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Socio-Ecological Controversies from Chilean and Brazilian Sustainable Energy Transitions

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Abstract: Chile and Brazil have been historically recognised in South America for having a high share of renewable sources in their primary energy matrices. Furthermore, in the last two decades, aligned with the global efforts to conduct a sustainable energy transition, both countries have experienced a successful introduction of nonconventional renewable energy for power production. Nevertheless, some experiences with renewable sources have been demonstrated to be not entirely societally and environmentally friendly, as some local human communities and ecosystems are threatened, and conflicts have emerged, regardless of low-emission technology. Using the cases of Chile and Brazil, we aim to explore the socio-ecological dimension of sustainable energy transition—which has sometimes been ignored. We analyse the controversies regarding renewable energy and the emergence of socio-ecological conflicts through the principles of justice in transitions. Critical renewable conflicting power projects are identified using the Atlas of Environmental Justice's database. Considering those experiences, we believe that reinforcing decision-making processes should be in synergy with identifying new alternatives to develop energy in both countries. Placing justice approaches at the centre of public policies is imperative to developing sustainable policies in the future.

Keywords: energy transition; energy justice; environmental justice; political ecology; Chile; Brazil

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1. Introduction

Some of the main challenges to sustainable energy transition are related to decarbonisation, digitalisation, democracy, decentralisation, and justice. A just transition combines energy with climate and environmental justice, being a fair, equitable process towards a post-carbon society [1,2] and minimising adverse social, environmental, or economic impacts [3]. Two global parameters regarding the sustainable path are the Paris Agreement and the United Nations' Sustainable Development Goals (SDGs) contained in Agenda 2030, which cover the environment, economy, and society as its main pillars. SDG 7 aims to achieve universal access to affordable, reliable, sustainable, and modern energy by 2030 [4]. In South America, Chile and Brazil have experienced a well-marked introduction of nonconventional renewable energy (NCRE) over the last two decades. Furthermore, they also had hydropower dependence—at least—until the 2000s [5]. Nonetheless, both hydropower (renewable) and NCRE projects have not been exempt from socio-ecological conflicts [4,6].

This study aims to explore the socio-ecological dimension of the sustainable energy transition based on the emergence of conflicts that were linked to the low-carbon power infrastructure in Chile and Brazil. Thus, it seeks to highlight a disregarded side of sustainable energy transition. Through the lens of justice in sustainable energy transition [7–11], we try to respond to the questions of which projects, where these conflicts emerge and the people, ecosystems, and spaces they affect.

We can see from Figure 1 that Chile and Brazil reached approximately 20% of power generation by biomass, solar, wind, and geothermal sources—above South American levels [12]. Since the 2000s, along with national energy policies, a quota law has driven NCREs in Chile; meanwhile, financial incentives triggered biomass and small-scale hydropower (SHP) in Brazil [5,13]. Note that between 2000 and 2020, Chile intensified its economic activity, which increased energy requirements. Electric power generation increased by 100% during this period; consequently, in 2000, the Chilean power sector produced 53,502 GWh, which increased to 77,696 GWh in 2020 (To know the national power generation profile of both countries, see Appendix A). Additionally, Brazil increased its electric power generation by 78%, from 348,921 GWh to 621,198 GWh. In both countries, the rise in electrical power generation is strongly correlated with economic growth. Consequently, NCREs are not necessarily substituting fossil fuels but are adding new energy [6,12].

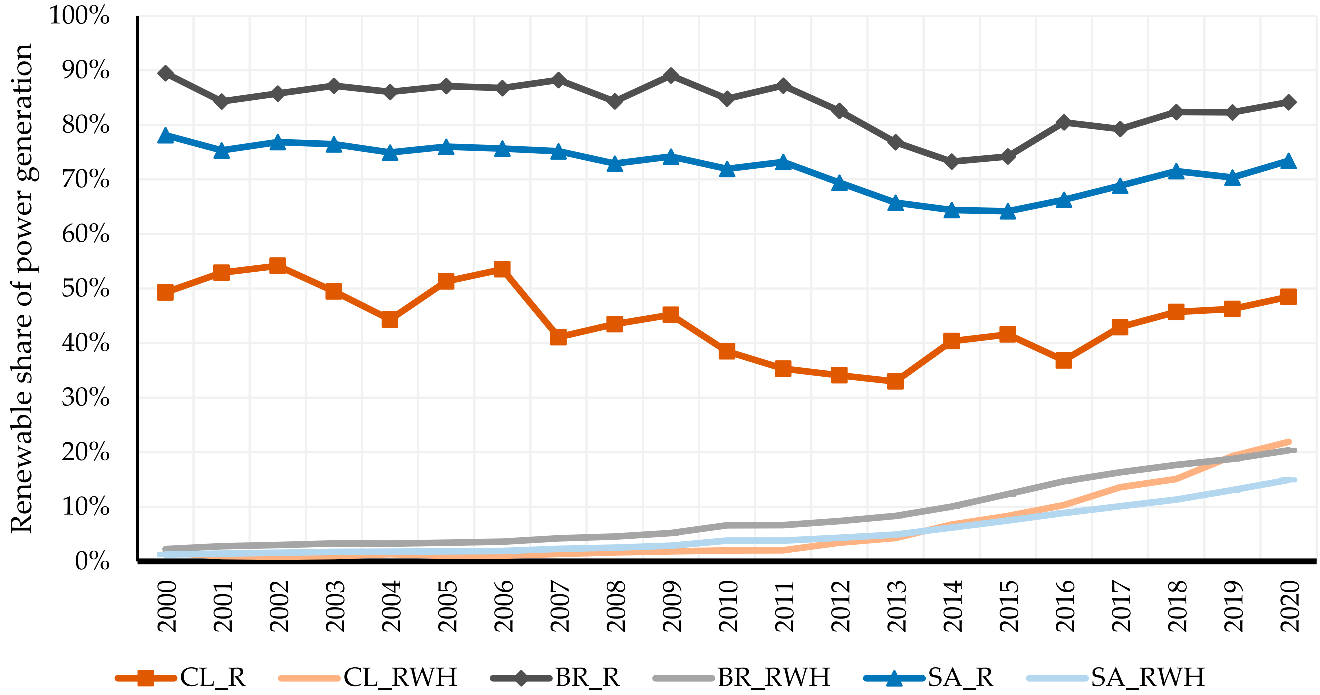

Figure 1. Share of renewable sources in power generation. Source: OLADE [12]. CL_R: Share of renewable power generation in Chile, including hydropower. CL_RWH: Share of renewable power generation in Chile, disregarding hydropower. BR_R: Share of renewable power generation in Brazil, including hydropower. BR_RWH: Share of renewable power generation in Brazil, disregarding hydropower. SA_R: Share of renewable power generation in South America, including hydropower. SA_RWH: Share of renewable power generation in South America, disregarding hydropower.

As the International Energy Agency (IEA) has pointed out, electrification is pivotal to realise the Paris Agreement and the net zero emissions (NZE) goal in 2050. IEA assessments in an NZE scenario project that approximately 50% of the final global energy will come from electricity in 2050 [14]. As shown in Figure 2, Chile and Brazil had approximately 20% of their final energy from electricity in 2020 [12]. If linearly forecasted in both data series (1970–2020), both countries might reach approximately 30% by 2050, which implies the necessity, on the demand side, for technological investments and policies to align with the NZE scenario. Demand-side management is a crucial tool for efficient energy use in many economic sectors [15].

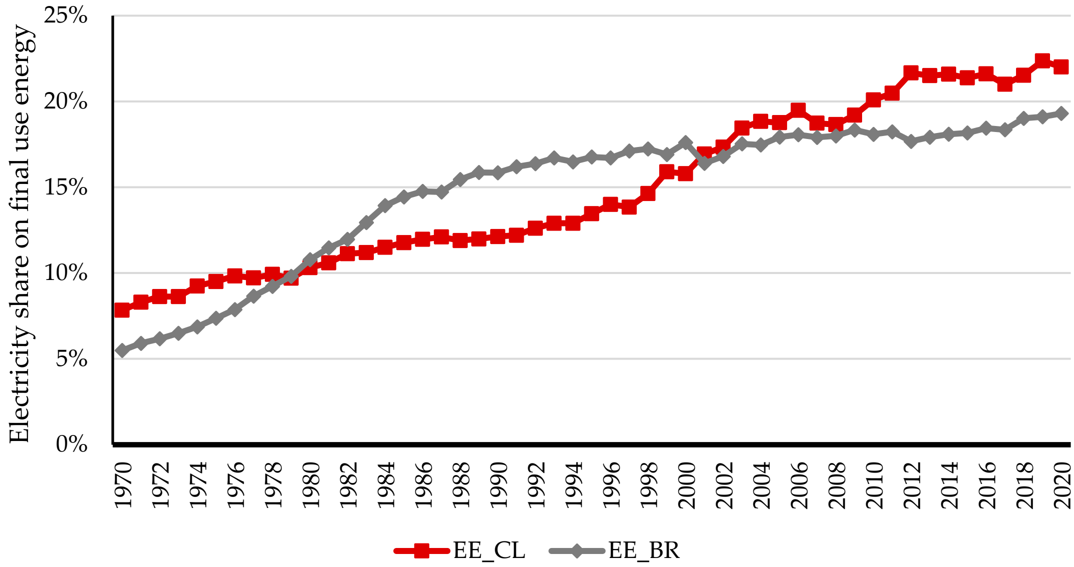

Figure 2. Share of electricity in the national final energy consumption. Source: OLADE [12]. EE_CL: Share of electricity in the final use energy in Chile. EE_BR: Share of electricity in the final use energy in Brazil.

This study highlights an often-disregarded dark side of sustainable energy transitions. Moreover, using the novel lens of justice in sustainable energy transition, it evidences local societal and ecological issues related to low-carbon power infrastructure. Furthermore, it illuminates a path towards sustainable and just energy transition for all, which is helpful for researchers, policymakers, and stakeholders—in line with SDG 7.

The rest of this paper is structured as follows: Section 2 recapitulates a background on crucial topics on energy and just transitions; Section 3 introduces both study cases and presents the materials and methods used; Section 4 presents the main results; Section 5 discusses the results; Section 6 concludes the paper; and Section 7 offers scope for further work in this field.

2. Background—Energy Transition and Socio-Ecological Controversies

According to Scheidel et al. [8] (p. 594), 'sustainability transitions can ironically trigger a whole new set of unsustainabilities and conflicts'. Although using renewable sources might promote a greener, healthier, safer, and likely cheaper global energy system [16], it might camouflage justice issues associated with—usually large-size—renewable electric power projects [17]. Dunlap and Marin [18] listed at least two dimensions of (un)sustainable renewables: those related to high raw materials requirements for low-carbon power plants and those related to land use change for more extensive infrastructures than commonly imagined. Moreover, following Lennon [19,20], large-renewables—and the associated production chains—are in a continuing trend of commodification and colonisation, reproducing inequalities and injustices depending on race, ethnicity, and income.

At least two sometimes-overlapping scholarly lenses emerge with regard to justice in sustainable transition studies: environmental and energy justice. From the political ecology perspective, environmental justice is linked to populations that are subjected to the unjust distribution of environmental benefits and burdens, which sometimes emerges from developing energy projects [9]. Energy justice incorporates the idea of transition from the production side, moving towards low-carbon sources, and the consumption-based concerns of achieving energy efficiency in the long term, without compromising individual well-being, community cohesion, and considering justice principles [1,7]. Notably, McCauley and Heffron [1] call for dialogues on climate, environmental, and energy justice under the banner of just transitions.

2.1. Environmental Justice and Ecological Distribution

'Environmental justice' highlights the link among pollution, race, and poverty, and tackles the socio-spatial distribution of externalities (e.g., emissions and toxins) and benefits (such as green spaces and better services). The concept of environmental justice emerged during the early 1980s when some United States minority communities suffered disproportionately from being exposed to higher ecological burdens. The environmental justice theory has recently garnered more attention, including new perspectives and studies on emergent topics such as low-carbon transitions [9,10,21]. McCauley and Heffron [1] pointed to the literature on environmental justice as grappling with how to balance the social and ecological dimensions involved in this transition.

'Ecological distribution' is a term linked to environmental justice. It refers to the social, spatial, and temporal asymmetries or inequalities in the human use of environmental resources and ecosystem services, and unequal and unsustainable allocations of environmental burdens, such as the loss of biodiversity, pollution loads, or waste [9,22]. Scheidel et al. [9] studied the relationship and interactions among processes of social metabolism, ecological distribution conflicts, environmental justice movements, and transitions towards sustainability. This relationship is 'driven by patterns of unsustainable social metabolism, [and] ecological distribution conflicts often provoke the emergence of environmental justice movements' [8] (p. 595). Thus, such conflicts might dispose of potential contributions towards building more sustainable solutions.

2.2. Energy Justice

The term 'energy justice' emerged around the 2010s to refer to the justice issues of obtaining, producing, distributing, or using energy. Jenkins et al. [7] presented three tenets of justice: distribution, recognition, and procedure. Distributional justice investigates where energy injustices emerge and the uneven distribution of responsibilities. Recognition-based justice considers which sections of society are ignored, misrepresented, non-recognised, or disrespected. It considers acknowledging different social, cultural, ethnic, racial, and gender perspectives through dialogues with the ecological distribution terms. Finally, procedural justice explores how decision-makers engage with communities, seeking remediation to reveal and reduce injustices.

Nuances in energy justice emerged recently, considering prohibitive and affirmative principles, notions of restorative justice, and spatial justice. Gender, income, race, age, religion, and even location have been identified as factors linked to people suffering from energy injustices. We must understand that the impacts of justice are multi-scalar and not restricted to a single country [8].

3. Materials and Methods

This study addresses the interface between environment and society which faces an interdisciplinary challenge that highlights energy as a pivotal point that raises questions of democracy, equity, and efficiency in achieving sustainability [23]. It adopts a qualitative comparative case-based format, exploring the Chilean and Brazilian experiences on socio-ecological conflicts linked to renewable power generation. Notably, it discards the 'fossil fuels versus renewable energy' dichotomy in its framework. It applies a critical exploration regarding qualitative socio-ecological issues that are often concealed under the overvaluation of 'green' paths [18]. As mentioned in Section 2, mixing environmental and energy justice terms contribute in configuring a novel approach.

Studies on the socio-ecological limitations of renewables and sustainability transitions have recently gained interest, connecting societal justice and ecological concerns [9,18,24–26]. The socio-ecological implications of hydropower projects have already been studied in Chile and Brazil, considering that they have high hydropower shares [27–31]. Nevertheless, assessments based on the conjunction between environmental and energy justice in both cases are still pending, as well as analyses considering NCREs.

This study was carried out through a qualitative methodological framework using secondary data, having two critical concatenated stages oriented to environmental and energy justice, respectively. Owing to the case study nature of this investigation task, every stage has triggered questions that drive the research process. Stage 1 focuses on evaluating environmental justice, and stage 2 focuses on energy justice. In stage 1, a data list with conflicting socio-ecological renewable energy projects was created for every country. In this phase, the triggering questions are why, where, how, and when conflicts emerge, performing the analysis through an environmental justice lens. Sequentially, stage 2 evaluates the energy justice dimension of the renewable projects listed in stage 1. Table 1 recapitulates the main dimensions of the energy justice approach and its evaluative and normative reach, with the main target of each of them characterised by pivotal questions that act as triggering questions of this phase.

Table 1. Approaches to energy justice.

Tenets	Evaluative Reach	Normative Reach
Distributional	Where are the injustices?	How should we solve them?
Recognition	Who is ignored?	How should we recognise this?
Procedural	Is there a fair process?	Which new processes?

Source: Jenkins et al. [7].

In stage 1, the Atlas of Environmental Justice (EJAtlas) [10,11], an online tool based on knowledge co-production among academics and activists, provides the main renewable power projects stimulating socio-ecological conflicts in Chile and Brazil. It considers two types of projects: in operation or under construction. The data collected in this stage include the names of conflicting projects, the estimated size of the projects, their status, the conflict sources, their main impacts, the region where they are located (regions in Chile, states in Brazil), and the estimated date when conflicts emerged. Later, as suggested by Ylä-Anttila et al. [32], these data were validated and complemented (when necessary) by publicly available datasets at the country level. The National Electrical Coordinator (CEN) database was used for the Chilean case [33]. The Brazilian Electricity Regulatory Agency (ANEEL) database was consulted in the Brazilian case [34].

Stage 2 focuses on evaluating the lack of energy justice linked with every Chilean and Brazilian renewable listed project. Following Table 1, three questions address the analysis of the three critical tenets of energy justice: distributional (*where* are the injustices?), recognition (*who* is ignored?), and procedure (is there a fair process?). Then, aiming to answer these questions, every conflicting project is consulted in Google Scholar, encompassing Spanish, Portuguese, and English literature. Words used in the search process include the project's names and the type of technology—for example, 'Ralco hydropower'. Table 2 points to the main questions and the expected answers to every stage, plus the used sources, search parameters and the criteria for the discrimination. Regarding the normative reaches of energy justice and the associated questions, as shown in Table 1 (column 2), they trigger the discussion—Section 5—around the ways to improve energy justice based on the studied cases.

Study Cases

Chile and Brazil were chosen by having a well-marked penetration of NCREs—within South America—that started during the 21st century. Moreover, both countries have power systems that are historically linked to hydropower and have socio-ecological conflicts associated with them [5]. It is valuable to compare both countries because of their successful performance in SDG 7 as a universal indicator of sustainable energy transition. However, sustainable energy transition is a more complex process, and from these cases, we aim to highlight the disparities emerging from socio-ecological issues. Consequently, taking the lessons from these cases, new, more sustainable, and fairer paths are discussed in terms of the South American backdrop.

Table 2. Methodology.

<table>
<tr><th colspan="2">Stage</th><th>Research Question(s)</th><th>Sources</th><th>Parameters</th><th>Criteria</th><th>Output</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5">Environmental justice (Searching renewable energy socio-ecological conflicts)</td><td>Which are the conflictive projects?</td><td rowspan="5">EJAtlas plus CEN database and ANEEL database</td><td rowspan="5">• Country
• Technology
• Status</td><td rowspan="5">• Chile and Brazil
• Power production projects, renewables, and NCRE projects
• In operation and under construction</td><td>Projects' names and sizes (listed)</td></tr>
<tr><td>Why did conflicts emerge?</td><td>Source of conflict</td></tr>
<tr><td>How did conflicts emerge?</td><td>Impacts</td></tr>
<tr><td>Where did conflicts emerge?</td><td>Region/State</td></tr>
<tr><td>When did conflicts emerge?</td><td>Year</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Energy justice (Evaluating energy justice on listed projects) [(a)]</td><td>Where are the injustices?</td><td rowspan="3">Google Scholar</td><td rowspan="3">Language</td><td rowspan="3">English, Spanish, and Portuguese</td><td>Distributional evaluation</td></tr>
<tr><td>Who is ignored?</td><td>Recognition evaluation</td></tr>
<tr><td>Is there a fair process?</td><td>Procedural evaluation</td></tr>
</table>

[(a)] As a concatenated process, stage 2 uses the project list created in stage 1.

Table 3 presents the Chilean and Brazilian indicators associated with SDG 7 [35].

Table 3. Introducing Chile and Brazil under the SDG 7.

SDG 7	Item	Chile	Brazil
	2021 GDP per capita (current prices USD)	16,503	7519
7.1.1	2020 Share population with access to electricity (%)	~100	~100
7.2.1	2019 Share of renewable energy in total final energy consumption (%)	25.26	47.57
7.3.1	2019 Energy intensity level of primary energy [(a)]	3.66	3.93
7.a.1	2019 International financial flows (millions of constant USD)	—	50.98
7.b.1	2020 Renewable electricity generation capacity (Watts per capita)	669.287	705.901

Source: UN [35]. [(a)]: Megajoules per GDP expressed in the constant purchasing power parity of 2017.

Table 3 shows a promising path to sustainable energy transition in Chile and Brazil compared to global numbers. Specifically, following Tracking SDG 7 [36], in 2017, the share of renewables in total final energy consumption reached 17.3% worldwide. The same year, global primary energy intensity reached 5.01 MJ/USD (2011 PPP).

4. Results—Deepening Justice Issues in the Chilean and Brazilian Energy Transition

This section presents the implementation outcomes of stages 1 and 2 on socio-ecological conflicts in renewable power projects in Chile and Brazil. The results are discussed by country—4.1 focuses on Chile, and 4.2 focuses on Brazil. Sections 4.1.1 and 4.2.1, complemented by Appendix B, provide the results of stage 1 and summarise the main characteristics of these projects: their estimated size (MW), status (in operation or under construction), source of conflict (*why* they became projects with conflicts), the impacts (*how* are they causing conflicts), the region (*where* the projects are), and the conflicts' starting year (*when*). All of them are identified in the EJAtlas and verified and complemented by the CEN and ANEEL databases, mainly concerning the size and status of the projects. Tables 4 and 5 provide the main results of stage 2 on energy justice.

Table 4. Summarised evaluation of energy justice in the controversial renewable projects in Chile.

Tenets	Questions	Chilean Case
Distributional	Where are the injustices?	Atacama Desert (Antofagasta Region), Bío Bío (Bío Bío Region) and Maipo (Metropolitana Region) basins and Ñuble River (Ñuble Region)
Recognition	Who is ignored?	Indigenous and local inhabitants' cultural and natural heritage and ecosystem services
Procedural	Is there a fair process?	Weak evaluations, regulations, and punishments for violating water access rights, entitlements, and land properties

Table 5. Summarising an evaluation of energy justice in the controversial renewable projects in Brazil.

Tenets	Questions	Brazilian Case
Distributional	Where are the injustices?	Brazilian Amazonas: Tocantins, Xingú, Teles Pires Uatumã, Madeira and Tapajós Rivers; Pelotas River (Rio Grande do Sul and Santa Catarina States); Cuiabá River (Mato Grosso State); Aimorés River (Minas Gerais); and Caetité (Bahía State) and Sirinhaém municipalities (Pernambuco State)
Recognition	Who is ignored?	Indigenous and local inhabitants' cultural and natural heritage and ecosystem services
Procedural	Is there a fair process?	Weak evaluations and regulations, rules avoided and practically inexistent punishments

4.1. The Chilean Case

4.1.1. A Brief Analysis from the Environmental Justice Perspective

According to the EJAtlas [10], as shown in Table A1, five renewable power plants are currently in operation in Chile, and one is under construction, all of which are associated with socio-ecological conflicts. One of them is a geothermal plant—NCRE. The rest of them are large hydropower plants with capacities higher than 100 MW. Only the Hidroñuble is currently under construction. The Alto Maipo project comprises two hydropower plants that capture water from the tributaries of Maipo River. Only Ralco has been in a long-time conflict, as the social confrontations started around 1996. The remaining projects started having conflicts after 2000.

4.1.2. Evaluating Energy Justice

Cerro Pabellón was the first South American geothermal power plant [37]. However, local indigenous groups claimed that it had threatened their cultural and natural heritage [10]. Conversely, constructing the Ralco hydropower plant during the 1990s was considered one of the most controversial episodes associated with power projects and was widely observed internationally. In 1998, the plant began to be constructed in Alto Bío Bío, in southern Chile. It started operating in 2004, marking a precedent regarding 'glocal' socio-ecological conflicts owing to the disruption of nature at the local scale, but based on the policies defined by global organisations and interests. Disputes between environmentalists, Mapuche-Pehuenche indigenous communities, the Chilean state, and the Endesa-Chile company became a turning point in its history. After filing a lawsuit at the Inter-American Court of Human Rights in 2002, the affected groups convinced the government to approve the International Labour Organization (ILO) Convention no. 169 on indigenous and tribal people [30,38]. Later, Angostura was constructed in the Bío Bío basin too. The Bío Bío basin harbours three main rivers—Laja, Bio Bío, and Renaico–Malleco—with a total of 11 hydropower plants currently operating in the region [39].

The Alto Maipo hydropower project comprises two power plants—Las Lajas and Alfalfal II—located in the Maipo basin in the central Chilean zone of the Andes range. Besides Alto Maipo, the basin has five other functional hydropower plants, with the oldest—Los Maitenes (32 MW)—being functional since 1924. Alto Maipo was seen as a threat to the water and ecosystem balances and a potential trigger for the locals to lose their ecosystem services [40]. A similar context involves the Hidroñuble project in the south of Chile [41].

4.2. The Brazilian Case

4.2.1. A Brief Analysis from the Environmental Justice Perspective

According to the EJAtlas [10], as shown in Table A2, hydropower projects are currently operational in Brazil that are associated with socio-ecological conflicts. All of them are large projects, with Belo Monte and Tucuruí among the most extensive hydropower infrastructures in the world [42]. Despite the fact that the idea of Belo Monte and Tucuruí began to be discussed around the 1970s, only Tucuruí began functioning in the 1980s. Belo Monte began functioning in 2016 [10,34]. In 2021, Brazil was ranked second in the world in terms of installed hydropower capacity 109.4 (GW), surpassed only by China with 391 (GW) [43]. Regarding NCREs, as shown in Table A3, Brazil presents one conflicting biomass project that has been active since 1980 and a similar conflicting emergent wind power pole in Bahía state.

4.2.2. Evaluating Energy Justice

Tucuruí (Tocantins River) and Balbina (Uatumã River) were the first mega-dam projects in the Brazilian Amazonia, which began working in 1984 and 1987, respectively. Both have flooded more than 2.500 km^2 of land. Jirau is in the Madeira River, a region with one of the highest aquatic diversities in the world [27].

The São Manoel, Sinop, and Teles Pires dams are in the Teles Pires River, in the Tapajós basin. Forty-three hydropower plants are working or planned in Tales Pires River. Those projects have triggered confrontations with the indigenous peoples, colossal fish mortality, threats to natural and cultural heritage, and police violence. Similarly, in the Xingú river, Belo Monte was a case where project licensing processes were accelerated, ignoring in-force procedures, such as the ILO Convention no. 169 on indigenous consultation. Being one of the most extensive hydropower projects in the world, it displaced more than 20,000 people, leading to questioning the political system because of allegations of corruption [27]. Outside the Amazon, only three projects have been registered as stimulating socio-ecological conflicts—Barra Grande on the Pelotas River, in south Brazil [44]; Manso, located on the Cuiabá River [45]; and Aimorés in Minas Gerais state [46].

Caetité is a municipality in the Bahía state that became a pole of wind power. Based on the ANEEL database [34], 14 wind parks are in operation or under construction in the region (Table A3), which has triggered controversies about the impact on the soil and changes in the landscape of the rural space. Meanwhile, environmental licensing agencies have not duly addressed social acceptance issues [47,48]. Conversely, Usina Trapiche S.A. and the fishing community in the municipality of Sirinhaém, on the southern coast of Pernambuco, have been engaged in an ongoing conflict as, according to the fisherfolk, the company expelled its chemical waste into the estuary of Sirinhaém [10].

5. Discussion

This section discusses the conflicting renewables in Chile and Brazil through the environmental and energy justice lenses. After the diagnosis, we discuss energy alternatives and new paths within sustainable energy transition and into the juncture of possible eco-socio-economic scenarios.

5.1. Some Lessons

5.1.1. A Brief Discussion on Justice and Sustainability in the Energy Transition

Despite contributing to decarbonisation, renewables trigger new socio-ecological conflicts, some of which were exposed by the Chilean and Brazilian cases. Land disputes emerged with wind energy in Brazil and hydropower in both countries. Subsidised by the notion of just transitions, we identified a long-term uneven ecological distribution from developing renewables in Chile and Brazil, mainly in cases of hydropower. They are under threat of perpetuation in the hands of the NCREs if large and centralised projects continue prevailing in overloaded ecological settlements, as evidenced by Caetité municipality in Brazil. It is a crucial commonality identified in this study. Although renewables contribute towards achieving SDG 7 for affordable and clean energy for all, as mentioned by Sankaran and McIntyre-Mills [17], they have also created different justice issues that need to be addressed.

Particularities are associated with geothermal energy in Chile and biomass in Brazil. While Chile is a pioneer in geothermal energy, Brazil is a pioneer in biomass within South America. Nevertheless, both cases highlight and illustrate that innovation must be linked to societal and ecological dimensions.

5.1.2. The Hydropower Development under Question

Water establishes confrontations of worldviews as, on the one hand, using it is known to guarantee energy sovereignty and security in a low-carbon direction. On the other hand, from the political ecology perspective, hydro dams modify the natural fluxes of water, stimulating irreversible socio-environmental damage [38]. Independently from this perspective, in addition to security, equity, and environmental sustainability, decision-making processes must consider justice as the central point in the development of energy systems [1]. According to Valdes [49], public goods and their benefits must be distributed equally, which is becoming increasingly evident in energy systems.

According to Fearnside [27] (p. 104), 'dam construction in the Brazilian Amazon has often caused social impacts that violate what most people would consider basic norms of environmental justice'. Dams cause extensive floods, displace populations, impact fishing activities, block the migration of native fishes, and affect the cultural values of local inhabitants, as seen in the Chilean and Brazilian cases. The issues caused by dam construction have aroused scientific interest [28,29,31,38]. Meanwhile, as mentioned above, Ralco, Belo Monte, and Tucuruí, for example, have long-term unresolved socio-ecological conflicts in both countries.

The south of the Andes Mountain range in Chile and the Amazonia in Brazil have concentrated hydropower development. The Tocantins, Xingú, Teles Pires, Uatumã, Madeira, and Tapajós Rivers received documented socio-ecological effects in Brazil. The Bío Bío and Maipo Rivers and the associated ecosystems have a more significant environmental burden in Chile. Furthermore, water availability has become a critical issue in the current ecological crisis because of severe droughts in the last decades. Between 2000 and 2019, hydropower infrastructure use decreased in both countries [5,6]. This might contrast with the idea of sustainable development, where current necessities are satisfied without jeopardising the next generations' resources, raising a big challenge to the intergenerational sense of sustainability [50].

5.1.3. What about NCREs?

According to Olave and Vargas-Payera [37], geothermal exploitation in Chile's had weak environmental evaluations compared to the principles of sustainable development. Note that the Chilean state has owner participation in the Cerro Pabellón project as the National Petroleum Company (ENAP) has a part of the companies' shares via a joint venture. Despite indigenous groups calling Cerro Pabellón a threat to their cultural heritage, the formal cause ceased in 2022 in the Chilean Justice system [10].

A successful niche emerged in Brazil regarding wind energy. By 2019, Brazil became eighth in global installed capacity for onshore wind. The country has favourable natural conditions for onshore wind energy, especially in the northeast region, having an average capacity factor of 46%, compared with a global average of 36.3%. The Brazilian wind case stands out as the industry supply chain also developed substantially, having more than 100 companies taking part in the wind industry by 2018 [51]. Nevertheless, uneven environmental loads emerged with the fast development of the sector. With 14 wind farms, the case of Caetité is well-known for the Quilombolas communities' resistance against the overcrowding of lands by large wind farms. This municipality's land could be overloaded as a uranium mine and an iron ore mining project are situated there, leading to several socio-ecological effects. The estimated wind potential in the region is around 14.5 GW (10.1% of the national wind power potential), which might trigger the development of further wind projects there [10].

Chile and Brazil have not yet registered conflicts associated with solar infrastructure in the EJAtlas platform, which might situate this source as less aggressive in socio-ecological terms. Furthermore, both countries have a high solar potential [52–54], which might pave the fairest and most sustainable path within energy transition. Nevertheless, according to Ostrom [55], we must remember that there are no panaceas for resolving socio-ecological issues.

5.2. Thoughts on Energy Justice—A Normative Analysis

Large conflicting hydropower project cases in both Chile and Brazil reveal that governance systems do not ensure plenty of justice across society. For example, when those projects were placed near indigenous settlements, the heterogeneity that characterises worldviews and the complexity implied by different socio-natural perceptions, knowledge, and aspirations have not been respected with integrity. Nevertheless, those cases opened a flank to modify social, economic, judicial, and cultural hegemonic visions since the local resistance [38]. That is the case of Ralco, which started as a local case and became known worldwide, stimulating the Chilean signature for the ILO Convention no. 169. Table 6 summarises the main findings regarding the evaluation of energy justice in the Chilean and Brazilian cases.

Table 6. Summarising the energy justice evaluation analysis.

Tenets (Questions)	Chile	Brazil
Distributional (Where are the injustices?)	• Large hydropower • Geothermal	• Large hydropower • Wind • Biomass
Recognition (Who is ignored?)	Indigenous and local inhabitants' cultural and natural heritage and ecosystem services	Indigenous and local inhabitants' cultural and natural heritage and ecosystem services
Procedural (Is there a fair process?)	Weak evaluations, regulations, and punishments for violating water access rights, entitlements, and land properties	Weak evaluations and regulations, rules avoided and practically non-existent punishments

Distributional inequalities are probably the most obvious pending tasks in both studied cases because the water, wind, and geothermal potentials are located in specific areas, which turned into development poles. They stimulate uneven ecological distribution when socio-ecological evaluations are not severe enough. When distributional inequalities are associated with precedent societal inequalities, sometimes projects intensify and reproduce them. Then, social, cultural, ethnic, racial, and gender factors become markers for deeper inequalities; the areas close to the hydro dams in the Amazonia and Chilean mountain range serve as examples. Ecosystems were overloaded, threatening different endemic plant and animal species. Moran et al. [28] call for moving away from big dams and towards combining technologies that do not disrupt stream ecology and people's lives near the great rivers. An important task is to repair past damages, which implies repairing ecosystems and the services they provide [56]; the river restoration practice, which has precedents worldwide, is an example [57,58]. As Vasconcellos Oliveira has pointed out [50], future eco-socio-economic scenarios must support actions that promote the saving of irreplaceable goods.

Recognition could be a key to avoiding conflicts associated with (but not only with) energy projects during the sustainable transition era. Based on Hegel's theory of intersubjective recognition, Honnet [59] points to three ways of mutual human recognition: love, rights, and ethics. Here, improving equal political rights and ethical behaviour in energy systems and societal and environmental surroundings becomes critical. As an alternative solution to recognition paths in energy systems, Milčiuvienė et al. [60] point to distributed NCRE prosumers as an option for more sustainable, efficient, decentralised, democratised, and decarbonised systems in line with the energy justice principles.

Procedural energy justice highlights were lacking in both countries because the affected communities had no full access to critical decision-making spaces. The ILO Convention no. 169 on indigenous consultation has not been considered in some cases of Brazilian dams despite being in force. Therefore, the first step is to respect the responsibilities that those tribes have taken for themselves. Conversely, the Cerro Pabellón case in Chile exposes the necessity of having a continuous relationship with communities over time, from the exploration phase itself. This also applies to the wind case in Brazil. Early community engagement and information diffusion are imperative for effective processes.

From this study, we value the usefulness of environmental justice as a standard parameter to recognise conflicting energy projects within several industrial sectors (mining, cement, agro, etcetera). Then, energy justice allows a deep analysis of the socio-ecological dimension of energy projects (Figure 3 summarises the main common findings of this approach).

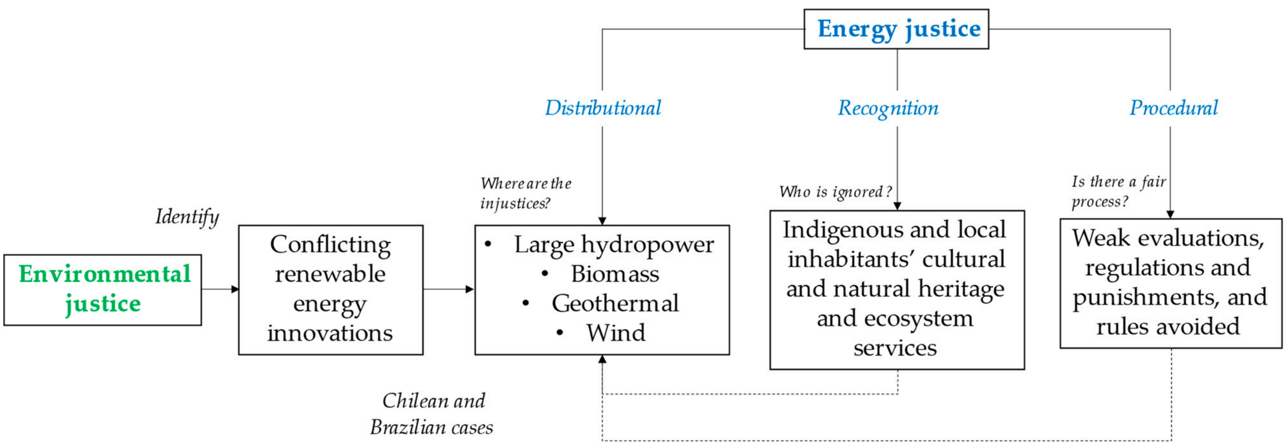

Figure 3. Commonalities in the Chilean and Brazilian environmental and energy justice analysis.

Furthermore, local knowledge could be critical to improving projects, mainly from communities heavily dependent on the local ecosystems or those who have been settled in those territories for a long time. Including different forms of local knowledge is also a way to get better procedural justice systems [7]. Additionally, Sovacool and Dworkin [61] consider energy justice as a decision-making framework to start making energy decisions that promote: (1) availability, (2) affordability, (3) due process, (4) good governance, (5) sustainability, (6) intergenerational equity, (7) intragenerational equity, and (8) responsibility; this may apply to Chile and Brazil, at least in the generation of long-term public energy policies.

5.3. What about Alternatives Fora Just and Sustainable Energy Transition?

During the 1970s, when the Meadows report warned us of the limits of growth [62], Ilich [63] pointed out the mirage of massive scale energy consumption, regardless of whether they were low-carbon technologies, as a sign of socio-ecological issues. As Max-Neef proposed, a key to the ecological issue could be a human-scale economy which focused on the satisfaction of essential human necessities instead of capital-based development [64,65].

Based on the countries' cases, supported by Avila [66], we affirm that if we only add new renewables to the same finite economic subsystem, we have a partial solution to the ecological issue. In other words, as advertised by Ilich, perpetual energy consumption increase implies necessary and unavoidable new power generation capacities. Then, uneven ecological distribution and social inequalities tendencies will perpetuate, associated with the poles of development. It intensifies if energy projects are large-scale and not prospectively well-planned.

5.3.1. Citizen Engagement and Energy Commons

Hydropower development has been linked to the ill-treatment of highly environmentally loaded settlements in particular basins of both countries. Another side of the same coin is that the commons, associated with energy sources' use, are not distributed equally. We must think that some sources, such as water, are not used only for energy generation. Emerging literature discusses Elinor Ostrom's commons theory [67] in the energy sector [68–70]. Ostrom highlights the common-use resource management's environmental and social benefits through collective efforts involving the users [67,71]. Byrne et al. [69] call for a change in energy-ecology-society relations and a move from an energy commodity to an energy commons regime. Then, local citizens and communities must be at the centre of the energy system, reinforcing social awareness and cohesion and democracy [70,72]. Furthermore, inspired by the Ilich discourse, de Majo [73] suggests that within the idea of commons lies the possibility of promoting environmental sustainability globally, connecting the universe of collective properties to ecological thought. Meanwhile, Sankaran and McIntyre-Mills [17] add the ecological democracy dimension.

Some authors have stimulated the discussion about the collective, democratic, and decentralised use of NCREs as a means to a sustainable future [66,71,74]. Under the Max-Neef stimuli, Brand-Correa et al. [64] argued that bottom-up approaches are 'necessary to address the complex sustainability challenge of living well within environmental limits', which became critical in developing societies where basic needs are not covered, or new inequalities arose. New sustainable energy transition research considers citizens as critical agents in developing and preserving new knowledge [75]. Nevertheless, a pending task for the studied countries is identifying citizens who are engaged or able to get more involved in energy systems.

5.3.2. Energy Communities as an Example of Alternatives Emerging with NCREs

An energy community (EC) is a group of citizens producing, managing, and using their energy locally, customarily, in a distributed modality, based on renewable sources, and occasionally applying energy conservation/efficiency methods/technologies [2]. As an alternative to centralised and property-closed traditional energy systems, ECs might redistribute the social power over energy systems as it empowers the prosumers as collective actors, reinforcing the democratisation of systems [76,77]. Thus, several challenges and opportunities emerge, including resource management, human and environmental synergic well-being, regulation improvements, and the reinforcing of territorialism and cultures [2]. Consequently, with bottom-up collective small-size projects, the path to sustainable development and post-carbon economies might be viable without compromising on justice for all. However, it is not a panacea; it is just one alternative that should be implemented synergically with others.

Both Chile and Brazil opened a regulatory space to ECs because they allow the conformation of communitarian bodies of citizens injecting surplus energy into the public grid. In the Chilean case, since 2018, the legislation for residential power generation provides an institutional definition of collective owners of NCRE or efficient cogeneration infrastructure smaller than 300 kW. In Brazil's case, since 2015, shared generation allows the injection of surplus energy by a cooperative or consortium of consumers into the same concession area, using renewable sources or quality cogeneration smaller than 5 MW (except hydropower, which can be smaller than 3 MW) [2].

6. Conclusions

This study uses a just transition perspective to evaluate, from a comparative insight, the Chilean and Brazilian energy transitions and the employment of renewable sources in both electrical systems. Furthermore, it captures lessons and identifies lacks, failures, and challenges within the sustainable transition paths. Novel environmental and energy justice approaches help to discuss why, how, where, and when conflicts associated with renewable energy emerge, and what and who they affect. Furthermore, this study corroborates McCauley and Heffron's [1] idea of establishing dialogues between both lenses, which applies to analysing the conflicting power projects in sustainable energy transition.

In simple terms, it would seem that the energy trilemma supported by security, equity, and environmental sustainability dominated a development based on hydropower as a low-carbon and secure source, which might continue with NCREs' emergence. Nevertheless, it conflicted with territorial communities close to the high potential of renewable development zones. Although the two countries have differences in relation to emerging NCRE, the socio-ecological conflicts associated with them have common roots and consequences. Both cases showed that indigenous and local inhabitants' cultural and natural heritage and ecosystem services are affected by close renewables. Furthermore, water and land turned into pivotal disputed resources that confronted interests.

Based on past experiences, both countries require clear and modern instances of civil society engagement and decision-making processes. Relationships among stakeholders should be extended over time, from the exploration project to the operational phases. Furthermore, NCREs open the door to new opportunities, such as the possibility of prosumers' active engagement in collectively and democratically developing energy projects.

With the emergence of NCREs worldwide as a sustainable path to reach post-carbon societies, sometimes, states take part in fostering those projects. Nevertheless, states' promotion and involvement through direct capital investments are not exempt from critical socio-ecological conflicts. In Chile, the ENAP owns a part of the Cerro Pabellón geothermal plant. In Brazil, governments have stimulated wind development. States must establish severe multi-disciplinary evaluations before participating in projects that reproduce injustices, and justice must be considered as a central principle in public policies. There are no panaceas, and innovation must be strongly linked to the ecological and societal dimensions and justice energy policies and regulations. We think that reinforcing decision-making processes should synergise with looking for new alternatives to develop energy in both countries. Moving forward in sustainable and justice-based directions implies putting justice approaches at the centre of public policies.

7. Further Research Directions

We studied the Chilean and Brazilian cases because of their well-known performance in the sustainable energy transition. Using this framework to analyse other countries' cases that were less developed in implementing low-carbon technologies might be interesting. It might show the main socio-ecological barriers to renewables in premature environments having less developed regulations and policies. Regarding Chile and Brazil, a pendant task is deepening the citizens' and communities' involvement in energy systems.

In this study, we focused only on power plants. Consequently, further studies might focus on the production chains linked to the production of low-carbon technology. This opens up a range of possibilities for studying countries that produce critical transition minerals and the possible externalities associated with it, and the possible linked ecological and societal threats.

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Abbreviations

The following abbreviations are used in this manuscript:

AM	Amazonas
AN	Antofagasta
ANEEL	Brazilian Electricity Regulatory Agency
BA	Bahia
BI	Bío Bío
CEN	The National Electrical Coordinator
EC	Energy Community
EJAtlas	Atlas of Environmental Justice
ENAP	National Petroleum Company
IEA	International Energy Agency
ILO	International Labour Organization
IO	In operation
MG	Minas Gerais
MT	Mato Grosso
NB	Ñuble
NCRE	Nonconventional renewable energy
NZE	Net zero emissions
PA	Pará
PE	Pernambuco
RM	Metropolitan
RO	Rondônia
RS	Río Grande do Sul
SC	Santa Catarina
SDGs	United Nations' Sustainable Development Goals
SHP	Small-scale hydropower
UC	Under construction

Appendix A. Chilean and Brazilian Power Generation in 2020 by Sources

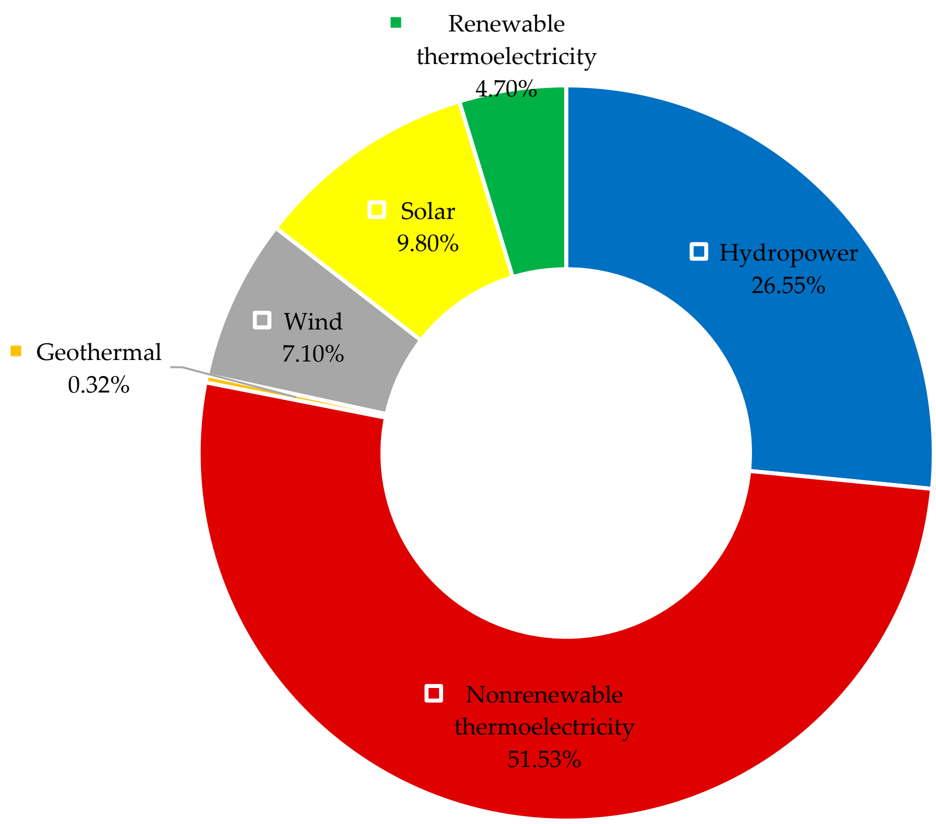

Figure A1. Chilean power generation in 2020 by sources. Source: OLADE [12].

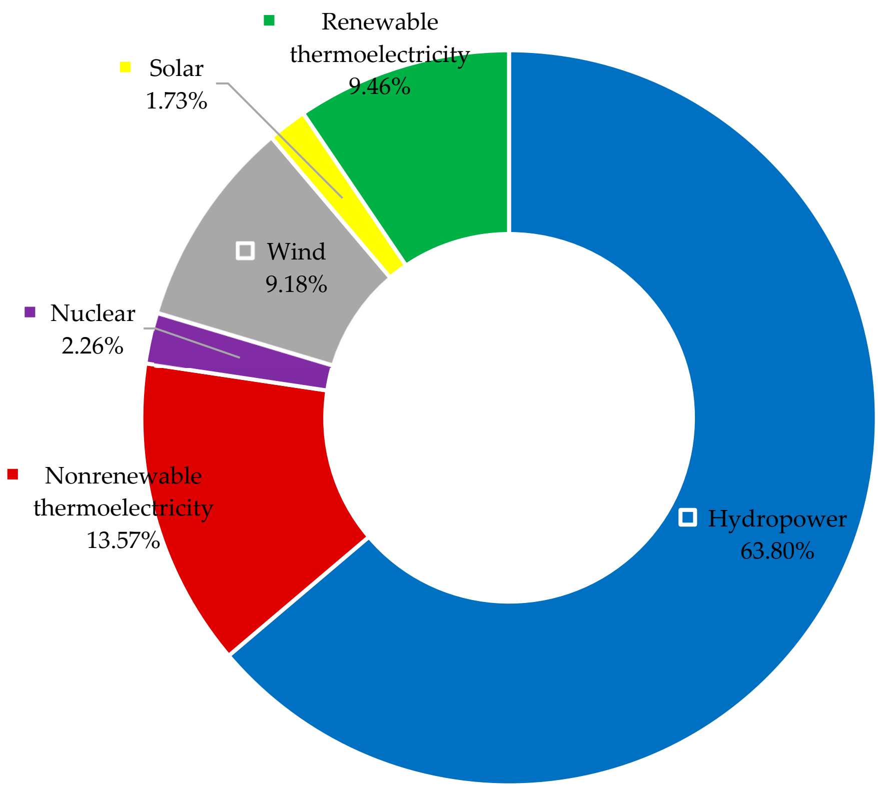

Figure A2. Brazilian power generation in 2020 by sources. Source: OLADE [12].

Appendix B. Power Projects with Socio-Ecological Conflicts

Table A1. Power projects with socio-ecological conflicts in Chile.

Name	Size (MW)	Status [(a)]	Source of Conflict	Impacts	Region [(b)]	Year
Cerro Pabellón (Geothermal)	51	IO	• Climate and energy justice • Geothermal energy installations	Socio-economic	AN	2017
Ralco (Hydropower)	685	IO	• Water management • Water access rights and entitlements • Transport infrastructure networks • Land acquisition conflicts • Dams and water distribution conflicts.	Displacement; loss of livelihood; militarisation; social problems; violations of human rights; land dispossession; loss of landscape	BI	1996
Angostura (Hydropower)	321	IO	• Water management • Water access rights and entitlements • Establishment of national parks • Dams and water distribution conflicts	Biodiversity loss; loss of landscape; deforestation and loss of vegetation cover; surface water pollution; reduced ecological and hydrological connectivity; displacement; loss of traditional knowledge, practices, and cultures; militarisation; land dispossession; loss of landscape	BI	2014 [(c)]
Alto Maipo—Alfalfal II (Hydropower)	264	IO	• Water management • Water access rights and entitlements • Transport infrastructure networks • Dams and water distribution conflicts • Building materials extraction	Fires; foods; loss of landscape; noise pollution; deforestation and loss of vegetation cover; increase in corruption and co-opting of different actors; militarisation; violations of human rights	RM	2007
Alto Maipo-Laja (Hydropower)	146	IO			RM	2007
Hidroñuble (Hydropower)	136	UC	• Water management • Land acquisition conflicts • Dams and water distribution conflicts	Loss of landscape; soil contamination; deforestation and loss of vegetation cover; surface water pollution; decreasing water quality; groundwater pollution or depletion; large-scale disturbance of hydro and geological systems; reduced ecological and hydrological connectivity; displacement; loss of livelihood; loss of traditional knowledge, practices, cultures; land dispossession; loss of landscape	NB	2007

Source: Temper et al. [10] and Coordinador Eléctrico Nacional [33]. [(a)] Status: In operation (IO); Under construction (UC). [(b)] Regions: Antofagasta (AN); Bío Bío (BI); Metropolitan (RM); Ñuble (NB). [(c)] Starting operation year. This table only considers visible impacts.

Table A2. Hydropower projects with socio-ecological conflicts in Brazil.

Name	Size (MW)	Status [(a)]	Source of Conflict	Impacts	State [(b)]	Year
São Manoel	700	IO	• Water management • Water access rights and entitlements • Deforestation • Transport infrastructure networks • Land acquisition conflicts • Dams and water distribution conflicts	Biodiversity loss; Food insecurity; Loss of landscape; Oil spills; Deforestation and loss of vegetation cover; Surface water pollution; Groundwater pollution or depletion; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Malnutrition; Mental problems, including stress, depression and suicide; Increase in violence and crime; Loss of livelihood; Militarisation; Specific impacts on women; Violations of human rights; Land dispossession; Loss of landscape	MT/PA	2010
Sinop	402	IO	• Water management • Water access rights and entitlements • Deforestation • Land acquisition conflicts • Dams and water distribution conflicts • Aquaculture and fisheries	Biodiversity loss; Food insecurity; Loss of landscape; Deforestation and loss of vegetation cover; Surface water pollution; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Desertification; Groundwater pollution or depletion; Malnutrition; Accidents; Displacement; Loss of livelihood; Loss of landscape	MT	2010
Teles Pires	1820	IO	• Water Management • Water access rights and entitlements • REDD/CDM • Deforestation • Transport infrastructure networks • Land acquisition conflicts • Dams and water distribution conflicts	Biodiversity loss; Loss of landscape; Deforestation and loss of vegetation cover; Surface water pollution; Reduced ecological and hydrological connectivity; Food insecurity; Malnutrition; Mental problems, including stress, depression, and suicide; Displacement; Loss of livelihood; Violations of human rights; Loss of landscape	MT/PA	2010
Tucuruí	8535	IO	• Water management • Deforestation • Transport infrastructure networks • Land acquisition conflicts • Dams and water distribution conflicts.	Desertification; Food insecurity; Loss of landscape; Surface water pollution; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Deforestation and loss of vegetation cover; Groundwater pollution or depletion; Violence-related health impacts; Health problems related to alcoholism and prostitution; Displacement; Loss of livelihood; Violations of human rights; Land dispossession; Loss of landscape; Loss of traditional knowledge, practices, and cultures	PA	1976

Table A2. *Cont.*

Name	Size (MW)	Status [(a)]	Source of Conflict	Impacts	State [(b)]	Year
Dardanelos	261	IO	• Water Management • Dams and water distribution conflicts	Biodiversity loss; Floods; Reduced ecological and hydrological connectivity; Large-scale disturbance of hydro and geological systems; Malnutrition; Displacement; Loss of traditional knowledge, practices, and cultures; Loss of landscape	MT	2010
Barra Grande	690	IO	• Water Management • Deforestation • Land acquisition conflicts • Dams and water distribution conflicts	Floods; Deforestation and loss of vegetation cover; Loss of landscape	RS/SC	2004
Aimorés	330	IO	• Water Management • Dams and water distribution conflicts	Biodiversity loss; Floods; Food insecurity; Loss of landscape; Soil erosion; Waste overflow; Deforestation and loss of vegetation cover; Surface water pollution; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Infectious diseases; Increase in corruption and co-opting of different actors; Displacement; Loss of livelihood; Loss of traditional knowledge, practices, and cultures; Violations of human rights; Land dispossession; Loss of landscape	MG	2005
Manso	210	IO	• Water Management • Water access rights and entitlements • Dams and water distribution conflicts	Food insecurity; Deforestation and loss of vegetation cover; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Lack of water in the new settlements; Displacement; Loss of livelihood; Violations of human rights; Land dispossession	MT	2003
Balbina	250	IO	• Water Management • Deforestation • Land acquisition conflicts • Dams and water distribution conflicts	Biodiversity loss; Floods; Food insecurity; Loss of landscape; Deforestation and loss of vegetation cover; Surface water pollution; Reduced ecological and hydrological connectivity; Soil erosion; Groundwater pollution or depletion; Displacement; Loss of livelihood; Loss of traditional knowledge, practices, and cultures; Violations of human rights; Land dispossession; Loss of landscape	AM	1979

Table A2. *Cont.*

Name	Size (MW)	Status [(a)]	Source of Conflict	Impacts	State [(b)]	Year
Belo Monte	11,233	IO	• Water Management • Water access rights and entitlements • Land acquisition conflicts • Dams and water distribution conflicts	Air pollution; Biodiversity loss; Desertification; Floods; Food insecurity; Loss of landscape; Noise pollution; Soil contamination; Soil erosion; Deforestation and loss of vegetation cover; Surface water pollution; Groundwater pollution or depletion; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Accidents; Malnutrition; Mental problems, including stress, depression, and suicide; Violence-related health impacts; Health problems related to alcoholism, prostitution, and infectious diseases; Loss of landscape; Increase in corruption and co-opting of different actors; Displacement; Increase in violence and crime; Lack of work security, labour absenteeism, firings, and unemployment; Loss of livelihood; Loss of traditional knowledge, practices, and cultures; Militarisation; Social problems (alcoholism, prostitution, etc.); Specific impacts on women; Violations of human rights; Land dispossession	PA	1975
Jirau	3750	IO	• Water Management • Land acquisition conflicts • Dams and water distribution conflicts	Floods; Food insecurity; Loss of landscape; Large-scale disturbance of hydro and geological systems; Reduced ecological and hydrological connectivity; Biodiversity loss; Soil contamination; Soil erosion; Surface water pollution; Groundwater pollution or depletion; Accidents; Malnutrition; Mental problems, including stress, depression, and suicide; Violence-related health impacts; Deaths; Loss of livelihood; Violations of human rights; Loss of landscape; Displacement; Increase in violence and crime; Lack of work security, labour absenteeism, firings, and unemployment; Loss of traditional knowledge, practices, and cultures; Land dispossession	RO	2006

Source: Temper et al. [10] and Agência Nacional de Energia Elétrica [34]. [(a)] Status: In operation (IO); Under construction (UC). [(b)] States: Mato Grosso (MT); Pará (PA); Rio Grande do Sul (RS); Santa Catarina (SC); Minas Gerais (MG); Amazonas (AM); Rondônia (RO). This table only considers visible impacts.

Table A3. Renewable power projects with socio-ecological conflicts in Brazil.

Name	Size (MW)	Status [(a)]	Source of Conflict	Impacts	State [(b)]	Year
Trapiche (Biomass)	26	IO	• Biomass and land conflicts • Intensive food production • Wetlands and coastal zone management • Agro-fuels and biomass energy plants • REDD/CDM • Agro toxics • Land acquisition conflicts • Aquaculture and fisheries	Food insecurity; Surface water pollution; Deforestation and loss of vegetation cover	PE	1980
Caetité 2 (Wind)	30	IO	• Climate and energy justice • Large-scale wind energy plants • Land acquisition conflicts	Loss of landscape; Noise pollution; Deforestation and loss of vegetation cover; Reduced ecological and hydrological connectivity; Increase in corruption and co-opting of different actors; Displacement; Increase in violence and crime; Loss of livelihood; Land dispossession; Loss of landscape	BA	2011
Caetité 3 (Wind)	30	IO			BA	2011
Caetité (Wind)	30	IO			BA	2011
Caetité 1 (Wind)	30	IO			BA	2011
Caetité B (Wind)	22	IO			BA	2011
Caetité A(Wind)	24	IO			BA	2011
Caetité C (Wind)	9	IO			BA	2011
Aura Caetité 03 (Wind)	29	UC			BA	2011
Aura Caetité 04 (Wind)	21	UC			BA	2011
Caetité D (Wind)	50	UC			BA	2011
Caetité E (Wind)	38	UC			BA	2011
Caetité F (Wind)	25	UC			BA	2011
Aura Caetité 01 (Wind)	29	UC			BA	2011
Aura Caetité 02 (Wind)	29	UC			BA	2011

Source: Temper et al. [10] and Agência Nacional de Energia Elétrica [34]. [(a)] Status: In operation (IO); Under construction (UC). [(b)] States: Pernambuco (PE); Bahia (BA). This table only considers visible impacts.

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