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Overcoming Resource Nexus Conflicts With a Normative-Institutional Approach: A Case Study of Brazil

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Water-energy nexus research highlights the need for co-management across water and energy sectors, whereby joint planning and solutions under better integrated governance of resources could make action more efficient and cost-effective to advance the SDGs. A gap remains in the literature with regards to the normative dimension of the resource nexus. At the background or resource nexus conflicts there are norms, which need to be considered and applied in the resolution of disputes. Brazil has been chosen as case study because of rising conflicts around its high dependency on water and hydropower generation to keep affordable tariffs, while securing multiple water uses. Hydrological factors (e.g., prolonged droughts) and non-hydrological factors (e.g., chronic delays in delivery of new plants and transmission lines) have impacted on water availability, which led to constraints for hydropower generation, with cascading economic, social and environmental impacts. Electricity prices have risen, while water quantity and quality have decreased, affecting multiple users and ecological integrity of rivers. All of which impact negatively on livelihoods and water services and sanitation, aggravated by the fact that electricity represents one of the fastest growing costs for Water services, Sanitation and Hygiene (WASH) suppliers. The novel combination of research methods based on metrics, historical-institutional analysis, questionnaire, and in-depth interviews served as instruments for the assessment of the water-electricity nexus issues and development of a new legal approach to manage conflicts arising in Brazil. Most of the existing work has favored integration of water and electricity sectors based on quantitative approach to address the interlinkages between them and tackle trade-offs. However, from a legal perspective, very little is known about how these sectors could be better integrated in practice. This study proposes a normative-institutional approach that offers a flexible, integrated, and adequate legal treatment to overcome the conflicts between water and electricity in the context of their asymmetrical governance, policies, regulation, planning and environmental injustices. Split in substantive, institutional, and procedural dimensions this approach is necessary to enhance participatory and equitable resource governance based on the laws of balancing legal principles, rational, inclusive, and transparent procedures. It was concluded that for water-electricity nexus thinking to be connected

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to the idea of integration it will be necessary to consider justice by taking a normative-institutional approach that can support advances to the SDGs in more holistic and fair ways.

Keywords: water-energy nexus, governance, sustainable resources, legal principles, SDGs, fair resource management

INTRODUCTION

Sustainable resource management and governance are amongst the most pressing challenges in the context of climate emergency, population growth and development needs, recognized under the Sustainable Development Goals (SDGs). When examining water and energy flows, it has been proven that the intersections of agriculture, water and electricity generation are priority areas that need further research (Hoff, 2011). There are trade-offs amongst the latter, as well as rapidly changing cycles that affect their resource quantity, quality, accessibility, affordability, and sustainability. The operational and resource interdependencies between water and electricity, for example, require consideration of trade-offs and how to manage rising conflicts between competing uses under two operational silos and multiple scales. Water and electricity have been the subject of several nexus studies that analyse the complex interactions involving resource use at system level and beyond (water-energy nexus). Water is withdrawn and consumed directly or indirectly along the energy supply chain, from generation to supply, and electricity is needed for water extraction, treatment and distribution to end-users. Research assessing the critical interlinkages between water and electricity use several methods that account for the physical aspects of our society, such as Life Cycle Assessment, Material Flow Analysis, footprint analysis, environmental extended output analysis and critically assessment (van der Voet and Guinée, 2019). Most technical studies focus on risks, security, and economic rationales (Weitz et al., 2017). They commonly advocate that actions under both sectors could become more efficient and cost-effective through co-governance of resources, joint planning, and solutions (Venkatesh et al., 2014). Moving away from the institutional silo mentality in policymaking, with better integrated solutions and greater coordination across sectors and stakeholders is seen as one of the best ways to optimize trade-offs (Sinha et al., 2006; Sovacool and Sovacool, 2009; Siddiqi et al., 2013; Oliver and Hussey, 2015; Peel, 2015; JRC, 2018). Integration has been the main proposition of studies that quantitively assessed the water-energy nexus trade-offs. However, there are many governance, planning, policy and legal obstacles combined with a plethora of opposing interests, regulatory capture and conflict that represent obstacles toward new cross-sectoral governance regimes. Institutions, decision-making powers, policies, regulation, planning, knowledge and information are mostly restricted to sectoral boundaries and fragmented between different scales and actors.

Cross-sectoral co-ordination is hard in the context of the unique set of governance instruments particular to water and electricity, with different rationales, policy setting and capabilities (Oliver and Hussey, 2015). Different processes, norms and interests influence how resources are allocated and how technical information and trade-offs are translated into action (Al-Saidi and Elagib, 2017). From a governance perspective, a multi-level model approach is considered to offer the necessary mobility in between scales to integrate existing governance functions (Wallis, 2015). The latter combines the adaptive governance rationales of "learning by doing" and the optimisation requirements of the nexus to improve decision-making processes (ibid.). Hussey and Pittock (2012) argue that at the core of every water-electricity nexus issue is the problem of lack of policy integration. Peel (2015) identified common elements under the literature which are useful to advance integration of policies, including instruments that go beyond market based approaches, distribution of power between scales, broad participation, including planning tools and adaptative decision-making. Artioli et al. (2017) argues that integration raises many risks that can lead to very generic policy recommendations, increasing complexity too much and making decision-making ineffective. However, research advocates that procedural justice tools are enough to tackle interdependencies and complexities when allocating disputed nexus resources (Larcom and Gevelt, 2017).

We argue that if tackling nexus conflicts means nothing more than adjustments between competing interests and integrating policies, to some extent, modern environmental law and policy has always been doing this particularly in its development of more integrated pollution controls. The very subject "environment" pertains to the entire spectrum of human activities, including direct ecological impacts, economic enterprises, social interactions and public policies (Bosselmann, 2016). Depending on how narrowly or broadly the environment is legally defined, they will determine the scope and integrative character of environmental law (ibid.). Reconciliation between environmental values, property rights, social justice is at the core of environmental law cases. The nexus can learn from it, but if used merely for integrating conflicting interests based on win-win objectives, without a benchmark, hardly anything will be achieved. Middleton et al. (2015) teaches that in order to tackle the risks of the nexus becoming a tool of reproduction of inequalities, there are important questions about who are the winners and losers that need to be answered to address the issue of justice. Contrary to most discussions favoring integration, research has flagged out the importance of scalar politics to grapple with issues of uneven geographies and just governance responses (Williams et al., 2014, 2018). They criticize the panacea of integrative approaches by flagging out the importance of "politicizing the nexus" and questioning if integration would necessarily result in more sustainable outcomes, because it currently stands on "purely efficiency-based techno-managerial solutions to tensions and trade-offs between electricity and water,

and one that is entirely consistent with market-based approaches to environmental governance" (Williams et al., 2018, p. 3). To overcome insufficiencies of nexus discourses, Weitz et al. (2017) suggest the co-ordination across institutionally different sectors, different levels of authority and governance mechanisms through environmental integrative governance. Nevertheless, they identify there would still be a lack of clarity permeating the nexus concept due to the lack of guiding principles, which makes hard to define the aims and purposes of what the nexus should achieve beyond efficiency. We identify the lack of a normative-principled approach to the resource nexus as one of the possible reasons explaining the previously identified conclusions. Gaps still remain in relation to the normative dimension of the water-electricity nexus and questions are raised about the role of the law in providing solutions to complex nexus conflicts and advance equitable resource governance.

Analyzing the legal architecture and norms in which the resource nexus operates, including where disputes happen and how norms are applied in the resolutions of conflicts becomes as important as accounting for trade-offs at biophysical and systemic levels. Questions arising from resource nexus conflicts should be answered on the basis of empirical evidence and economic rationales, but also on the basis norms (legal principles and rules). It is key to consider the role of legal principles, including the legal principle of intra- and inter-generational equity and due legal process to advance nexus governance. We fill this gap by taking a mixed method approach to assess the water-electricity nexus in Brazil, combining metrics and the legal dimension in which it operates, introducing legal principles as corrective tools to manage nexus conflicts and potential governance shortcomings. The water-electricity nexus is a central concept to advance the SDGs, and at the background of every nexus conflict there are environmental legal principles together with legal principles that apply to the state. Legal principles are norms based on agreed values of society which are found within different jurisdictional scales—international and national laws, regional statutes, and case law (Scotford, 2017). Environmental legal principles that are relevant to this research include: integration (environmental protection should be integral part of policy areas); precaution (lack of scientific evidence should not preclude or postpone prevention action where there is serious risk of ham); polluter-pays (those who cause environmental harm should take the burden of proof and the costs); inter-generational equity (equity issues and access to resources between current and future generations, with the former owing duties to the latter to conserve resources); and intra-generational equity (equity issues and access to resources between people of present generations and between states). Given the state plays a central role in the management, legislation and governance of water and electricity resources and sectors, the legal principles applicable to the state (e.g., due legal process and proportionality) are also important. These principles are not an exhaustive list of applicable legal principles, because this will vary according to circumstances of each water-electricity resource nexus conflict. However, these are all key legal principles that reflect courses of actions for sustainable resource management.

Given there are several equally valid legal principles that may apply to advance solutions to a same resource nexus conflict, which can result in distinct legal outcomes, these legal principles inevitably collide and require balancing. Consequently, we discuss the importance of developing an institutional-normative approach to manage the resource nexus disputes and promote fair solutions through the laws of balancing legal principles under a dedicated institutional environment. It involves the creation of second-degree institution for sectoral integration and participative decision-making through pre-stablished procedures and following the rationales of the laws balancing of legal principles. Water-electricity nexus conflicts are complex problems that require constant assessment and revision of trade-offs, with no pre-stablished hierarchy between sectors. The latter are hard to grasp and tackle because of the entangled nature of problems, incomplete knowledge and impossibility of arriving at definite solutions (Mercure et al., 2019). Consequently, the challenge is in developing a normative-institutional solution that can be flexible enough to deal with ever changing nature of resource nexus conflicts in context operational silos under multiple scales, and related asymmetries of governance, planning, policy and regulation. Our proposal on how the law can support solutions to resource nexus conflicts is a novel contribution that aims to overcome the insufficiencies of nexus discourses. Section Materials and Methods explains the interdisciplinary methodology based on metrics, historical-institutional analysis, questionnaire, and in-depth semi-structured interviews applied to Brazil. The results and analysis are under section Analysis and Results. Both are followed by the legal based discussion and proposal to enhance equitable resource governance in the context of sectoral asymmetries (sections Discussion: Overcoming Nexus Conflicts with a Normative-Institutional Approach, Conclusions). As a method based on the laws of balancing legal principles through fair, rational and transparent procedures under dedicated institutional environment, it can be expanded to include other natural resources such as land and replicated for other cases of resource nexus conflicts in Brazil and beyond. For example, the potential conflicts and governance shortcomings related to the resource trade-offs identified by Lilia et al. (2019).

MATERIALS AND METHODS

We developed an interdisciplinary methodological approach to assess and address the water-electricity nexus in Brazil by engaging with different disciplines, including law and social sciences, as well as different methods, combining metrics, historical-institutional analysis, and surveys (questionnaire and semi-structured in-depth interviews). Desk-based research using databases from Brazil's National Grid Operator, Ministry of Mines of Electricity, Water Regulatory Agency, and Electricity Regulatory Agency support the definition of metrics and quantitative assessment (**Figure 1**). The historical institutional analysis, questionnaire and semi-structured in-depth interviews form the basis of the qualitative assessment (**Figure 1**). The analysis of constitutional norms through time, sectoral laws,

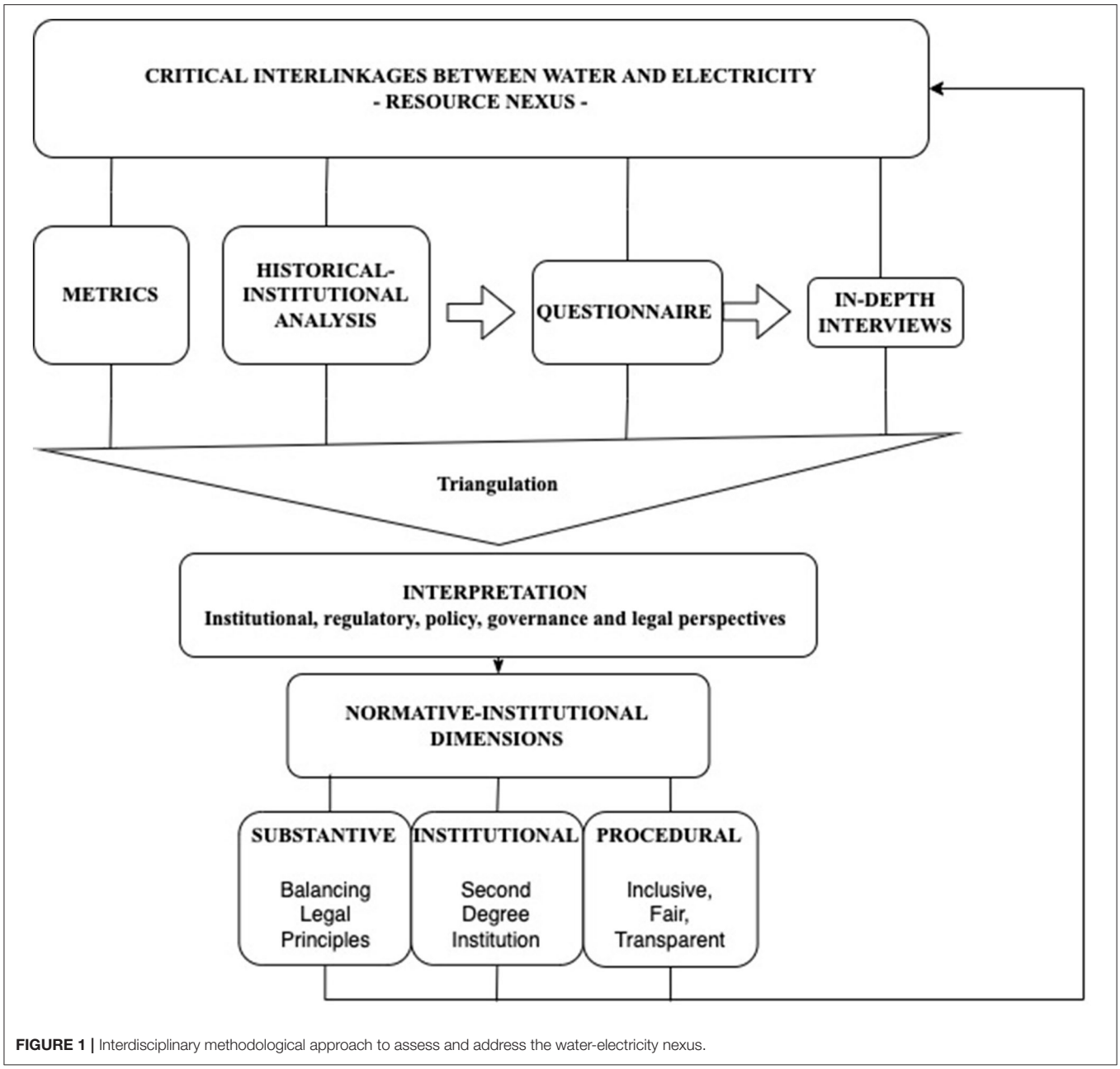

FIGURE 1 | Interdisciplinary methodological approach to assess and address the water-electricity nexus.

regulatory framework, institutions, planning, and policies supports the historical-institutional analysis and assessment of asymmetries. The data collected through field work using one questionnaire and in-depth semi-structured interviews provides a deeper understanding of the decision-making processes involving scarce common-pool resources in the São Francisco basin in Brazil. The latter support conclusions about power asymmetries, capture of water by electricity, and the possible strategies to advance sustainable resource governance. The participants are purposefully selected based on expertise and experience in one or both sectors, so generalizations that would have been made possible by using a high number of participants was not the goal. Altogether, the methods depicted in **Figure 1** serve as instruments for the development of a rich understanding of the water-electricity nexus issues in Brazil, so that a legal mechanism to address and advance equitable resource nexus governance could be developed in the section Discussion: Overcoming Nexus Conflicts with a Normative-Institutional Approach.

The metrics are the starting point. Throughout very severe drought years (e.g., 2013–2018) multiple normative resolutions authorized the decrease of water dispatch levels by major hydropower plants below the minimum levels set under their environmental permits (M^3/s) (Carvalho et al., 2019). In the São Francisco basin, responsible for more than 95% of the energy security of Brazil's Northeast electricity Subsystem, the

TABLE 1 | Metrics on cascading impacts of reservoir depletion.

Cascading impacts of reservoir depletion	Metrics	Description
Energy security	Number of dams and % of contribution to system security	% of energy security provided by the three large hydropower generation plants to Northeast electricity subsystem
Reductions of water outflow of hydropower plants	m^3/second	Water dispatch level reduction of hydropower power plants
Reduction of hydropower generation and increase of thermal power generation	MW average	Hydro generation reduction by main hydropower plants of São Francisco basin and Northeast electricity subsystem, and thermal generation rise
Reduction of river flow	m^3/s	Water flow
Costs of water to hydropower plant	$\$/m^3$	Fixed costs of water to power plant in the form of royalties paid at a fixed rate of 6%
Short-term electricity market cost increase (PLD)	BRL/MWh	PLD of regulated and non-regulated electricity markets
Rise of Marginal Operational Costs of electricity sector	R$/MWh	Marginal operational cost of electricity system, calculated per electricity subsystem
Risk of energy deficit	R$/MWh	Marginal Operational Cost (MOC) equal to or above certain thresholds
Electricity for water	kWh/m^3	Electricity needs for wastewater treatment
Rising costs of electricity to water services	BRL/kWh	Costs of electricity to water services
Electricity tariff revisions	%	
Rise of GSF related costs	R$/MWh	Ratio between hydropower generation and physical guarantee of plants needs be equal to 1, or 100%, so less hydro generation can result in negative GSF and exposure of producers in short-term market

first authorization to reduce discharge levels from 1,300 to 1,100 m^3/s for the hydropower plant "Sobradinho" was in 2013 (ANA, 2013). In 2017, the dispatch levels for Sobradinho went as low as 550/523 m^3/s (ANA, 2017). The latter evidence and the national hydro resource policy setting the watershed level as management unit of water resources guided our decision to focus on a specific basin and develop metrics accordingly (**Table 1**). Given that decisions to reduce dispatch levels are taken under "critical events room" developed specially for watersheds facing emergencies of resource stress or scarcity, it also explains the importance of focusing on this level for assessment of resource conflicts and issues of distributive and procedural injustices. These latter decisions are like developing a norm for each case of resource stress at basin level, so the normative discourse becomes a necessary one, while the basin level the necessary scale of analysis. Both push the nexus beyond a technocratic approach into a legal sphere. In Brazil, many basins face water stress that have led to reductions of hydropower dispatch levels (e.g., Paraíba do Sul). The decision to focus on the São Francisco basin also emerged from the analysis of the metrics, as no other basin is exclusively responsible for more than 95% of the energy security of an entire electricity subsystem (out of four) in Brazil. The São Francisco is the largest river starting and finishing in Brazil and counts with the largest hydropower complex of the country (Nascimento do Vasco et al., 2019). Many hydrological shifts happened in this basin after the construction of hydropower power plant Xingó in 1994, with its operation regulating the river flows and contributing to more than 30% of flow decline in the last 18 years (ibid.). The basin also counts with the largest water transfer project in Brazil, which is highly electric-intensive because of pumping requirements for taking water to states located in semi-arid region. Chronic inefficiencies involving the water sector means that a lot of the water being transferred is lost at arrival in different municipalities which represents losses of both water and electricity.

Parallel to the metrics, the historical-institutional method captured governance and legal asymmetries between water and electricity through time. This method supports the analysis of the historical factors which have, collectively, shaped water and electricity sectors, laying the foundations for today's structures. The main sources analyzed include the constitutional norms applicable to water and electricity under each constitutional period in Brazil, starting from the edition of the Water Code in 1934 up to the present date (1934–1937; 1937–1946; 1946–1964; 1964–1988; 1988-today). National sectoral laws, regulations, institutional structures and policies are also analyzed. Electricity has always followed a top-down and centralized governance approach, with a lot of concentrated powers under the national government, including after the regulatory reforms of 2004. For hydro resources, until the edition of the National Hydro Resource Policy, all institutions were managing the resources for the purposes of hydroelectricity. For water services, sanitation and hygiene (WASH), a new regulatory framework enacted in 2020 grants powers to the National Water Regulatory Agency to regulate the services where Municipalities have not done so. A new regulatory framework enacted in 2020 grants powers to the National Regulatory Agency for Water to regulate WASH. During the seventies, a water and sanitation plan and financing mechanisms were introduced at national level, which helped expand services. However, the latter were canceled in 1984 leaving a gap for many years that compromised further developments to the WASH sector. It was only in the year of 2007 that a national policy for sanitation was enacted. Comparatively, the electricity sector counts with more robust and continous regulatory development to promote the expansion of its services

and hydropower. Whereas electricity has always been under national powers, the governance of hydro resources and WASH have seen historical shift of power across scales. Today, the national government holds the exclusive competence to explore the services and installations of electricity and holds exclusive legislative powers in any and all matters related to electricity. Hydro resource domain for electricity, ownership of services and legislative competence are all under the national government, including aspects of infrastructure, services and norms. It holds power to formulate laws, deliberate and monitor electricity generation and services. When it comes to hydro resources, even though these three dimensions are also under state control it is split between federative scales. Hydro resources are under national and state domain, with some legislative and monitoring capacities held at both levels. As a general rule, municipalities are competent to render and explore the services of water and sanitation. Many areas of the country do not have a local level with technical, financial and administrative capacities to develop services. The levels of supply and efficiency are very low, especially in the poorest regions as the Northeast.

The metrics and historical-institutional analysis make evident the critical interlinkages between water and electricity in terms of resource use, cascading negative impacts of reservoir depletion and river flow reductions in the context of historical asymmetries between water and electricity governance, regulatory framework, planning and policies. The findings from both methods were complemented by the empirical work split in a two-step methodology: questionnaire and semi-structured in-depth interviews. The questionnaire combined closed-response questions with open-ended questions to gather data about water and electricity integration, as well as nexus issues of increased importance in the views of experts in Brazil. The in-depth, semi-structured interviews support the collection of more detailed and thorough data on practical ways in which the stakeholders from these sectors collaborate on problem solving, how these collaborative decisions are taken and how the different resource uses are valued, including what participants consider crucial to advance the rational and fair allocation of resources. The interviews were conducted with experienced professionals from the executive, regulatory and legislative governmental powers working with water or electricity, including the intersection of both. The empirical data supports conclusions about the historical capture of hydro resources by electricity sector.

All the methods were combined into a single framework that entails the SGS, water-electricity nexus and normative-institutional perspectives (**Figure 1**). Triangulation is used for the analysis of the results, so the conclusions and strengths of the findings of each method supports the eventual limitations of the conclusions provided by the others. The limitations of the metrics to provide evidence about the legal architecture in which resource conflicts emerge were supported by the findings of the historical-institutional analysis, and both were further complemented by the results of the empirical data. The latter includes findings about governance shortcomings, policy, and regulatory asymmetries, as well as legal issues. Analyzed and interpreted in light of our water-electricity nexus framework, regulatory theory, governance, procedural environmental justice and policy coherence, these methods support the same conclusion: In the current context of asymmetries between water and electricity there is a risk that a new interpretation of the law required to address resource nexus complex conflicts will end up subordinate to the mandates and imperatives of the most developed, technically robust and strongest of the three sectors in Brazil (water, WASH and energy), which is electricity.

ANALYSIS AND RESULTS

The water-electricity nexus conflicts in Brazil are aggravating with more severe and recurring droughts in the context of climate emergency, combined with weak resource nexus governance, mismatches in water and electricity planning, distinct levels of sectoral regulatory maturity, policy asymmetries, regulatory capture and environmental injustices. In the São Francisco basin, trade-offs are made between storing water in dams in benefit of electricity security and affordability, and dispatching water downstream of hydropower developments in benefit of multiple water users and ecological flow. These trade-offs happen in the context of high risks of total reservoir depletion, energy insecurity and rising electricity costs. For example, the dam of Três Marias hydropower plant in the São Francisco would have been entirely depleted by August 2014 if no reduction of its dispatch levels had occurred, including below the levels set under the environmental permit (Senado Federal, 2015). The latter affects water quantity and quality downstream of dams, with negative cascading impacts, including on levels of water salinity, WASH suppliers, riverside communities, fisherman, agriculture and transport sector (**Figure 2**). In the São Francisco basin, the WASH sector had to do more investments in infrastructure affected by salinity levels of the water at the same time it had to fetch water from greater distances due to reduced water quantity and quality (Carvalho and Spataru, 2018). Communities are experiencing high blood pressure due to water salinity levels, especially in areas closer to the river mouth because of the weak river flow on arrival at sea (Landoli, 2017). Torres (2015) suggests that around 250 km of salt intrusion has occurred and collected the views of riverside communities who claim to be "living thirsty in front of an oasis" (ibid).

The reduced levels of water under reservoirs not only in the Northeast electricity subsystem, but also in the Central-Southeast and South means that more expensive thermal power plants are required to attend demand, increasing the marginal operational costs of the electricity system (Carvalho et al., 2019). Electricity security and affordability are at stake with impacts on the energy sector and on electric intensive sectors like WASH (ibid.). At national level, for example, the WASH sector reduced its overall electricity consumption during the severe drought year of 2015, but their total electricity costs were still 50% higher than in previous year (Brasil, 2018; Secretaria Nacional de Saneamento Ambiental, 2018). The analysis of the balance sheets of each WASH company operating in the São Francisco basin support conclusions about their rising debts toward electricity providers during severe drought years, which in some cases doubled (Carvalho et al., 2019). Moreover, one of the interviewees flagged

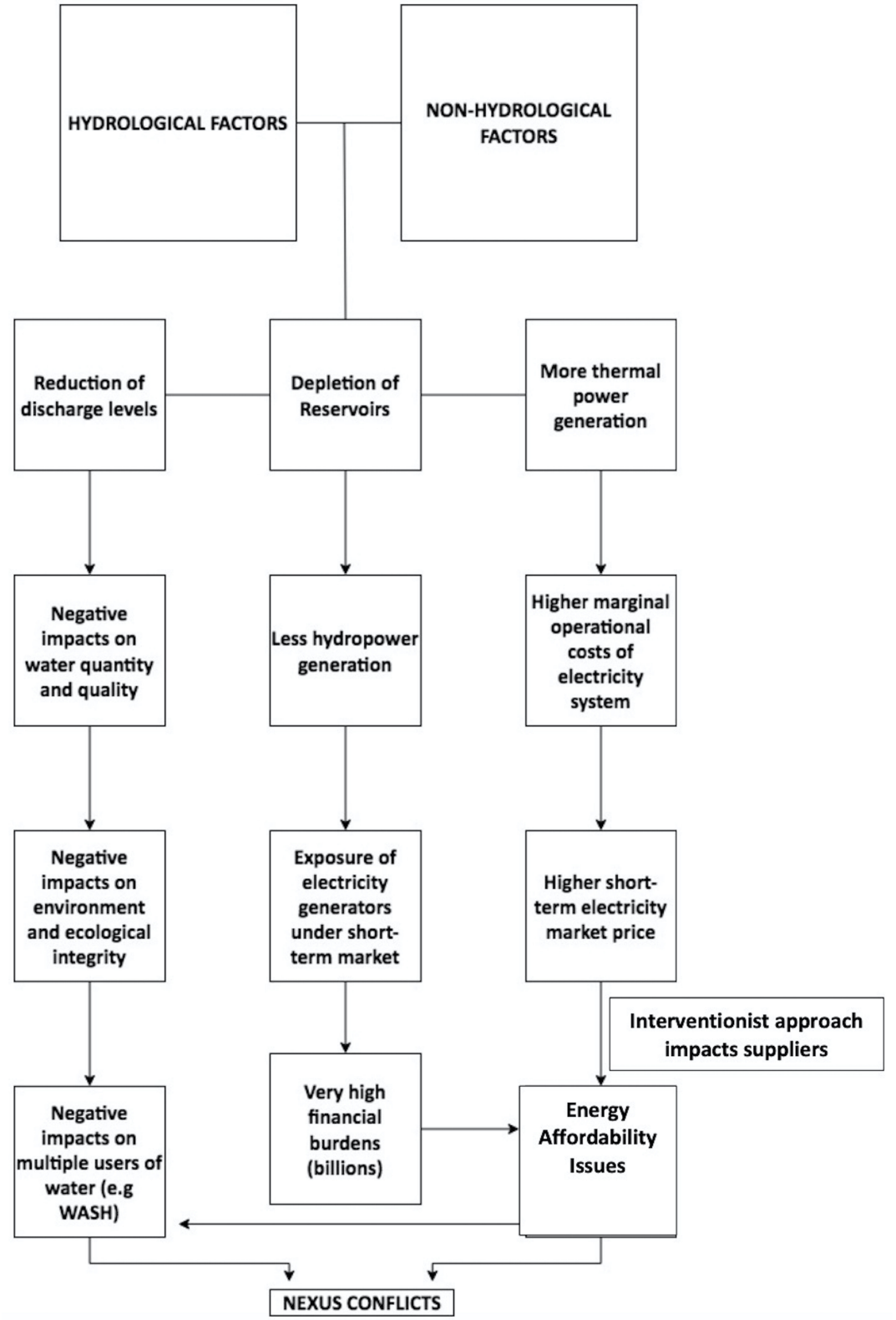

FIGURE 2 | Cascading impacts of water-electricity nexus in Brazil.

out that "electricity costs represent 70% of the overall costs of the inter-basin water transfer project in the São Francisco, which is currently passed on through tariffs, so end-users pay not only higher electricity bills, but also higher water bills due to the rising electricity costs included in it." The situation is only aggravating with less water available for electricity generation. At national level, hydropower producers repeatedly generated less than their total assured output due to water stress. Consequently, they faced exposure under the short-term market and had to buy the missing electricity when the spot price hit its peak in 2013/14. The high losses (bn) and regulatory instability led to high rates of judicialization and significant increase in electricity prices. Moreover, the increased dispatch of thermal power plants to attend demand, including outside the economic merit of energy models, also led the rise of retail electricity price from 2013 onwards. The interventionist policy approach of the national government in 2012 (Provisional measure 579/2012 converted to Law 12.783/2013) aggravated electricity affordability even further, with exposure of suppliers under the short-term market when spot prices also reached its peak, and high costs that are also being transferred to consumers.

The rising costs of electricity in the context of reduced water quality and quantity do not support advances to the goals of affordable, sustainable and clean energy, neither does it help the goals related to hydro resources and WASH. Water-electricity nexus conflicts and challenges will continue growing in frequency and scale, which raises many questions about the suitability and robustness of the existing governance approaches to manage the resource nexus conflicts. Given that metrics fail to capture important aspects of water and electricity governance, regulation, policies, information and knowledge, as well decision-making processes involving disputed resources, the results of the historical-institutional analysis, questionnaire and in-depth interviews provide further knowledge about the challenges depicted by the metrics.

Asymmetries Between Water and Electricity Regulation

There is a common understanding between participants of both the interviews and questionnaire that electricity, hydro resources and WASH are regulated differently, and the sector facing the most severe regulatory gaps is WASH. Electricity is regulated at national level, hydro resources are regulated at national or state levels depending on the water domain, and WASH is regulated at municipal level. A recently edited law (Law 14026/2020) has expanded the competences of the national water regulator to regulate WASH. Electricity, hydro resources and WASH are not only regulated under different scales and powers, but they also follow different regulatory rationales. Electricity has experienced a regulatory intervention premised mainly on economic rationales to tackle market failures and foster competition, while water services and sanitation continue to be under state monopoly and lacks a robust regulatory framework, security of supply and efficiency. Hydro resource regulation focuses on guaranteeing access to multiple water users through decentralized and participative management. Contrarily, electricity is highly centralized and counts with a national market and a national reference price known as "preço de liquidação de diferenças–PLD." Competition exists for electricity generation and trading activities, and despite discussions of modernization of current regulatory framework, the supply is still subject to network natural monopoly and consumers cannot choose their suppliers. There is an independent regulator with more than 20 years of experience, which has dealt with multiple challenges such as the rationing of electricity 2001 and the governmental interventions of 2013. The levels of regulatory maturity and experience of the electricity regulator in relation to hydro resources and WASH regulators are higher. The powers which that national regulatory has been granted to regulate WASH means it will need to broaden its area of action and expertise, but this is still in initial stages of development.

WASH is marked by low tariffs (most of which do not cover the costs of services) and very high levels of inefficiency. Despite the enactment of the Law 14.026 of 2020 that aims to create a more robust institutional and regulatory framework to attract investments and minimize risks, WASH still needs to give the first steps to universalise its essential services. The business model is not very clear and there is no profitability, which is even more challenging under the existing pulverized regulatory context. There are 49 regulatory agencies, of which 23 are municipal agencies, 23 are state agencies and the remaining 3 are inter-municipal agencies (Ceri and Bid, 2018). Today, it is clear the regulator is far more worried in developing a more robust regulatory environment to attract investment than in tackling market failures connected to natural monopolies, which is an aspect the electricity sector has advanced. Considering a strictly pragmatic scale approach to the regulatory developments of electricity and water in Brazil, where a first step would be to secure minimum access to resource and services, the second step would be a regulation based economic rationales, and a third step, a regulation based non-economic rationales—neither of the sectors have guaranteed all three yet. However, the electricity sector is the closest to achieving them. It provides the most universal service in Brazil and counts with the most robust economic regulation of these sectors, but the non-economic bases for regulating in the public interest (e.g., environmental protection and water conservation) still plays a subsidiary role. Its main concerns are still related to the second step. Contrarily, hydro resources regulation has mainly advanced on non-economic rationales, with decentralized and participative governance as main aim, but it still lacks advances on the second (economic regulation) step. WASH is the least advanced in three aspects.

Asymmetries Between Water and Electricity Planning

The multi-leveled approach to hydro resource governance has resulted in multiple plans at national, state and watershed levels. They have different timeframes, objectives (general vs. specific), overlapping areas of implementation, distinct funding streams and different management bodies that count with different administrative, financial, and technical capacities

(OECD, 2015). The lack of coordination makes it hard to align water plans with other sectoral plans such as electricity. According to one interviewee from electricity sector, there are some attempts in trying to build bridges between "Empresa de Pesquisa Energética–EPE" (electricity planning body) and the water regulator, but many uncertainties remain about the best way to formalize an integrated agenda, including the level of government. Today, the water regulator steps in at a stage when the hydro powerplants are almost at their operational phase, which is considered too late. This siloed approach to planning compromises sustainable resource management.

Asymmetries Between Water and Electricity Information and Knowledge

Despite the split views about levels of integration/non-integration of water and electricity information and knowledge, most participants agree there is a lack of data for water and a lack of robust integrated databases for electricity and water. Since the start of industrialization, the national government focused its administrative, technical, and financial resources to develop the electricity sector, which led to the gradual construction of a national database for electricity. Under the constitutional periods prior to 1988, there were regional water division districts studying water regimes on the ground, but with a focus on its use for hydroelectricity. Interviewees confirmed that it is common for watersheds to have most of its hydrometers in strategic points for electricity, instead of taking a whole-basin approach. Today, the electricity sector counts upon a special committee to manage information of the electricity sector, aimed at guaranteeing integration, coherence and quality of information and statistics for electricity policy formulation. For hydro resources, at national level, the water regulator is responsible for implementing and managing the national information system, while at state level it varies—in some cases it is under the competence of a state regulator or under the secretariat of environment. However, the information systems are not well developed at state level and there are yet desired levels of transparency of available data (OECD, 2015). Consequently, the current state of art does not support the consistent and robust development of knowledge and information about the actual state of resource use. The lack of information about real state of resources is an accountability gap (ibid.). It has direct impacts on water-electricity nexus decision making processes. Evidence shows that the electricity sector has a strong capacity to influence decision-making because of its better developed information and knowledge, as well as technical capacity.

Water and Energy Policy Coherence

For hydro resources there is a national hydro resource policy and a policy per state, for WASH there is national sanitation policy, while municipalities are responsible WASH policies at local level. However, most municipalities are not able to develop or implement their policies due to lack of funds and capabilities. For electricity there is not one general policy, but multiple scattered laws at national level. The national energy policy focuses on oil and gas but contains the general principles and objectives applicable to the electricity sector (e.g., affordability, security, and sustainability). Other relevant policies that go beyond the individual sectors include Brazil's environmental policy and climate change policy. In general, there is a lack of coordination between different policies horizontally and verticially. Asymmetries are discussed in the next subsections in relation to certain water and electricity policy objectives, instruments and implementation. Policy coordination challenges are also connected to the disparate institutional capacities of each scale and sector. Moreover, considering that earlier policies were not designed to deal with problems such as climate change it may also help explain the little coordination amongst them. In the context of policy analysis, Nilsson et al. (2012) developed an analytical framework to assess policy coherence, with rationales that have been adapted to this study. Our main objective is to examine two of the main policies of the two sectoral domains, so that asymmetries, conflicts, and gaps are identified (**Table 2**). The latter is done following the steps informed under **Table 3**, considering the layers of analysis provided under the framework developed by Nilsson et al. (2012).

Water and Energy Policy Objectives Asymmetries

Water conservation, multiple uses of water, or the rational use of hydro resources are not reflected in the government's energy policy objectives. However, water intensive sources such as hydropower and biomass are key for energy security in Brazil. Biomass was added as policy objective of energy in 2011. A water intensive electricity sector can challenge some of national and state policy objectives regarding multiple uses of water at different scales, specially under watersheds marked by resource stress and increasing nexus conflicts. Without water-related objectives and expansion of mandates to safeguard multiple water uses, the energy sector will mainly address its policy objectives of energy security and affordability when managing hydropower dams. Given it is a sector that counts with more robust and better developed databases, including larger technical body and capacity to guide resource nexus discussion and influence its results, procedural environmental justice issues need to be considered. To some extent these issues were confirmed in the São Francisco, according to interview extracts:

> *"The main reason the electricity sector wanted to reduce water discharge levels of hydropower was to safeguard water under reservoirs thinking about their interests, their needs, and ways of keeping water levels for their use. This was their original interest."*
> *"The water regulator got people around a table, but the electricity sector brought its demands to reduce discharge levels based on its planning and management of its own risks. The electricity sector is way more organized than other water users."*

The hydro resources policy requires that in situation of scarcity the priority in water allocation should be given to human and animal consumption. However, it has no specification on how other users should handle the shortage. One of the interviewees from water sector has confirmed that this is a "bottleneck of our policy flagged out in planning documents, as there is a need to advance issues of setting priorities in

TABLE 2 | Framework for assessment of water and electricity policy asymmetries.

Policy dimension		Scale dimension	
		Horizontal	**Vertical**
External (different policy domains)	Water-electricity nexus	National electricity policies in relation to national hydro resource policies and vice versa	National electricity policy in relation to state hydro resource policy and municipal policy for water services and sanitation
Internal (single policy domain)	Water	National hydro resource policy in relation to national sanitation policy and national solid waste policy	National hydro resource policy in relation to state hydro resource policy
	Electricity	National electricity policy in relation to national electricity efficiency policy	Not applicable

TABLE 3 | Steps to assess water and electricity policies asymmetries.

WE policy interactions	Steps
Objectives	1. Are there any water-related objectives under the national energy policy?
	2. Are there any electricity-related objectives under the national hydro resource policy, or national sanitation policy, or solid waste policy?
Instruments	3. Are there any key instruments under the hydro resource policy that supports the objectives of the national electricity policies?
	4. What key instruments of the national energy policy supports the objectives of the national hydro resource policy?
Implementation	5. What does the triangulation of the following datasets: (i) interviews, (ii) institutional historical linkages and (iii) metrics provide in terms of conclusion about electricity and water policy implementation?

the use of resources, because the law says the priority should be given to human consumption and animal consumption, but we need to advance to answer the open question: what about the other uses?" The latter uncertainties create legal insecurities and raises conflicts between users. The strongest, best organized, and most influential of the sectors, specially from an economic perspective, is more likely to lead and define the outcomes of the discussions, taking precedence in the use of disputed resources. Consequently, there is a gap that needs to be addressed by the policies. Under the São Francisco, the solutions were usually supply-driven, emergency-driven and industry-driven. Torres (2015) argues that, in practice, electricity generation was prioritized, with several negative impacts on local communities, which resulted in distributive and procedural environmental injustices. The latter is confirmed through the unfair distribution of burdens connected to resource stress, which affected the livelihoods of vulnerable riverside communities who were continuously excluded from decision making about use and allocation of scarce and stressed resources. The lack of effective cross-sectoral policy objectives does not support the fair and rational allocation of common-pool resources, especially in times of scarcity, raising risks of supply security and irreversible impacts on the environment. There are environmental injustices from both distributional and procedural aspects. Small riverside communities and WASH are not getting the resource in adequate quantity and quality levels, while their voice are underrepresented in decision-making. In general, the policy objectives have little coordination between them, which raises risks of implementation at different scales and spillover effects that one-dimensional sectoral policies usually have. This is aggravated by the fact that several managing institutions do not count with specialized technical body and different resource users have diverging views that challenge the governance of policy objectives (Jacobi and Barbi, 2007).

Water and Energy Policy Instrument Asymmetries

There are no explicit instruments under the national energy policy to support the rational and fair use of water resources by the electricity sector, or water conservation. Water regulatory charges apply to all other uses where these charges have been implemented at basin watershed level. They are the main instrument of the national hydro resource policy to support the rational use of resources. It does not apply to hydroelectric power producers, as electricity sector pays a flat fee of 6.75% as royalty for economic exploration of water, hydro resources, with funds that do not necessarily return to watershed being explored. Nevertheless, the electricity sector is highly dependent on water for electricity generation, which has a direct effect on drinking water availability in Brazil (Mercure et al., 2019). The main drivers for implementing the hydro resources policy instruments are connected to the implementation of these regulatory water charges, which first requires rectification of water uses (register, revision, and grants), drafting of water basin plans and the creation of water agencies before charges can be made operational. The funds return to the basin to support the execution of basin plans and help fund the water sector. However, the lack of its implementation in most watershed areas compromises sustainability, water plans, funding, control of pollution and the coordinated actions between different users. Stakeholders identified a variety of problems connected to water permits issued under basins without water charges implemented. There are many problems to estimate the correct quantity of resource use or needs based on existing permits. According to an interviewee from water sector:

> *"When permits are requested, users commonly ask to reserve a greater amount of hydro resource than what will actually be used.*

Where there are no water charges, the amounts of hydro resource reservation requested under the permits are extremely high."

Asymmetry and equity issues are raised in relation to the destination of funds. Given the royalty that serves as compesation for the use of hydro resources by the electricity sector do not necessarily return to the watershed being explored, those bearing the distributive burdens of such use are not necessarily benefitting from use of these funds. The royalty is managed by the national government and part of the funds are transferred to National Water Regulator, while the rest is shared between municipalities and states impacted by hydropower development, but with no track that these funds being returned to the basin being explored. From a water management perspective, the flat fee paid by hydropower should be revised to consider better issues of water availability, competition, and destination of funds (OECD, 2015). In 2019, 121 companies generated 338.092.198,86 MWh and paid R $1.813.919.287 as compensation for use of hydro resources (Carvalho, 2021). In 2020, 122 companies generated a total of 335.709.157,58 MWH and paid a total of 1.859.576.975,53 for compensation (ibid.). Between 2001 and 2018, hydropower producers paid a total 2,969 billion reais as means of compensation for the use of hydro resources in the São Francisco basin. Thirty municipalities within the basin are beneficiaries of these funds (Santos et al., 2020). The main issues of distributive justice are explained by an interviewee from water sector as follows:

"These funds do not return to the basin and no one knows how or where they are used. This is very different than what happens to irrigation and water projects such as the inter-basin transfer of the São Francisco. The latter pay for electricity, but also pays for water charges-12 million reais. This amount returns to the basin, but the royalty paid by electricity does not. It is a foggy instrument that needs greater clarity."

Water and Electricity Policy Implementation Asymmetries

Water and electricity policies are implemented in different capacities, rhythms, and scale. Whereas, for electricity it follows the top-down approach and is implemented at national level, with supply levels of electricity reaching almost 100% of the population. For hydro resources, the national and state policies have similar objectives and instruments, but they are implemented at watershed level in distinct ways. Most watershed committees (at national and state level) struggle to implement all of the instruments of the hydro resource policy. Only 40 out of 204 state watershed committees managed to implement all instruments, while four out of nine federal watershed committees have implemented all the policy instruments, including the São Francisco (ANA, 2015). Under federal basins such as the São Francisco there are additional challenges to implementation because of the asymmetrical management systems that coexist within the basin. The São Francisco river and its serving rivers counts with the national system and those of all states part of it: Minas Gerais, Bahia, Pernambuco, Alagoas, Sergipe, Goiás and Distrito Federal. These states have their own watershed committees for the management of its hydro resources and implementation of policy instruments at state level. Given that many rivers at state level feed the São Francisco, limitations faced at state level in implementing the instruments affect the São Francisco as well. Many states still need to implement their watershed committee, while many that have committees in place still need to implement most of the policy instruments. The National Council of Hydro Resources approved the federal water charges for the São Francisco watershed, but none of the states that are part of the basin, with exception of some areas of Minas Gerais, have implemented state water charges (Braga et al., 2008). This kind of asymmetry raises risks to the entire system (ibid.).

Managing Water-Electricity Nexus Conflicts in Context of Asymmetries

The fundamental oversight, policies, governance and regulatory frameworks of electricity and water are decoupled under multiple scales and two operational silos, which result in the asymmetries discussed above. At the outset of this research existing work suggested that the best way to improve effectiveness and efficiency of water and electricity disputed resource nexus was through integrative approaches to these sectors (Bazilian et al., 2011; Gain et al., 2015; Wallis, 2015). This seemed a logical area of focus for the questionnaire, before any solution-oriented legal approach could be developed. Stakeholders answering the questionnaire have different points of view in relation to electricity and water integration in Brazil, with 52.6% considering these sectors to be integrated, while 44.7% consider these sectors to be non-integrated, and 2.3% skipped (**Figure 3**). The participants from academic/research institution (16%) and professional consultancies (13%) represent the majority of the people that consider these sectors to be non-integrated (**Figure 4**). Most public stakeholders taking part consider water and electricity as integrated (**Figure 4**). This indicates that those working under governmental and regulatory bodies do not necessarily recognize there is a problem of non-integration, with infrastructure, planning, regulation and monitoring considered to some extent integrated by most respondents (**Figure 5**). It was important to investigate under the semi-structured interviews how these sectors are currently integrated and cooperating in practice, as well as the problems considered serious of fairly serious by those who consider sectors to be integrated (**Figure 6**). All interviews were conducted with public stakeholders and they provided the same example of existing integrative efforts: "Critical Events Room" (CER). The CER is a management instrument used in Brazil for situations where there is an emergency or urgent topic that requires deliberation between different governmental agents. Those participating in these discussions are usually representing the interests of the sector they come from. Different views are brought to the table for a decision-making process that should consider the multiple views and concerns. This governance tool has been implemented at national and state levels for the management of common-pool hydro resources since 2009. The CER for São Francisco basin

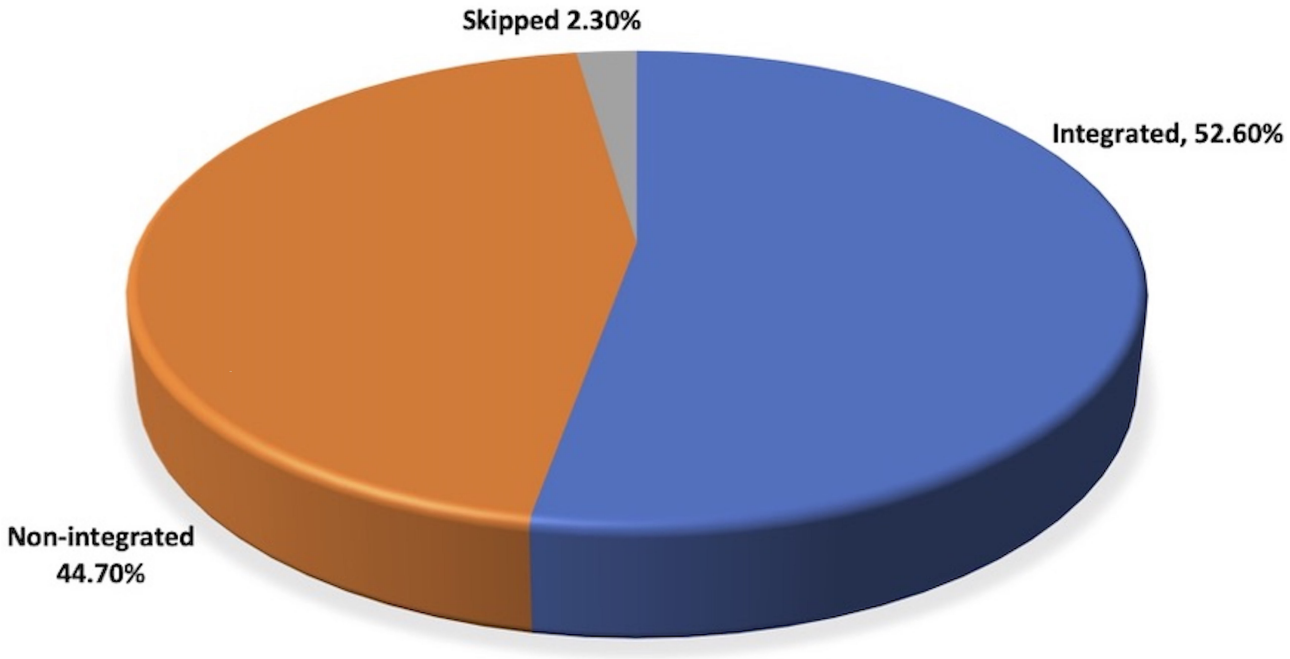

FIGURE 3 | Stakeholder perception on water and electricity integration in Brazil.

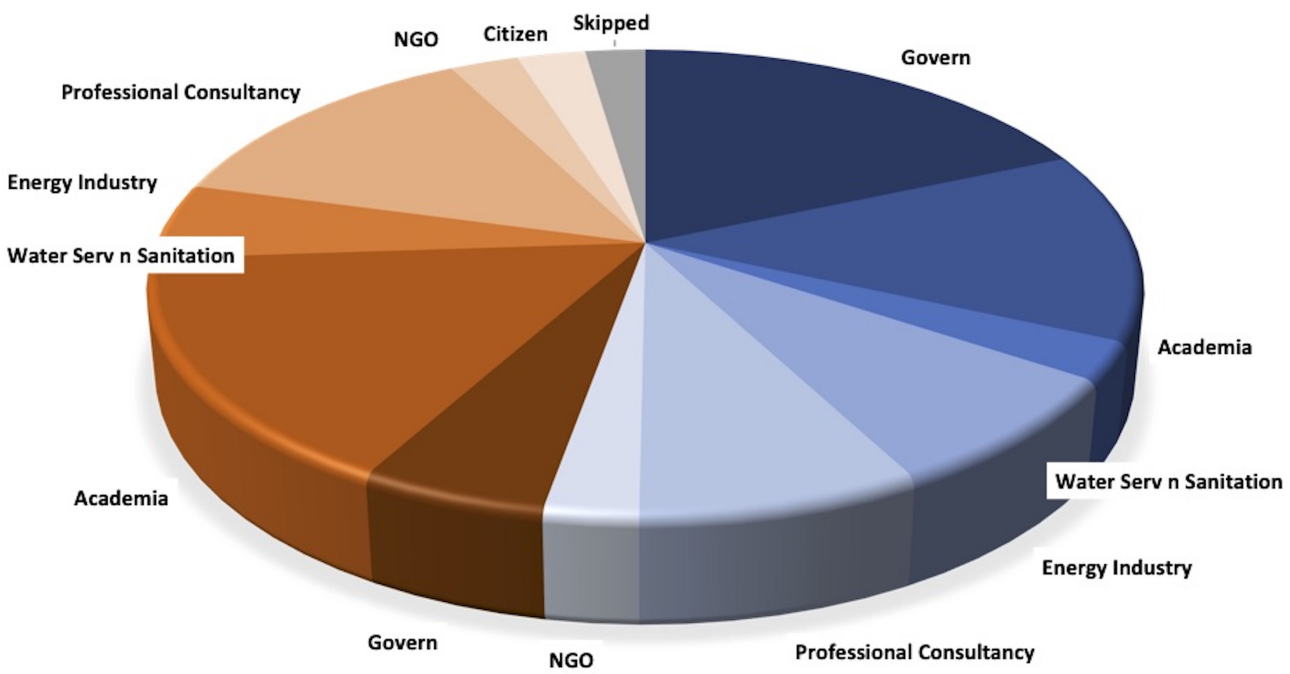

FIGURE 4 | Spread in stakeholder's views on water and electricity integration in Brazil.

was implemented in 2013 as temporary solution to manage the water-electricity nexus conflicts, amongst other resource nexus disputes. According to one interviewee, "the CER was created to tackle emergency situations through meetings with everyone around the table and where the most important decisions are taken and where the losses each sector will experience are evaluated to minimize its impacts as much as possible."

Even though this emergency-driven response was supposed to be provisional, in the case of São Francisco basin it has been kept in place since 2013. The latter can hardly be considered a

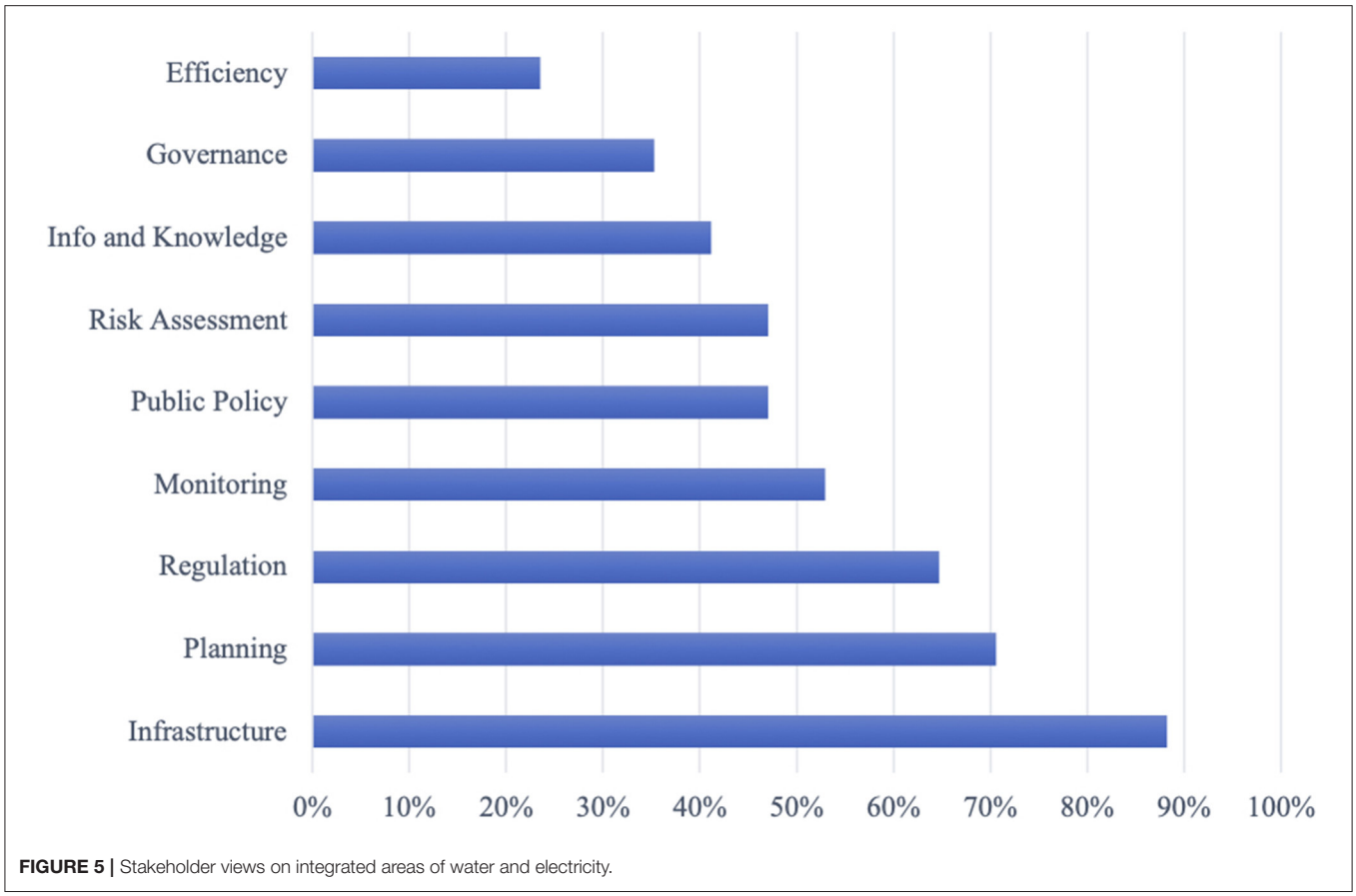

FIGURE 5 | Stakeholder views on integrated areas of water and electricity.

temporary action and for many years the management of hydro resources in the São Francisco is following a different approach to what is set under the national hydro resource policy. In many ways, the CER suppresses the competences of the existing watershed committee of the São Francisco basin responsible for managing resources in decentralized and participative manner, because it shifts the decision-making and planning environments to a different structure made up of less resource users and more concentrated powers and interests (Carvalho et al., 2019). A stakeholder from the electricity sector explains that "the critical events room takes away the role of watershed committees, but given they are supposed to be temporary, once they are over the watershed committee should have its competence re-established and serve as forum for relevant discussions." It is problematic that an emergency governance tool is seen by all interviewees as the main integrated approach to water and electricity. This example is characterized for being an exception and something that would not exist if the current legal framework provided the substantive, procedural and institutional frameworks to integrate sectors and manage high-impact resource nexus conflicts fairly.

However, the fact that an emergency governance solution has been maintained for several years to manage the water-electricity nexus raises many relevant points. First, where there is scarcity and objective tension between electricity and water there is no way of escaping an integrated discussion. Empirical evidence shows this governance tool was useful and very much needed, validating the views under the water-electricity nexus literature. However, in many ways it also indicates there is not much integration in the current governance set-up like some survey results suggests. As soon as a real issue of scarcity happened the existing governance structure was not able to respond to the challenges. It was necessary to create an *ad-hoc* solution. Lastly, it continues to be in place after many years because there is no other better structure capable of offering an integrated environment for discussions and solution to water-electricity nexus conflicts in fair and transparent ways considering norms and evidence. According to one interviewee, decision-making within CER is led by the national water regulatory body through coordination of different information and proposals for resource allocation presented by stakeholders from different sectors and government bodies. The meteorological body center (CEMADEN) presents estimates or precipitation levels for the horizon of a maximum of 2 weeks. The National Grid provides technical studies, estimates of dispatch levels and simulation for the reservoirs to determine their conditions in the end of each relevant rainy and dry period of each year. These technical information serve as guidance for companies to bring forward their positions and requests that informs the decision-making process. Procedural environmental injustices issues are raised to the extent that discussions are mostly guided and restricted to

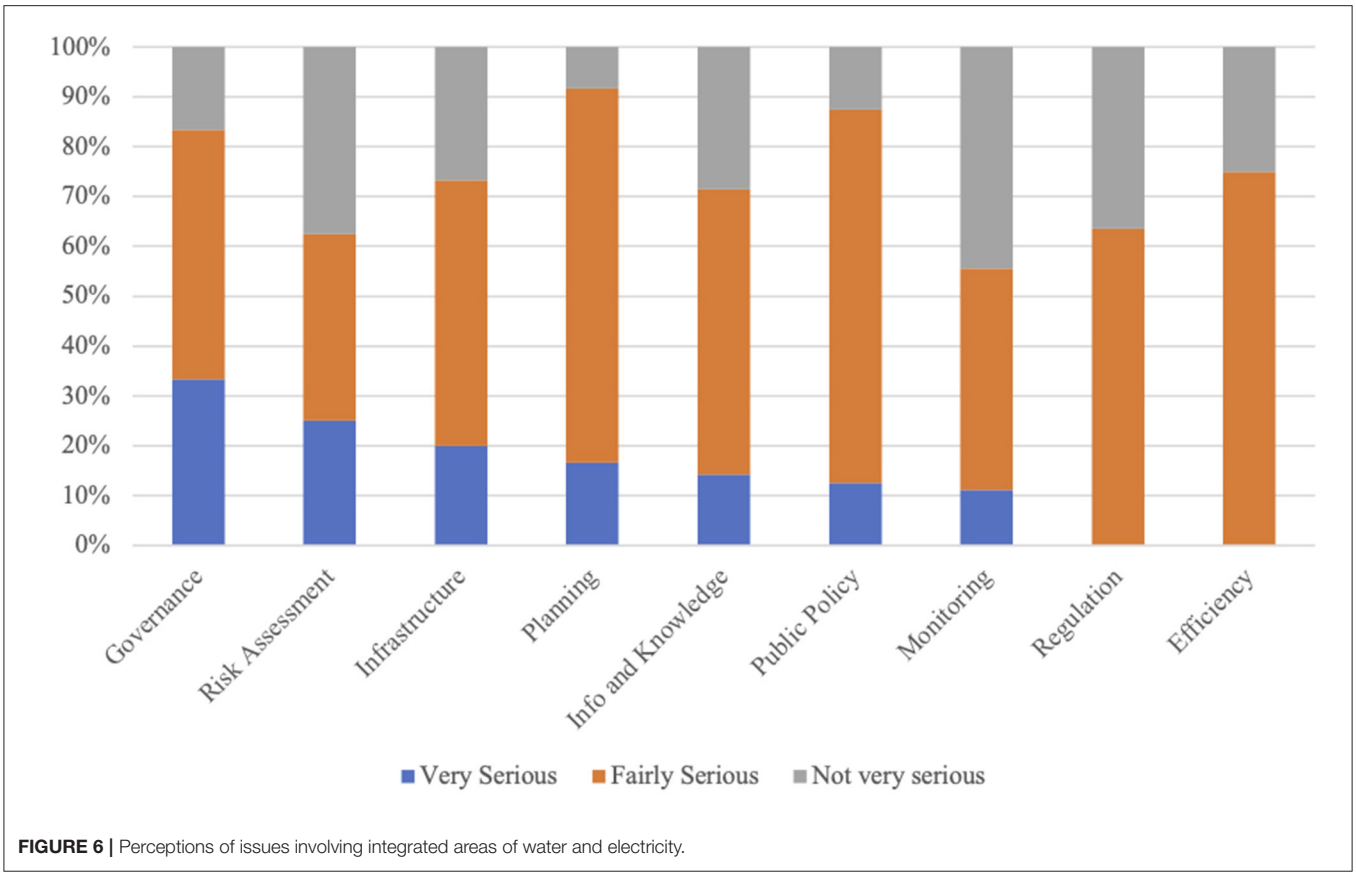

FIGURE 6 | Perceptions of issues involving integrated areas of water and electricity.

the strongest and better organized of the sectors, as confirmed by an interviewee:

> "*The water regulator gets the information from national grid operator to make the decisions. Everything comes from the electricity sector and the water regulator does not change. If national grid operator says discharge 500 cubic meters it will discharge 500 cubic meters, because the water regulator only replicates what national grid brings forward*."

Stakeholders representing the interests of water emphasize that decision-making process and management of water under the São Francisco are in many ways captured by the electricity interests. Accounts from the interviews show that national water regulator manages and leads discussions with aim of guaranteeing multiple water uses, but the electricity interests takes precedence. In the words of an interviewee from water sector: "what we can observe is that from a legal perspective the priority should be given to the supply of water, but from a practical point of view that is not what happens, because there is a lobby from the electricity sector." They go further to explain that "those that are better organized have an advantage because they have more information and are able to provide evidence for decision-making." The asymmetries between water and electricity information and knowledge analyzed above help explain the latter reality. It is not a surprise that in their words, "water users suffer, while the interests of electricity sector take the lead and the environmental interests are always kept behind in a begging position." The questionnaire results also confirm the very high influence of the electricity sector on water management (**Figure 7**). Although a few participants skipped this question, 53% chose that government authority in charge of electricity and electricity business have high to moderate high influence on water management (**Figure 7**). On the other hand, 71% consider electricity business to have the highest influence on electricity management (**Figure 8**). The concentrated interests and highly coordinated efforts of the electricity sector provides it with disproportionate influence and power over some regulatory decisions governing its activities. This confirms Stigler (1971) central hypothesis that the demand for regulation comes from politically effective interest groups. Electricity is a powerful interest group under the São Francisco basin and the regulatory decisions about water allocation in situation of resource stress affects its security, prices, services, and quality. Consequently, creating a natural incentive for it to influence the regulatory process (Baldwin et al., 2012).

Contrarily, representatives from the executive power responsible for the electricity sector argues they are managing hydro resources for its multiple uses, so that in their words "everybody wins." Further suggesting that "in reality, if analyzing from the standpoint of electricity sector, the probability is very high that it is bearing the highest costs." According to their

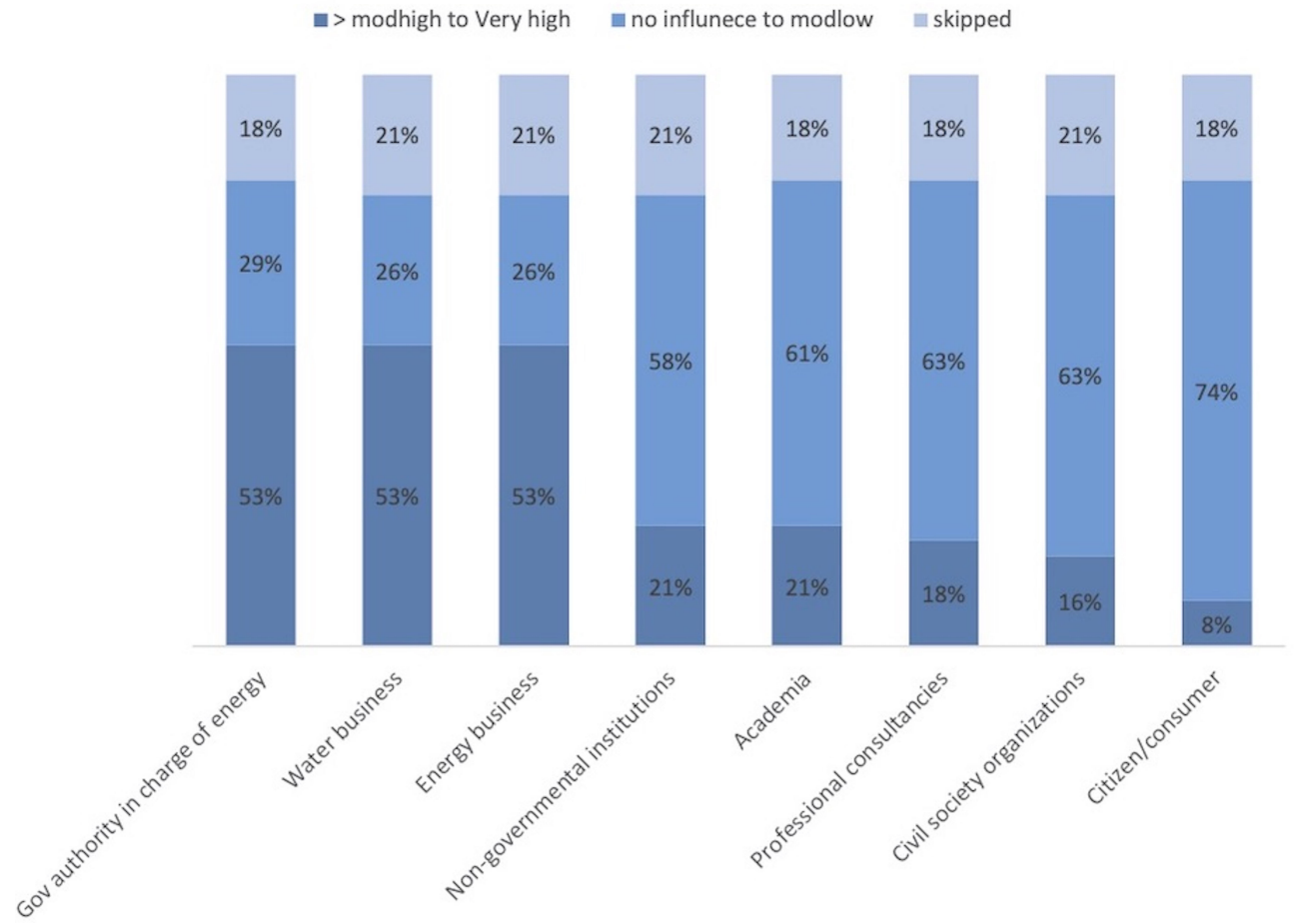

FIGURE 7 | Stakeholder views on non-integrated areas of water and electricity.

words, the "electricity sector can only be responsible for what it effectively impacts, so if different uses of water were planned considering a flow of 900 m^3/s and the river is not able to provide that, why should it be the responsibility of the electricity sector to adjust different water captures?" Considering that no other sector has influenced or can influence the river flow as much as the electricity sector through multiple hydropower dams in different watersheds, there are fair reasons to think why they should bear some responsibility for managing water for multiple uses. To a certain degree this happened in the São Francisco case, as findings show electricity sector helped safeguard some minimum levels for human consumption, even though the overriding and prevailing interests were those of the electricity sector, as explained by one interviewee: "this is to maximize the use of hydro resources, because whereas other users usually generate expense in the use of water, electricity generates revenues and this will always be the logic." These findings from in-depth interviews raises the importance of discussing double mandates when managing water-electricity nexus conflicts (section Discussion: Overcoming Nexus Conflicts with a Normative-Institutional Approach). If those invested with power to manage resource nexus disputes operate on single mandates of energy or water security, the conflicts between interests of individual sectors will continue on the rise and the strongest and better informed of the sectors will hold a favorable position to guide and inform outcomes.

Given interviewees confirmed this provisional governance tool serves as an environment for resource conflict resolution—"led by national regulatory for water, several hydro resource users met not only to deal with water storage under reservoirs, but to tackle conflicts emerging from water scarcity" —it certainly raises normative enquiries. The questions of who and what should be prioritized in terms of water and electricity resource allocation or services under different circumstances of resource stress and conflicts raise questions that should be answered in light of evident, but—as this research confirms—also in light of legal principles that potentially apply to different solutions of water-electricity nexus conflicts. The normative-principled approach is relevant and novel to advance the literature and close some gaps with respect to the theoretical assumptions of the water-electricity nexus. The process in which binding decisions are developed to determine how resource should be allocated in a given conflict is the same as developing a norm for that case, so the normative discourse is not an

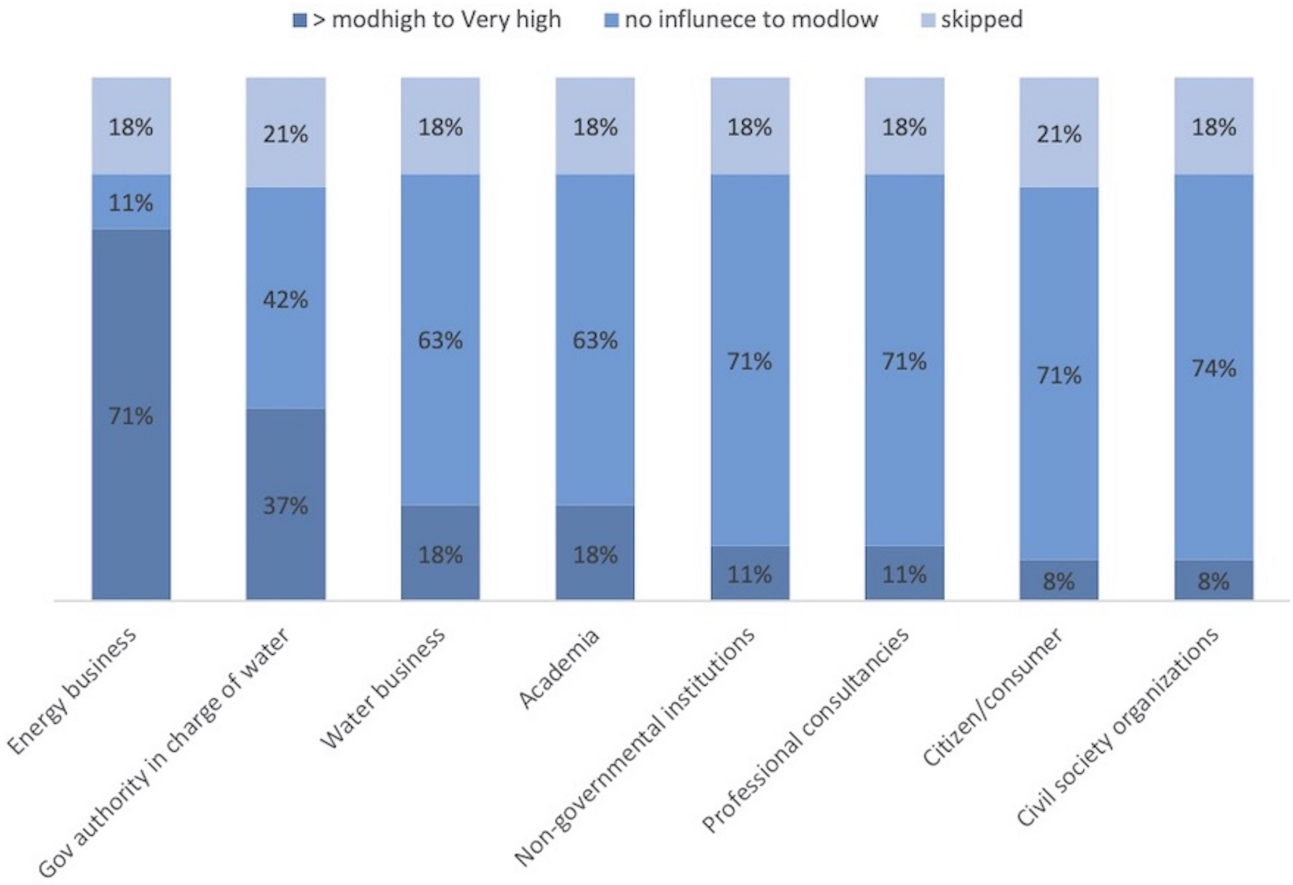

FIGURE 8 | Perceptions of issues involving the non-integrated areas of water and electricity.

optional one, but extremely necessary to advance solutions to water-electricity nexus complex problems more fairly in Brazil and elsewhere. Resource nexus conflicts are complex problems known to accept no definite or predefined solutions. Every case requires a thorough assessment and raises multiple questions and issues that should be answered on the basis of not only evidence, but also the several norms that might apply in each case. Every time an administrative, regulatory, judicial or legislative decision about any nexus issue can be justified by applying different legal principles, there is a collision of principles. When legal principles collide there are unavoidable costs emerging from the conflict of principle, so balancing becomes extremely necessary (Alexy, 2014). Under water-electricity conflicts like the one in São Francisco not everyone can win, as there are always costs and burdens, so questions remain about who bears them and to what extent those bearing these costs are currently participating of decisions affecting their livelihoods and being duly compensated. Some of the responses identified by this research reveal procedural environmental injustices and regulatory capture. Stakeholders representing the interests of water emphasize that decision-making process and management of water under the São Francisco are in many ways captured by the electricity interests.

DISCUSSION: OVERCOMING NEXUS CONFLICTS WITH A NORMATIVE-INSTITUTIONAL APPROACH

The way in which the water-electricity nexus is being managed under the São Francisco is more a result of necessity than of actual planning and organization. There are no transparent, rational, fair and inclusive methods for decision-making involving resource nexus conflicts. Many public authorities consider the decisions in the Critical Events Room to be successful because they prevented the total depletion of reservoirs and to some extent guaranteed multiple water uses. However, questions remain about the legitimacy of these decisions and how legal principles, such as intra-generational equity and participation were applied. The deeper knowledge and need to overcome the tensions between water and electricity resource use in the context of asymmetries and regulatory capture requires a new legal approach. The latter brings the discussion to the deficit of a normative-institutional dimension under the resource nexus literature. We fill this gap in the next subsections considering three dimensions: substantive, institutional and procedural. Through these dimensions we aim to provide a framework where

greater intragenerational equity is promoted with fairness and balance in access resources, in bearing environmental burdens, and in participating in decision-making.

Substantive Dimension

Considering there is no definite legal solution to nexus disputes, or the possibility of pre-defining the hierarchy between what uses should take precedence in every case, the latter should be answered considering facts, evidence and norms (legal principles and rules). The nexus literature focuses on sectoral integration, as well as the most efficient and cost-effective ways of solving nexus conflicts. However, it lacks to recognize that, counterfactually, and for normative reasoning, the result can be different. We develop normative-principled approach to the water-electricity nexus to advance the literature and close some gaps. Revealing the normative dimension is extremely necessary because of the nature and complexity of water-electricity nexus conflict. Whenever binding decisions need to be taken to determine who, what and how a given resource should be allocated, it pushes the nexus discourse beyond technocratic approach into a legal sphere.

Long-term and sustainable approaches to resource management require cross-sectoral decisions that address in its substantive dimension, the multiple legal principles that apply in each case (collision of legal principles). Legal principles are fundamentally malleable concepts (Scotford, 2017) that serve well the purpose of the nexus. They accept different levels of fulfillment and priority, with one taking precedence over the others under certain circumstances. However accepting this can also change to the extent that circumstances change too. **Table 4** contains a non-exhaustive list of legal principles extracted mostly from Brazil's Constitution that should apply to the water-electricity nexus and sustainable resource management. Legal principles are optimisation commands that should be applied to greatest extent possible relative to the factual and legal possibilities (Alexy, 2014). When principles collide, which we argue will be the case for some of the high-impact nexus conflicts, there will always be unavoidable costs, so balancing principles becomes extremely necessary. The normative dimension is what gives sense to the laws of balancing principles. Whereby a problem, such as resource conflict between water and electricity will be solved by determining a conditional priority of one principle over others according to the specific circumstances of the case. Ultimately, the water-electricity nexus can be translated into manifold collisions of principles. There are no definite and pre-established solutions, and every case requires a thorough assessment and consideration of both norms and empirical evidence, including legal and technocratic discussions. Where there are critical interlinkages and disputed interests, there are likely collision of principles to the extent that fulfilling the objectives of electricity affects the fulfillment of the objectives of water and vice versa, so meeting both them fully would not be possible. The procedures and rationales of weighing legal principles are key to address the water-electricity conflicts.

The laws of balancing and weighing principles developed by Alexy (2014) provides the variables that should be considered by decision-makers managing the water-electricity nexus and the multiple colliding principles therein. It is relevant for the São Francisco case in Brazil, because decision-making is currently happening without pre-stablished guidance, rational steps and consideration of some important variables and due reasoning that addresses all viewpoints and affected interests. Even though decisions have been successful in preventing important dams from total water depletion, they have been taken without confronting the collision of principles therein. Consequently, there are substantive and formal defects and legal flaws that raise legitimacy issues. Different legal principles may apply to solve a given resource nexus conflict, so they all need to be considered by those working on the solutions to these conflicts. In verified cases where multiple principles apply, collision of principles is unavoidable and the balancing of them rooted on the principle of proportionally is necessary for promotion of fair solutions. The latter has been developed by Alexy (2014) as way of making explicit the rationality behind the decisions of judges confronted with equally valid principles to solve a same case. The rational steps are based in the laws of weighing and balancing principles. This research proposes the use of Alexy's (2014) formula as a method for legal reasoning and rationalizing decisions involving resource nexus conflicts. On one hand it reserves a place for scientific evidence, but on the other it includes important normative variables which are also relevant to the nexus, especially considering its nature of wicked problem and recognition of limitations involving knowledge of shifting trade-offs. The variables, according to the law of balancing principles developed by Alexy (2014) are as follows:

$$\text{“}W_{p1,p2} = \frac{I_{p1} \times AW_{p1} \times R^{e}_{p1} \times R^{n}_{p1}}{I_{p2} \times AW_{p2} \times R^{e}_{p2} \times R^{n}_{p2''}}$$

These are important variables from both normative and factual perspectives that will need to be considered to support a more fair and rational allocation of resources in light of disputed interests. It follows the rationale that principles have a dimension of weight (Dworkin, 1967) and that each nexus dispute requires the balancing of different legal principles applicable in each case. Equally valid principles may lean the balance toward opposing solutions for a same nexus conflict. The overall weight of principles P_1 in relation to its colliding principles P_2 defines the principle that should take precedence as a result of the quotient of all three factors that define the weight of each individual principle: (I) intensity of interference; (AW) abstract weight; (Re) reliability of the empirical assumption; and (Rn) reliability of normative assumptions (ibid.). These variables need to be assessed for each individual principle before balancing them. I_{p1} and I_{p2} represent the intensity of interference of a given decision (e.g., reducing discharge levels) on P_1 and P_2, respectively. This way, if we consider that P_1 is hypothetically the principle of precaution, the question would be to what degree this principle would be affected by the decision of reducing discharge levels of hydropower. The conclusion may be that ecological flow

TABLE 4 | Non-exhaustive list of legal principles in Brazil applicable to the water-electricity nexus.

Legal principle	Description
Integration	It requires that policies integrate into them a high level of environmental protection from initial steps of decision-making procedures. Integrating environmental concerns and considerations of human wellbeing into development processes in under (Constitution, Art. 225). Through its two dimensions internal and external (at general level) it requires integrated approach to the regulation and management of electricity and water, making sure that electricity and water policies are developed together with environmental policy.
Sustainability	The use and management of resources in a way that promotes economic and social development without over-exploiting natural resources or causing irreversible environmental harms. Any citizen in Brazil has standing to bring a popular action to annul an act injurious (…) to the environment; except in a case of proven bad faith, the plaintiff is exempt from court costs and from the burden of paying the prevailing party's attorneys' fees and costs (Constitution, Art. 5, LXXIII).
Equity	Inter-generational equity refers to equity issues and access to resources between current and future generations. While intra-generational equity is the term used to refer to the equities between different community groups and stakeholders of a region, distributing the benefits and burdens of nexus resource challenges (Constitution, Art. 5)
Polluter-pays	Any action or activity of a person or a corporate entity that is considered harmful to the environment will result in criminal and administrative sanctions, despite the obligation to repair the damages (Constitution, Art. 224, §1 and §2)
Precaution	Scientific uncertainty should not preclude environmental protection measures (Climate Change Law and Biodiversity Law)
Participation	The right to participate of decision-making processes in environmental matters. The law shall regulate the participation under the direct and indirect public bodies, regulating access to information about governmental acts (Constitution, Art. 37)
Access to information	Everyone is assured the access to information, protecting the confidentiality of sources when necessary for professional activities (Art. 5, XIV); all persons have the right to receive from public agencies information in their private interest or of collective or general interest; such information shall be furnished within the period established by law, under penalty of liability, except for information whose secrecy is essential to the security of society and of the National Government (Constitution, Art. 5, XXXIII).
Access to courts	The law will not exclude from the review of the Judiciary any injury or threat to any right (Constitution, Art. 5, XXXVI).
Proportionality	The State cannot impose obligations, restrictions and sanctions to individuals which are higher than those strictly necessary to attend the public interest.
Effectiveness	Requires that any measure or decision selected (amongst the opposing measures or other alternative ones) is proven objectively effective (in other words, is able) to satisfy the norm.
Efficiency	Any chosen measure or decision should be the least restrictive, onerous, or severe when complying with norms (Constitution, Art. 37).
Proportionality strict sense	Requires that a measure or decision that is proven adequate and necessary (in other words effective and efficient) produces a gain in the fulfillment of the principle with a higher weight in a concrete case (Constitution, Art. 37).

may suffer irreversible harms with many impacts to biodiversity and preservation of life. Consequently, the intensity of the interference with P_1 would be considered serious. Alexy (2014) considers there are light (L), moderate (M) and serious (S) interferences by using values of an ordinal scale to assign levels of intensities of interference: L = 20(1); M = 21(2), S = 22(4). AW_{p1} and AW_{p2} refers to the abstract weight of P_1 and P_2. It is abstract to the extent that the hierarchy is given by the norm. Constitutional norms and/or fundamental rights have the highest weight under legal systems. The last factor, reliability, is about the trustworthiness of the normative (R^n) and empirical (R^e) assumptions. They are classified, according to Alexy (2014), as "reliable" or "certain" (r), "plausible (p), and "not evidently false (e), to which the numbers 2^0, 2^{-1}, and 2^{-2}, that is, 1, ½, and ¼ are assigned, respectively (ibid.). When the epistemic value is 1 it does not affect the other two variables, but when it is lower than one it reduces their values accordingly. The reliability factor is extremely important to the analysis of the intensity of the interference with P_1 and P_2. It serves to check the degree of certainty about the assumptions involving the facts, and the assumptions related to the existence, validity, meaning and extension of the norms applicable in each case.

Decision-making that considers all variables will provide a more robust reasoning of why and how under specific circumstances a given principle is taking precedence over others in defining the solution for the allocation of resources or nexus conflict. The idea of enhancing the rationality of decision-making about water-electricity nexus wicked problems is not to develop a legal metric where there already exist scientific ones, so this is not what is being proposed under this research. The proposal behind the use of Alexy's balancing laws and weight formula is to introduce a legal rationality for decision-making involving resource nexus conflicts. From a normative perspective, it is not possible to exclude any of the equally valid legal principles that would apply to different nexus conflicts. On the other hand, Alexy's rational legal method of balancing principles reserves a space for scientific evidence like no other author discussing the balancing of principles has considered thus far. Accordingly, evidence is an element that should be extensively analyzed together with the applicable norms of each case, accounting for a reliability element that requires a thorough consideration of both normative and scientific assumptions. As a rational method for decision making that balances principles in connection to evidence, it is an appropriate method to manage the complex nature of water-nexus problems by considering norms, facts, normative reasoning and justice aspects. Those involved in the decision-making process about resource nexus conflicts should be forced to confront and explain the variables

and principles being balanced when developing solutions. The lack of pre-stablished procedures means that very little is known about all the rational and normative reasoning behind every decision. This was clear when one of the interviewees from the electricity sector avoided detailing the reasoning and all the specific variables behind the decision that reduced discharge levels to the lowest levels of 550 m^3/s, arguing it was "out of the scope of the present research." It is important develop clear legal specifications about the rational steps that should guide these decisions. A new interpretation of the law that recognizes the resource nexus and includes everyone affected under decision-making procedures is key. Even though in vast majority of cases the solution will likely end up following the most efficient and cost-effective result, this will not be true for all possible water-electricity nexus conflicts due to normative reasoning.

To the extent that managing the nexus is a balancing exercise and Alexy's theory provides the rational steps of how this is done, it provides the specific elements and steps that can help avoid voluntarism when allocating disputed common-pool resources. The lack of consideration of any of these elements, like it has happened thus far in the São Francisco raises risks of perpetuating decisions that lack due reasoning and due legal process. From an institutional organizational perspective, the rationale is to keep the existing water and electricity structures working toward solutions they can promote individually, but also develop a new second-degree environment that exists permanently, but acts in selective and subsidiary ways to manage relevant nexus conflicts through these rational steps of balancing principles. This new institutional environment builds on the strengthens of the "nestedness" approach of polycentric approach discussed by Ostrom (1990). Multiple authorities and stakeholders would manage the conflicts involving water and electricity common-pool resources.

Institutional Dimension

Even though a drastic "administrative reorganization" could effectively be counter-productive and should be avoided, there are other normative-institutional alternatives which can tackle the conceptual, normative, organizational and procedural deficits of nexus discourse. The recommendation is to develop an institutional and organizational structure of second degree. This means it is distinct and autonomous from the existing water and electricity institutions in which authorities are currently invested in power to manage and regulate water and electricity. It would operate in selective and subsidiary ways when a given matter or conflict involving water-electricity nexus is relevant and not possible to be considered by individual institutions of water and electricity. The existence, composition and functioning aspects should be disciplined by the law, but its operation should be in selective and subsidiary ways. When demonstrated that the nexus between water and electricity is specially affected by a certain matter, conflict or concrete case that cannot be adequately considered by the autonomous institutions regulating water and electricity and their ordinary procedures, instruments, and norms, it would trigger the action of this autonomous body. This competence needs to transcend the individual sectors of water and electricity and its decisions should be binding to all sectoral authorities. To overcome the limitations related to the sectoral mandates, resources, information, and expertise of existing institutional bodies, it will be important for the second-degree body to have a double mandate. Considering the nexus does not accept definite solutions, the balanced decisions relative to the actual conditions of a given case need to be inductive and provisional.

Procedural Dimension

The procedures for decision-making under the second-degree institutional environment should be inclusive, in-depth (consider several principles), transparent, and fair by following a multi-level, cross-sectoral and multi-stakeholder engagement. The legitimacy of its results is dependent upon the effective consideration of all the points of view of those impacted by the decision, or those that influence, or can influence the decision. Participation is important to guarantee not only the legitimacy of decisions, but also its binding effects. It is only through broad participation of multiple stakeholders that a fair and equitable process can be guaranteed to observe due legal process, full defense, and equity principles. A decision that does not consider all points of views of interested parties is questionable from ethical and legal perspectives due to its deficit of opinion. These relevant opinions go way beyond empirically evidence-base findings on trade-offs. The more participative and transparent the broader will be the discussions and the better informed will be decision. In the case of water-electricity nexus in Brazil, conflicts that are characterized by the collision of legal principles, should be solved with due consideration of views of riverside communities, non-governmental agencies, WASH companies, small- and large-scale farmers, fisherman, transport sector, hydropower producer, governmental representatives from all scales, environmental body representatives, environmental activists, women, youth, workers and trade unions, business and industry, science and academics.

CONCLUSIONS

Our research establishes an important and comprehensive evidence base on the use, impact and management of common-pool resources in Brazil, with a focus on the São Francisco watershed. It is a genuinely interdisciplinary research based on extensive empirical work linked to painstaking and thorough legal and regulatory theory, with invaluable impacts. The research found that water and electricity are critically interlinked at resource use level, with resource stress and scarcity that led to reductions of hydropower dispatch levels and hydropower generation with negative impacts to both sectors, including environmental injustices. The impacts were found to occur in the context of collision of legal principles and many relevant asymmetries between water and electricity governance, regulation, planning, information and knowledge and policies, increasing the complexities to manage resources fairly and overcome the precedence of the services electricity in relation to these aspects.

The legal approach taken for the discussion of the results, advances existing knowledge by adding an original normative-institutional dimension to the water-electricity nexus, which offers a flexible, integrated and adequate legal treatment to manage water-electricity nexus conflicts. Split in substantive, institutional and procedural dimensions this approach is necessary to enhance participatory and equitable resource management based on the laws of balancing principles through fair, rational, inclusive and transparent procedures, which can address different dimensions of resource nexus. It was concluded that for water-electricity nexus thinking to be connected to the idea of integration it will be necessary to consider procedural and distributive justice in order to advance the Sustainable Development Goals fairly. The interdisciplinary expertise and knowledge developed under this research is key to help advance different ways of dealing with the grand challenges related to sustainability in the context of climate change, resource scarcity and rising resource conflicts. Considering that water-electricity resource conflicts are aggravating both in terms of intensity and frequency, there are several beneficial impacts of this research outside academia. By developing a dynamic, rational and inclusive method for better integrated decision-making between sectors, this research supports participative, legitimate and fair solutions to cross-resource disputes. The latter represent an immediate and central interest to users of common-pool resources, institutions managing resources, policy-making bodies and NGOs. The result has been a substantial contribution to the debate on resource governance and its intractable challenges in the context of Brazil.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because all transcripts are kept anonymous and confidential. Further information can be requested from the corresponding author.

ETHICS STATEMENT

The study involving human participants were reviewed and approved by UCL Energy Institute. The participants provided their written informed consent to take part in this study.

AUTHOR CONTRIBUTIONS

Both authors contributed to the article and approved the submitted version.

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