDP per capita as the economic and cultural capital of the province. Yuxi's wealth is based on its famous cigarette industry. In fact, the tobacco industry represents the second greatest wealth generating industrial activity in Yunnan after smelting of non-ferrous metals, with some employees boasting of salaries as high as 150,000 yuan a year for working on the factory floor (Davey & Zhao, 2021). While Kunming's and Yuxi's wealth can therefore be explained by the concentration of key industries in the former and being the home of China's tobacco industry in the latter, Diqing's is slightly more confusing at first glance. However, upon closer inspection, its relatively high GDP/capita is likely a function of low population and condensed wealth in the hands of a few as demonstrated by its GDP of 217.52 100m yuan in 2018 (compared to Kunming with 5206.90), population of 414,000 (Kunming has 6,850,000), and 2013 poverty rate of 44.66% (the second highest in Yunnan.)

[14] While typically primary industry includes extractive industries such as mining, in China primary industry only refers to farming, forestry, animal husbandry, and fishery. As such, secondary industry includes all forms of industry including "mining and quarrying, manufacturing, production and supply of electricity, water, fuel, gas and construction". (Statistical Bureau of Yunnan Province, 2019, pg. 31)

select portion of the population, while the externalities created by power it uses to function is distributed to another.

3. Not only are the environmental externalities of hydropower dams predominantly occurring in regions that typically receive few benefits from their construction, CDM funded dams were built in or near fragile and ecologically important areas with high frequency.

There is an argument to be made that it is only logical that hydropower is being developed in the North and West of the province because that is where the greatest convergence of rivers and greatest variation in elevation occur. However, this does not take away from the fact that those who are benefitting are not the same as those who are suffering as a result of this development. For example, zooming out to a view of China as a whole, Zhang et al. (2018) demonstrate how export-based production has become a serious driving factor for air pollution in the country. As is the story within Yunnan, the costs and benefits of this trade model are not distributed equally. The authors calculate that while approximately 56% of national GDP induced by exports accrues in developed coastal regions, 72% of air pollution embodied in those exports has been suffered by central and western regions. Similarly, for each yuan of export-induced GDP, developed regions incur only approximately 0.4-0.6g of atmospheric pollutant equivalents (APEs) while less developed regions incur between 4 and 8 times as many. They make the point that non-coastal regions are stuck along the value chain in relation to coastal regions in the same way that China is stuck along the value chain in relation to the United States, Korea, and Japan. They further argue that this is due to historically preferential treatment given to the coast as well as access to harbors and export opportunities.

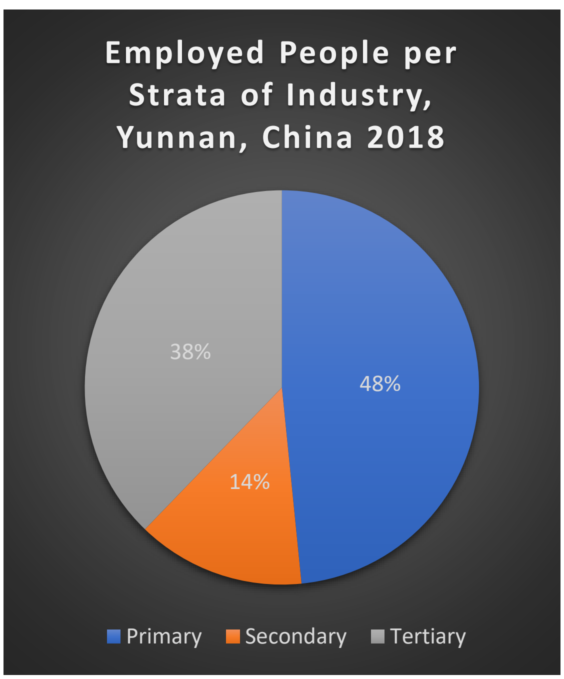

Figure 10: Number of people employed in Yunnan per strata of industry. Source: Statistical Bureau of Yunnan Province

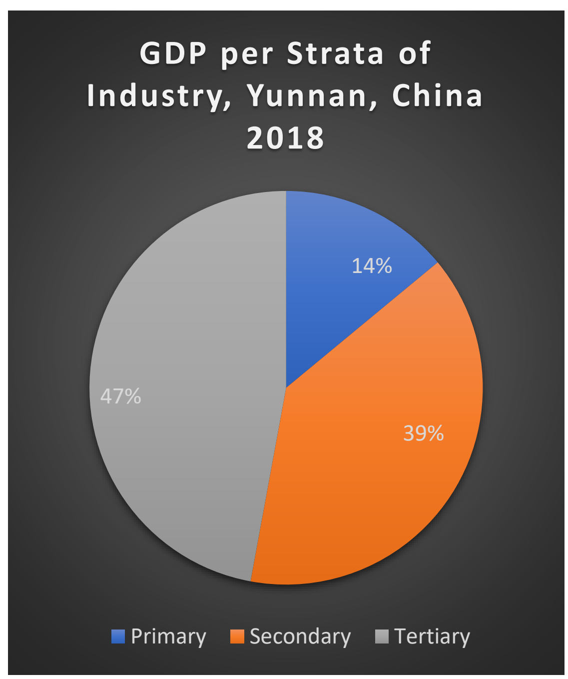

Figure 11: Gross domestic product produced in Yunnan per strata of industry.
Source: Statistical Bureau of Yunnan Province

This perspective seems to point towards the existence of an internal semi-periphery which, conforming to Clelland's and Dunaway's (2016) description, predominantly places the burdens of an extractive economy on impoverished and marginalized ethnic minorities. One need only look at the difference in GDP per capita between Western and Eastern regions domestically[15]. Frame (2018) also makes a case for China as a semi-periphery along the capitalist value chain by discussing the Chinese state's land grabs throughout Southeast Asia that feed the states' need for capital accumulation, despite its simultaneous exploitation by the core. Muldavin (2012) makes a similar case, discussing how China is attempting to decrease localized environmental destruction while maintaining rapid capital accumulation and industrial growth through the "geographic fix" of domestic and international land grabs.

This is currently unfolding through, among other things, the relocation of heavy industry to Yunnan province in order to make use of the copious amounts of cheap and "clean" energy produced through hydropower. In 2018, China produced 56.7% of the world's primary aluminum, and aluminum smelting is one of the most energy intensive industrial processes in the world (Hennig & Magee, 2021). For example, in 2019 alone, China's 217 aluminum smelters consumed 775TWh of electricity (Willuhn, 2019). That is more than six times the annual energy consumption of a country like Pakistan. As part of China's effort to reduce its carbon emissions, the Chinese state is encouraging large aluminum producers to relocate their activities to Yunnan in order to make use of the excess hydropower energy. Watching reports of large Chinese aluminum companies - like Chinalco, Hongqiao, and Shenhuo - that is now underway (Aluminium Insider, 2019, 2020; Daly, 2019; Reuters, 2020). While commendable on the surface, there remain three major issues:

1. While energy consumption during the aluminum production process is the primary source of environmental externalities and hydropower is largely carbon emission free, the process itself creates large amounts of carbon monoxide, several gaseous and particulate fluorides, sulfur dioxide, and various other polluting gases while also creating solid waste and wastewater (Dong, 2013).
2. The hydropower stations that these aluminum production facilities are connecting to are largely fed by SHP which, as discussed, only creates bountiful energy during the wet season from July to November. As a result, aluminum plants must still connect to and utilize thermal energy plants, which ultimately results in greater carbon emissions in Yunnan province. This is exacerbated by the fact that aluminum smelters often provide the impetus for the further development of power stations as investors know they will guarantee a full time base load (Brooks, 2012).
3. The Jevons paradox stipulates that increased efficiency leads to increased throughput of raw materials. Counterintuitively, abundant access to clean and cheap energy can therefore lead

[15] For example, in 2018 the average GDP/capita for the Western provinces of Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Chongqing, Sichuan, Guizhou, Yunnan, and Tibet was 48,266.5 yuan/annum. At the same time, the GDP/capita for the coastal provinces of Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, and Guangdong was 87,226.88 yuan/annum. The discrepancy between average regional GDP in 2018 was even greater, with the Western provinces averaging 14,666.04 100m yuan each and the coastal provinces averaging 55367.94 100m yuan each. Similarly, out of the 10 listed Western provinces, 9 have major recognized minority autonomous prefectures and counties, with ethnic minorities of those areas representing approximately 18.98% of the population. Of the coastal provinces, none of the regions had autonomous prefectures and only Guangdong and Zhejiang had autonomous counties, representing a total of .042% of the population. Note that large numbers of ethnic minorities also live outside of nationally designated minority areas, so both percentages would be larger when comparing total ethnic minority populations to provincial population. However, the comparison remains representative (National Bureau of Statistics of China, 2019).

to greater depletion of raw materials. Ciccantell and Bunker (2005, as cited in Gellert, 2018) make this point to demonstrate that more efficient technology can create "'diseconomies of space' as familiar raw materials become scarcer, further, and deeper from capital's grasp." (pg. 113) [16]

Essentially, then, the development of hydropower capacity in Yunnan can be seen as a form of environmental cost shifting as Eastern regions reallocate their industrial processes to the West to take advantage of laxer environmental regulation and cheap, "clean" energy, while continuing to benefit from the profits through headquarters based in the East.

Yunnan's second largest heavy industry is silicon smelting and production for ultimate use in computer chip production (Hennig & Harlan, 2018). Just like aluminum, silicon smelting is highly energy intensive and companies are seeing the benefits of utilizing cheap hydropower energy in its production. As of 2015, 31% of China's total silicon production was in Yunnan, with 94% of that coming from the Western provinces. In that same year, Dehong and Nujiang, which I have detailed above as being the two prefectures with the greatest CDM funded dam presence, respectively used 85% and 84% of their energy consumption for heavy industry (Hennig & Harlan, 2018). The environmental externalities of silicon production include deforestation (charcoal is a key ingredient) and large quantities of both atmospheric and ground pollutants. These pollutants have been shown to be related to respiratory and cardiovascular disease, chronic obstructive pulmonary disease, and all-cause mortality. Interestingly, this large (and rising) demand for silicon stems in part from its use in photovoltaic panels for solar energy (Z. Wang & Wei, 2017).

One could argue that the growth of these extractive industries in the West is what Magee's (2006) conception of the powershed uncovers. While he does not use the EUE or world systems language of core and periphery, he discusses how internal Chinese energy flows can best be seen through the powershed structure, which uncovers power (both material and political) dynamics and the Foucauldian discourses which drive them. From this perspective, he demonstrates how the Open up the West campaign and West-East Electricity Transfer programs exist predominantly to extract material resources from the "backwards" West and transform them into economic and political power for the East. Rousseau (2020) makes similar arguments regarding hydropower expansion and describes the phenomenon as a culmination of land, water, and green grabbing. He argues that by using the discursive power of carbon reduction to legitimize hydropower construction, the Chinese state and corporate stakeholders are able to continue constructing hydropower facilities despite associated livelihood impacts for farmers.

To expand to the global view, this is where the CDM can be viewed as a tool perpetuating (wittingly or not) the accumulation of wealth and technological capacity to the core while impoverishing the periphery. While hydropower development is not extractive in the sense of classic cases of EUE such as Bunker's (1984) description of rubber from the Amazon or Clark and Foster's (2009) discussion of the guano/nitrate trade, the development of hydropower extracts electricity from the natural environment through the development of structures (i.e., dams, weirs, and power stations) which lead to the inability

[16] Cheng et al. (2015) show that as of 2015 approximately 80% of eastern and coastal China's economically feasible SHP potential had been exploited, as opposed to a mere 50% in Sichuan and Yunnan. One could view this as an example of the diseconomies of space Ciccantell and Bunker refer to, whereby the raw material (in this case rivers available for damming) becomes farther and farther from the reach of capital (of which the majority in China is located in the coastal eastern regions.)

of rivers to provide the environmental services they once did. Essentially, the provisioning, regulating, supporting, and cultural services that the river and surrounding ecosystem once provided are extracted for electricity generation purposes, of which the electricity then feeds production whose value is ultimately captured by the industrial core.

If the first step in this global raw commodity chain is the extraction of environmental services to transform into electricity through hydropower development, the last is the consumption of products produced with that electricity. Since the large majority of power consumption in Yunnan goes to either aluminum or silicon production, in order to understand the ecologically unequal exchange occurring we must also know who is consuming those materials. This would be an excellent avenue for further research, particularly considering silicon's extensive uses in photovoltaic panel production and the rapid growth of that industry both domestically in China and globally (Z. Wang & Wei, 2017).

Referring back to the alternative perspectives mentioned in section 3.3, ecological modernization theorists might argue that while it is clear unequal exchange is occurring, the phenomenon is not inherent to a capitalist system but rather an outcome of an inadequate ordering of the means of production and modes of consumption. They might argue, as many scholars have over the previous two decades, that the problems the CDM has had with legitimate additionality and unaccounted for externalities are functions of incorrect environmental accounting or system organization rather than endemic to a capitalist carbon finance project (Axel, 2009). I argue that Harvey's (1985) discussions of the inherent contradiction of capitalism and the "spatial fix" and O'Connor's (1988) second contradiction of capitalism adequately refute these conceptions and further assert that a carbon finance project cannot address the fundamental issues underlying excessive carbon emissions and cannot curb emissions enough to prevent catastrophic global warming.

To elaborate, the first contradiction of capitalism as expounded by Marx refers to the contradiction between the forces of production on the one hand and the relations of production on the other. The forces of production refer to labor, technology, and general inputs into production. Relations of production refer to the class relation between capitalists and laborers. In Marx's, and later Harvey's (1985) view, these two forces will inevitably lead to overaccumulation and underconsumption. These simultaneous and seemingly antithetical phenomena are caused by the expansionary tendency of capital as fueled by exploitation of labor. If capital surplus is created through increasing exploitation of "living labor" (i.e., human working hours) which is the only thing that can create real surplus value in a finite world, then overaccumulation of capital and underconsumption of surplus occur as laborers become less voracious consumers (due to depressed wages), leading to crisis. Harvey (1985) expands upon this concept by introducing the "spatial fix" of late capitalism, whereby capitalists attempt to overcome the inherent contradictions of overaccumulation and underconsumption by expanding to new markets and by finding new resources. This expansion is, however, a temporary fix as over time these new markets and resources will in turn be depleted.

It is this theoretical thread O'Connor (1988) extends with his second contradiction of capitalism, which details the struggle between the combined forces and relations of production and the conditions of production, i.e., the environment. This contradiction details the systematic tendency of capitalism to undermine and destroy the material conditions of capitalist production. According to O'Connor (1988), because capitalism treats human labor power, nature, and space (the conditions of production) as tradable commodities, despite them not being produced as such, the law of the market assigns these conditions fictitious prices which systematically undervalue them. As these conditions of production, necessary for continuing capitalist accumulation or "growth", are used up, their market assigned value goes up and causes rising costs of reproducing the conditions of production, such as health care, fertilizers for depleted soil, and planned forestry. Capitalism therefore inherently creates ecological destruction despite its own dependence on those same conditions of production.

Applying these concepts to assertions that a reordering of modes of production (in this case carbon finance related to hydropower) can adequately address issues of externalities (such as building dams in biologically sensitive regions, river fragmentation, and unjust division of costs of production) renders them, in this author's opinion, inadequate. If a capitalist system, by definition, relies upon the exploitation of the living labor upon which all production is dependent and simultaneously requires ceaseless expansion through the spatial fix of late capitalism, then a carbon finance project created under those constraints cannot adequately govern carbon emission reductions. This is because carbon finance is about attributing the right price to carbon so that the free hand of the market can regulate externalities. However, if, as Hornborg (1998) asserts, market prices are culturally constructed and do not reflect the actual value of a traded material, then carbon finance *cannot* adequately price carbon. Building upon the concealing nature of market prices, O'Connor's (1988) description of the second contradiction of capitalism further demonstrates an inadequate valuing of the conditions of production (which carbon emissions undermine through the ecological effects of climate change). One cannot reorder carbon finance to address EUE or excessive carbon emissions because the contradictions which render it invalid are essential for the continued functioning of a capitalist system.

7. Conclusion and Recommendations

Ultimately, just as with Wallerstein's (1974) world-systems theory, the development of hydropower in Yunnan has been a consequence of both domestic and global forces. The governance and geographic context of Yunnan Province guided the rapid construction of hydroelectric dams and stations, while simultaneously the forces of global finance and international trade exacerbated the situation. While the events in Yunnan that have led to the deterioration of ecological integrity and socio-economic stability in relation to hydropower development are consequently not the exclusive fault of any particular actor or set of actors, this does not remove responsibility from those who have helped perpetuate the situation. European governments, the Chinese state, and domestic and international corporations taking advantage of a system of international finance which acts to shift environmental cost onto marginalized communities while siphoning value to the upper levels of the hierarchy of global actors are complicit, if perhaps not always intentionally.

In view of the growing evidence of ecologically unequal exchange as a fundamental operating principle in the functioning of the international capitalist economy, it becomes vital for core states extracting from the periphery as well as semi-peripheral states doing the same to recognize the consequences of their consumptive patterns beyond state boundaries. From an immediate standpoint, future avenues of research include raw material commodity chain analysis of silicon, aluminum, and other Yunnan based extractive industries. Understanding who the ultimate consumers of these materials are will give international actors a greater capacity to influence the outcomes of their production. In terms of carbon finance, the roll out of the Sustainable Development Mechanism (SDM) of the Paris Agreement will give academics and political actors alike the opportunity to analyze the efficacy of carbon trading as a tool for mitigating global warming. In order for the SDM to succeed, it must learn from the failures of its predecessor in regard to additionality and project externalities. Even more broadly, however, those international actors with greatest influence should question the ultimate potential for change of finance constrained by capitalist underpinnings. Continued research into the ultimate contradictions inherent in capitalism and the ways these constrain the capacity for systematic socio-economic and ecological preservation will be welcome.

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Appendix A

Please use the link below to access the CDM project database I compiled, which has further links to all CDM project documents and shows date of registration, parties involved, methodology, associated reductions, MW capacity, location, and river basin of each project, among other information. There you will also find access to data used from the Yunnan and China statistical yearbooks, as well as some relevant calculations. I have also uploaded a copy of the Yunnan Statistical Yearbook 2019 to the google drive.

https://drive.google.com/drive/folders/1LK9UXp632n__YwcYKf7RUZi3-8pxDKci?usp=sharing

The Chinese Statistical Yearbook 2019 can be found at http://www.stats.gov.cn/tjsj/ndsj/2019/indexeh.htm.