Hydropower policy in Ecuador: An analysis from environmental perspective and recommendations for future policymaking.

Andrei Briones-Hidrovo[a,b], Javier Uche[a], Amaya Martínez-Gracia[a]

[a]*Research Centre for Energy Resources and Consumption (CIRCE) - University of Zaragoza - Campus Río Ebro, Mariano Esquillor Gómez, 15, 50018 Zaragoza, Spain*

[b]*Centre for Environmental and Marine Studies (CESAM), Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal.*

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Renewable energies are vital to tackle climate change and reduce environmental issues. In this sense, hydropower plays a key role. Broadly speaking, hydropower is perceived as a climate ally and considered environmentally sustainable. However, its development is still controversial due to the well-known environmental and ecological impacts that put its environmental sustainability in question. In this sense, this study aims to analyze and discuss hydropower development and policy in Ecuador from an environmental perspective. The analysis addresses the research question of to what extent the business-as-usual hydropower policy is compatible and consistent with national environmental sustainability and *Buen Vivir* (Good Living) goals. For such purpose, the analysis is conducted by applying a proposed conceptual framework composed of critical elements such as Buen Vivir principles, rights of nature and the evidence on the environmental sustainability of hydropower. The analysis highlights the main environmental drawbacks of the BAU-HP policy and finds that the current development and policy of hydropower is ultimately detrimental to achieving national environmental sustainability and *Buen Vivir*. Moreover, it easily infringes the Rights of Nature and conflicts with the conservation of ecosystems and biodiversity. Following the findings, several environmental sustainability-oriented recommendations are suggested for future hydropower policymaking.

Keywords: Hydropower, environmental sustainability, Policy, Buen Vivir, Ecuador

1. Introduction

Hydropower is generally considered a climate ally and a strategy to reduce GHG emissions, putting it this way at the core of energy transition worldwide. Likewise, hydropower is commonly perceived as one of the most environmentally sustainable energy systems, regardless of size and scheme (e.g., (Atilgan and Azapagic 2016; Santoyo-Castelazo and Azapagic 2014). Such reasoning lies behind common national climate and energy policies (e.g., Asher and Bhandari, 2021; Berga, 2016; Kelly-Richards et al., 2017), which are aligned with global sustainable development goals (United Nations 2020). Moreover, the depletion of fossil energy resources and the need to meet present and future energy demand, have equally boosted hydropower construction since the beginning of this century (Zarfl, Lumsdon, and Tockner 2015).

To a lesser or greater extent, those countries with hydropower potential have bet on this low-carbon energy source, supported by their national policies. Examples of this can be seen widely in the literature (Erdogdu 2011; Wagner et al. 2015; Y. Li et al. 2015; Tang et al. 2019; Blanco et al. 2017; Tundisi et al. 2014). For instance, Austria has been developing hydropower largely since last century, and it is now almost fully developed (Wagner et al. 2015). Countries like China and Turkey keep increasing their hydropower capacity (X. zhu Li et al. 2018; Erdogdu 2011). These countries added 13.76 GW and 2.48 GW in 2020, respectively (IHA 2021). South America, Colombia, Brasil, Peru, etc., have likewise been planning and developing hydropower in the name of energy transition and sustainability (Morales et al. 2015; Tundisi et al. 2014; IHA 2021).

In particular, Ecuador has followed the worldwide hydropower development vision (Carvajal et al. 2019). Hydropower development has been massively boosted in the last 15 years thanks to a radical shift in energy policies, putting it at the core of energy policy for diversification and changing the energy matrix (CONELEC 2012). This, in turn, was aligned

with the National Plans for Good Living (Buen Vivir) and Electrification, aiming this way to achieve both environmental sustainability and *Buen Vivir* (SENPLADES 2009; SENPLADES 2013). Notwithstanding, the planning and development of this low-carbon energy source have been carried out without questioning their well-known and concerning environmental and ecological side effects (Briones-Hidrovo, Uche, and Martínez-Gracia 2020) which in turn has an impact on the overall human well-being. The "greening" and environmental sustainability of hydropower are still contested and cannot be taken for granted (Briones-Hidrovo, Uche, and Martínez-gracia 2021; Atkins 2020). This has conflicted with national goals for environmental sustainability, Buen Vivir and the Rights of Nature that are recognized in the Constitution of Ecuador (2008).

This study aims to analyze and discuss hydropower development and policy in Ecuador from an environmental perspective. The analysis addresses the research question of to what extent the past and current hydropower development and policy are compatible and consistent with national environmental sustainability and *Buen Vivir* goals. For such purpose, it is proposed a conceptual framework based on the interplay between key elements such as the constitutional framework, including Buen Vivir principles and rights of nature; evidence on the environmental sustainability of hydropower and the historical trend of water and hydro-energy national policies. The present study is structured as follows: firstly, Section 2 describes the conceptual framework applied to conduct the analysis as well as the components of the conceptual framework. Then, the historical hydropower development and policy and water law and policy in Ecuador are presented in Section 3. Section 4 and Section 5 discuss the critiques of the business-as-usual hydropower policy, the alternative based on *Buen Vivir* and their comparison. Lastly, policy implications and final remarks are discussed in Section 6.

2. Materials and methods

In order to address the research question, an analysis was conducted through the lens of a proposed conceptual framework described in Figure 1. Firstly, the 2008 Constitution of Ecuador is at the core of the conceptual framework. Within this constitutional framework, two critical elements gathered in the 2008 Constitution are relevant; they have a remarkable play in national environmental sustainability and human well-being: on the one hand, the *Buen Vivir* (Good living) and, on the other hand, the rights of nature. In this context, the overall philosophy, principles, and constitutional articles of *Buen Vivir* were considered as well as nature rights' articles. Secondly, it was included a global perspective framework which in turn takes into account the current hydropower policies and the evidence of the environmental-ecological impacts and sustainability of hydropower.

Thirdly, the business-As-Usual Hydropower Policy (BAU-HPO) was defined based on the identified characteristics of the current hydropower policy. Then, the trend and evidence of the environmental-ecological impacts of hydropower were extrapolated and put in the national context, to which available national hydropower case studies were also included in the analysis. Lastly, the water law and policy and the evolution of (hydro) energy policy in Ecuador are later included as a background to complete the overall analysis. To this respect, those national plans, laws, and standards related to water and energy were chosen and revised. Later, those documents were analyzed focusing on hydropower projects (types, reason of deployment), use of water resources for energy generation, ecosystem and biodiversity conservation and environmental sustainability as main criteria. Therefore, the policy analysis was conducted based on public documents (Browne et al. 2019).

Accordingly, the core of the analysis gathers the interplay between the abovementioned elements and their reflection in the case of Ecuador. Furthermore, a comparison between BAU-HPO and a proposed alternative was carried out. To this end, the comparison was conducted

following criteria such as meeting the constitutional framework, Buen Vivir, rights of nature and environmental sustainability.

[Figure 1 near here]

2.1. The philosophy of Buen Vivir

Buen Vivir is a cultural concept of wellbeing and it is inspired by the experience and practice of Sumak Kawsay (a life of fullness) by the Andean indigenous peoples (Villalba 2013). Its philosophy is based on the indigenous conception that nature, community and individuals all share the same material and spiritual dimensions (Guardiola and García-Quero 2014). Buen Vivir is a path itself, rather than a destination, and it is permanently evolving (Acosta and Martínez Abarca 2018).

Buen Vivir opposes Western thinking and forms of development. While the former focuses on the community, on living in harmony with Nature (Pachamama in the indigenous traditions) and is driven by a biocentric vision, the latter takes the individual as the basic social unit, is rooted in the anthropocentric vision and views the world as a machine and nature as a series of resources to be exploited (Villalba 2013; Acosta and Martínez Abarca 2018; Williford 2018). The Western ontology is dual which means that nature is separated from the society. Conversely, the ontology of the Andean indigenous peoples is relational, where nature is viewed as a whole, and human beings are considered a part of it. In addition, the break with the Western development also comes with the connotation of time. Western development considers time linearly. The Andean indigenous worldviews do not conceive a beginning or end in time; it is rather viewed in a spiral way. This entails that conditions of "development" or "underdevelopment" do not exist (Villalba 2013; Acosta and Martínez Abarca 2018).

According to (Guardiola and García-Quero 2014) and (Villalba 2013), Buen Vivir has mainly two approaches: the modern, extractive-western position which views natural resources as a way for achieving Buen Vivir; and the conservationist, Andean-indigenous position which seeks to respect and protect nature as a way to live the Buen Vivir. (Le Quang and Vercoutère 2013) classified the latter as a cultural approach. These authors also indicate two other approaches: the ecologist and the eco-marxist. While one of the key components of the ecologist approach is the Rights of Nature, the eco-marxist approach focus the debate on the natural resources and their exploitation (Le Quang and Vercoutère 2013). Lastly, it is worth highlighting that Buen Vivir cannot be achieved while commodifying Nature and pursuing economic growth (Acosta and Martínez Abarca 2018; Latorre, Farrell, and Martínez-alier 2015; Villalba-Eguiluz and Etxano 2017).

2.2. Constitutional framework overview

The Constitution of Ecuador was redrafted after 2007 and through a National Constituent Assembly, giving place to a constitutional milestone: acknowledging Nature as the subject of rights. Furthermore, the new Constitution of Ecuador was innovative for incorporating the concept of *Buen Vivir* (Constitución de Ecuador 2008). Constitutional articles on the primary related natural resources, the Rights of Nature, and *Buen Vivir* are compiled in Table 1.

Several key aspects of the constitutional articles can be highlighted. Water is recognized as a national patrimony, and access to it is a fundamental right. Environmental sustainability and conservation of ecosystems and biodiversity are both determined as rights. With regards to the Rights of Nature, the State has the authority to stop any (human) activity that threatens ecosystems, biodiversity, and the alteration of natural cycles. Lastly, avoiding negative environmental impacts, the sustainability of ecosystems and water, the declaration of biodiversity conservation as public interest, and the mitigation of climate change are at the core

of the constitutional rights under the *Buen Vivir* regime (Constitución de Ecuador 2008). The transformative constitutional framework should be seen as the starting point for a societal transformation where *Buen Vivir* is the central theme in a critique of the development (Villalba 2013; Acosta and Martínez Abarca 2018).

[Table 1 near here]

2.3. Evidence on the environmental-ecological impacts and sustainability of hydropower

The world's hydropower capacity keeps rising (IHA 2020a; Berga 2016) for the sake of climate change and (environmental) sustainability in the power sector, linked to sustainable development goals (United Nations 2020). Notwithstanding, hydropower has raised concerns due to its ecological consequences, which has put into question its sustainability in such regard. Environmental and ecological impacts of hydropower are well documented in the literature through the lens of several approaches, such as life-cycle assessment, greenhouse gases emissions (CO_2, CH_4), carbon budget, water footprint, ecosystem services, and energy analysis (Briones-Hidrovo, Uche, and Martínez-Gracia 2017; Intralawan et al. 2018; Dias Coelho et al. 2017; Pang et al. 2015; Jiang et al. 2018; de Faria et al. 2015; Demarty and Bastien 2011).

Several conclusions can be drawn from the literature regarding the environmental impacts and sustainability of hydropower. River damming contributes to the loss of river connectivity (Grill et al. 2019); it alters water and sediment flows, retention time, sedimentation, nutrient biogeochemical cycling and affects the river hydro-morphological and biological components in many ways, which is a major threat to river biodiversity at a global scale (Bunn and Arthington 2002; Vörösmarty et al. 2003; Jalón et al. 2017; Wang et al. 2018). Particularly, the construction of Andean reservoirs can disrupt the connectivity with the lower Amazon ecosystem (Tundisi et al. 2014), significantly impacting channel geomorphology,

floodplain fertility, and aquatic productivity (Forsberg et al. 2017). (Latrubesse et al. 2017) indicated that the accumulated adverse environmental effects of existing and proposed dams if constructed, would trigger massive hydro-physical and biotic disturbances that would affect floodplains estuary and sediment plume in the Amazon basin.

On the other hand, hydropower appears to be the most dangerous in its potential impacts on terrestrial and aquatic species, native habitats, and GHG emissions (Gibson, Wilman, and Laurance 2017). It is well-known that dam-based hydropower plants are sources of GHG emissions and hence contribute to climate change (Fearnside 2015a; Briones-Hidrovo, Uche, and Martínez-Gracia 2017; Demarty and Bastien 2011). Global expansion of renewable energy, including hydropower, will put pressure on biodiversity. Indeed, hydropower has the highest biodiversity footprint (Rehbein et al. 2020; Gasparatos et al. 2017). According to (Zarfl et al. 2019), hydropower development will disproportionately impact areas of high freshwater megafauna richness in South America. This goes hand in hand with the fact that hydropower plants will increase the number of fragmented rivers (Zarfl, Lumsdon, and Tockner 2015; Grill et al. 2019). Moreover, they will increase water evapotranspiration and further increase water scarcity at the global level (Scherer and Pfister 2016; Dias Coelho et al. 2017).

As dam-based hydropower generates losses of ecosystem services (Briones-Hidrovo, Uche, and Martínez-Gracia 2019; Intralawan et al. 2018), this low-carbon energy technology should be limited if ecosystem services are to be maintained (Moriarty and Honnery 2019). This is why hydropower projects should be carefully analysed, since they are not environmentally sustainable in an equal manner (Briones-Hidrovo, Uche, and Martínez-gracia 2021). In the context of Ecuador, (Carvajal et al. 2017) determined that generation of hydropower in Ecuador is highly uncertain and sensitive to climate change, which could put the power generation system at risk and trigger side effects such as the run of oil-based power plants and an increase in national GHG emissions.

It is worth highlighting the efforts made to assess the sustainability of hydropower, including the environmental aspects. Protocols, guidelines, and tools have been developed in such regard (IHA 2020b; HSC 2021). Nevertheless, (Y. Zhang, Ma, and Zhao 2021) stresses that the existing guidelines and frameworks have narrow scopes of application, uncomprehensive indicators, low practicability, and that they are flawed and not universal. In addition, the authors emphasize the fact that only few hydropower projects are sustainable. (Tahseen and Karney 2017) highlight the lack of broad vision which entails omitting key factors (e.g., environmental) associated with hydropower. The World Wildlife Fund (WWF) report suggests a low-impact hydropower scenario that does not add environmental and ecological impacts and maintains free-flowing rivers (Opperman et al. 2019).

2.4. Conceptualizing Business-As-Usual Hydropower Policy (BAU-HPO)

Under globalization, national borders no longer exist, and there is a consistent and growing interlink and interdependence across social, economic, political, cultural and environmental dimensions (de Sousa Santos 2006). In this sense, there are dominant and shared production and consumption patterns ruled by the global economy. Furthermore, national public policies are closely linked and shaped by the global agenda that, in turn, follows global geopolitics. In this context, in light of the steady growth of hydropower installed capacity and the evidence of its climate-environmental impact (directly and indirectly), BAU-HPO can be understood based on the form and the background. The former deals with the size and schemes of hydropower projects. The most prevailing implemented scheme is dam-based, with sizes from 50 MW and up to 22 GW (IHA 2021). This large-size scheme is usually implemented despite the high initial investment costs (IRENA 2020). On the other hand, the background encompasses the reasoning and justification for hydropower development which is linked to the global issues. The predominant arguments are, e.g., climate change mitigation, renewable, clean, and sustainable

energy sources, energy efficiency, social and economic sustainable development, energy security and sovereignty, etc. (Tur et al. 2018; Arroyo and Miguel 2020).

More importantly, it can be argued that the background of BAU-HP is attached to the notion of development and economic (green) growth (Briones-Hidrovo, Uche, and Martínez-gracia 2021; IHA 2020a). Both hydropower and economic growth are promoted under the sustainable development goals (Goal 7 and 8, respectively) (UN 2019). In this sense, (Hickel 2019) and (Zeng et al. 2020) note that the sustainable development goals are contradictory and may justify further environmental destruction. In any case, the green growth narrative dominates most political circles and it argues that technological progress and structural change will lead to a decoupling of natural resources consumption and environmental impacts from economic growth (Parrique et al. 2019). However, the literature reveals that decoupling is not currently happening (Haberl et al. 2020), and green growth is neither possible nor compatible with our planet's ecology (Hickel and Kallis 2019).

3. Water and hydropower background in Ecuador

3.1. Historical hydropower development and energy planning

Ecuador is a rich and biodiverse country. It has a theoretical hydropower potential of 73,390 MW, where only 21,520 MW can be technically and economically exploitable. 90% of this is located on the Amazon slope, and the remaining 10% lies on the Pacific slope (Consejo Nacional de Electricidad 2012). However, its significant hydropower potential had not been developed until recently. The Ministry of Natural and Energy Resources, created in 1970, undertook pre-feasibility studies for hydropower projects based on the formulation of the national water cadastre (López 2008). In 1973, the Electrification Law (Ley Básica de Electrificación) created the National Electrification Fund, which manages royalties from oil extraction. Meanwhile, one of the guidelines of the Third Electrification Master Plan (PME),

1973–1983, was the execution of the first hydroelectric projects such as Paute Molino and Pisayambo (Godoy Ortega 2013). The execution of projects has always depended on the oil exports budget.

The Constitution of 1979 ordered energy management to be a state-owned attribution, which was reflected in the National Development Plan. The “change of the energy matrix” was contemplated (Chamorro López 2012). Since Ecuador became an oil-producing country in the 1970s, hydropower was not at the heart of the national energy policies. Until 1987, the budgetary spending from oil royalties prioritized the payment of the foreign debt, which is why the execution of several hydroelectric projects, such as Agoyán, was delayed. Due to the lack of supply and constant blackouts, more feasibility studies were carried out in 1992 to expand the supply for both residential and industrial sectors (López 2008). In 1992, the hydropower installed capacity was slightly over 1,100 MW (Figure 1), with Paute Molino as the first large hydropower project in the country, developed on the Amazon slope.

[Figure 2 near here]

[Figure 3 near here]

After 2008, national energy policies experienced a radical shift, in particular the power sector. Since then, hydropower has been at the core of the national energy policy, aiming to change the energy matrix. In this context, the former government declared all hydroelectric projects as national priority, no matter their type or size, understanding that the renewable energy projects are sustainable, as water is considered to be a "virtually inexhaustible" resource (Chamorro López 2012; López 2008; SENPLADES 2009). In addition, hydropower was seen as an effective way to deal with climate change based on efficiency, equity, and inclusive

planning. The strategic prioritization of hydropower was aligned with the *Buen Vivir* National Plan (SENPLADES 2009) and supported by the 2008 Constitution, which would not only adopt such advancements but would go further in terms of guiding principles such as *Buen Vivir* (Sumak Kawsay), the Rights of Nature and the duties of the State concerning national resources (Godoy Ortega 2013). Therefore, hydropower was assumed as an ally on the path towards *Buen Vivir*.

Among the strategic guidelines were the expansion of the power sector based on "available energy", sustainable development based on renewable energies, reduction of losses in distribution, and energy efficiency based on institutional and regulatory strengthening. Until 2012, Ecuador had approximately 2,200 MW of hydropower installed capacity (Figure 1), accounting for barely 10% of the techno-economically exploitable potential, representing 42% and 53% of national power installed capacity and electricity generation, respectively (Ministerio Coordinador de Sectores Estratégicos 2015). As a result of the new policies and strategies, Ecuador's energy perspective was expanded in ten years (see Figure 2). Among the main executed large hydropower projects (>1 MW) were Mazar Dudas, Baba, Manduriacu, Sopladora, Toachi Pilatón, Quijos, Delsitanisagua, Minas San Francisco, and Coca Codo Sinclair, being the largest with 1,500 MW. This shows the increase in water concessions for hydropower by 70%, distributed in a total of 200 water basins (Godoy Ortega 2013) (Figure 2). This way, the country achieved 5,098 MW (Figure 1), generating up to 88% of the national monthly electricity demand to date (Ministerio de Energia y Recursos Naturales no renovables 2020).

The accelerated hydropower deployment sought to bring several achievements and benefits. First, the substitution and therefore the reduction of imported petroleum products. Second, self-reliance, energy security, and energy sovereignty. Third, reductions of greenhouse gases emissions and efficiency improvement in the national power system. Fourth,

socioeconomic benefits which are linked to the decrease in imported petroleum products and local community development projects (e.g., infrastructure). Last, an improvement of environmental sustainability in the national power sector, pointing towards the *Buen Vivir*. Like so, an entirely hydropower-based power generation was aimed at introducing new and more efficient electricity-based technologies such as induction cooking and electric water heaters, covering new electricity demand in the industrial (mining, cement, and steel) and transportation sector (tram and subway), and turning the country into a net electricity exporter (MEER 2012).

To date, national energy policy is aligned with the Sustainable Development Goals. There should be a tendency to generate clean, affordable, and non-polluting energy that ensures an increase in demand motivated by population growth (United Nations 2019). This, according to the United Nations, includes expanding energy sources and doubling the efficiency rate by growing infrastructure and improving technology.

3.2. Water law and policy

Between 1960–1972, water was declared a public good but with private investment. Thus, water management was characterized by a state immobilization (Rivera Pazmiño 2016). The Law of Decentralization and Irrigation Management Transfer was enacted in 1970, allowing a slight shift to public management of the water resources; yet it was not until 2000 that water management went back to being completely public under the enacted Law of Environmental Management (Ley de Gestión Ambiental). The law contains considerations of sustainable technology, rational use of the resource sustained on the preventive principle, and water pollution control.

In 2007, the return of the State came with knowledge hierarchization and new ways of governing the territory and its resources (Hidalgo-bastidas and Boelens 2018). According to the National Development Plan 2007–2010, it was necessary to problematize the water resource

linked to the demographic expansion and the development of economic activities. The 2008 Constitution gives water management and planning a starring role. Accordingly, the central government is in charge of regulation, control, and management of this resource at a national and at a local level by the Decentralized Autonomous Governments (GADs) who deal with irrigation and drinkable water as final goods. The Law prohibits privatization and promotes the formation of Water Users Associations for rural populations and communities. Water is for public use; however, hydraulic infrastructure can be public, private through concessions, or communal, depending on the sources of financing and on who executes the project (Asamblea Nacional 2014).

The National Secretary of Water (SENAGUA) was created for integrated water planning and management, with an order of priority in the type of usage: human consumption, irrigation, environmental flow, and productive activities. This prioritization is essential for managing water with a watershed ecosystemic approach (Benítez Carrasco 2018). Nevertheless, the National Plan for Water Resources was in place until 2010, which did not include integrated management, social or economic considerations (Rivera Pazmiño 2016; Asamblea Nacional 2014). The Buen Vivir National Plan (PNBV), 2009–2013, included integrated management as policy and gave a perspective of water's strategic resource, sociocultural and environmental valuation. Additionally, it was considered relevant to recover the functionality of water basins and promote the wise usage of watersheds to prevent floods and droughts.

In the case of hydropower projects, the importance of maintaining the environmental flow is stipulated in the Water Law (Ley Orgánica de Recursos Hídricos, Uso y Aprovechamiento del Agua) and its specifications in the Technical Standards. Thus, article 77 of the Law mandates "… it cannot be a subject to authorization for productive use or exploitation, except for those uses that do not pose consequences for the quality or quantity of

the ecological flow" (Asamblea Nacional 2014). The same Law establishes that water-protected areas are a part of the National System of Protected Areas, regulated by the Organic Environmental Law (Código Orgánico del Ambiente).

Among the obligations with co-responsibility for both the citizens and the State, there are fundamentally the reduction of unsustainable extractions, such as the diversion or damming of flows, and water waste reduction. Likewise, the Water Law exposes the order of priority for water use, where the ecological flow occupies the third place and the productive activities are on the fourth and last place. For energetic and industrial use, the Water Law mandates that the projects should be prioritized according to the PME. The ones approved, in this case, by the Ministry of Environment and Water (MAAE), must comply with the authorized flow.

The most innovative policy is the National Plan for Integrated and Comprehensive Management of Ecuador's water resources, basins, and micro hydrographic basins (Plan Nacional de Gestión Integrada e Integral de los Recursos Hídricos y de las Cuencas y Microcuencas Hidrográficas de Ecuador), enacted in 2016 and developed by SENAGUA. This National Water Plan has a macro and micro vision, broken down in management by region. It is based on an efficient and rational allocation of water resources for each use to intensify the integral and integrated management of water basins. However, it maintains an economic growth approach divided into standard and fundamental growth depending on the dry season. The main objective is to reduce floods and disasters and optimize the use of water resources (CISPDR 2016). The plan was envisaged for 37 hydrographic basins, and it recommends improving the capacity of reservoirs for greater regulation and storage of hydropower projects. Finally, the environmental technical standard to prevent and control pollution for the infrastructure sectors, i.e., hydroelectric power plants, defines the environmental flow according to the temporality of the project (CISPDR 2016). After 2017, water policy lacks clarity, and a concrete work plan is still unknown.

4. Critiques of BAU-HPO

4.1. Counterproductive aspects of BAU-HPO

BAU-HPO has been likewise applied in Ecuador, which has put hydropower at the core of the national energy policy and energy matrix shift in the last 14 years (Briones-Hidrovo, Uche, and Martínez-Gracia 2017; MEER 2012). Nevertheless, BAU-HPO was not questioned, despite its conflict with environmental sustainability and the constitutional framework (Figure 3). In this sense, several points can be highlighted.

Firstly, the issue of BAU-HPO arises due to the lack of understanding hydropower in a more complex manner (Figure 3). Such approach has been narrowly related to energy efficiency, energy sovereignty and security, energy matrix diversification, and the reduction of oil dependency and hence greenhouse gas emissions (MEER 2012). Nonetheless, the link between hydropower generation, reservoir' greenhouse gases emissions, climate change, ecosystem services, biodiversity, human wellbeing, socio-ecological conflicts and environmental sustainability has been ultimately overlooked for the sake of sustainable development and economic growth (Fearnside 2014; Hess and Fenrich 2017; Briones-Hidrovo, Uche, and Martínez-gracia 2021; Gasparatos et al. 2017; Mendieta-Vicuña and Esparcia 2022). It should bear in mind that BAU-HPO has been aligned with regulations of the United Nations Framework Convention on Climate Change, the Kyoto Protocol's Clean Development Mechanism (CDM), according to which carbon credit is granted to hydropower projects (Fearnside 2013; MEER 2012; Fearnside 2015b). In addition to this, the national development of hydropower projects depends on the oil extraction budget, which is affected by oil price fluctuations. Hence, this vicious cycle limits the "sustainable" view of hydropower production.

Secondly, BAU-HPO follows the belief of (sustainable) development (Rist 2007; Villalba 2013) that is shaped by narratives and reinforced through political discourses that in

turn end up legitimizing techno-environmental transformations (Tur et al. 2018; Jones and Mcbeth 2010), although this was contested in the initial Ecuadorian National Development Plan (SENPLADES 2009; Villalba 2013). Through discourses, the former government continuously enunciated that hydropower was necessary for diversification of energy matrix, national development, environmental sustainability, mitigation of climate change, and *Buen Vivir,* and the best path towards post-extractivism (Presidencia 2013). In this respect, Williams (2020) indicates that this is the part of hydropower narrative that shapes the "hydropower myth". Indeed, the use of expressions such as "sustainability", "sustainable development", "climate change" are commonly use within hydropower discourse (Flaminio, Piégay, and Le Lay 2021). Under Ecuadorian context, the development of hydropower has fallen within the so-called neo-extractivism, which is incompatible with the postulates of *Buen Vivir* (Villalba-Eguiluz and Etxano 2017; Svampa 2019). Furthermore, the externalities of hydropower are usually neglected (Williams 2020). Its deployment is aligned with the economic growth vision, which goes against the conservation of ecosystems and biodiversity (Otero et al. 2020), the overall environmental sustainability (Hickel 2019; Hickel and Kallis 2019; Schaffartzik, Duro, and Krausmann 2019; Zeng et al. 2020) as well as the theoretical basis of *Buen Vivir* (Villalba 2013).

[Figure 4 near here]

Thirdly, the Water Law considers water resources under the vision for productive use. Water is mainly seen as a strategic national resource linked to national productivity and human rights. This Law, in line with the National Environmental Law, mandates holistic and integrated water management with a watershed vision. Despite this, hydropower has been developed without the watershed vision and, on the other hand, it has been supported by the productive use vision of water resources (Asamblea Nacional 2014). This, therefore, has entailed relegating

water to a second place and overlooking it as a habitat, an ecosystem, and provider of services (Millennium Ecosystem Assessment 2005; IPBES 2019). Accordingly, it can be argued that BAU-HPO has distanced itself from what is mandated in both Water and Environmental Laws (Asamblea Nacional 2014; Asamblea Nacional 2017). Moreover, BAU-HPO lacks holistic vision, and it has not been integrated with the corresponding environmental-water policies. In this regard, no record of national multi-approach or integrated approaches has been found. Hence, hydropower policy should be built based on the National Environmental and Water laws and policies.

Finally, it can be argued that BAU-HPO is not fully aligned with the 2008 constitution since it effortlessly transgresses the principle of preserving the integrity of nature. The existing form of hydropower deployment manifests of the dominant human thinking and behaviour where nature is seen as an object to be dominated and exploited. Because of this, no socio-ecological harmony can occur, and therefore there is no compliance with the 2008 constitution. This environmental-legal conflicting situation leads to the question of how and to what extent hydro energy should be harnessed. On this basis, what should be sought is to implement hydropower projects (when necessary) that maintain the maximum integrity of ecosystems. Consequently, hydropower should not be prioritized at all costs; it should follow neither the same development model as the fossil fuel industry nor the economic growth vision. Conversely, it should seek a profound transformation of the power sector, where the interaction between Humans and Nature is well-balanced.

4.2. Hydropower cases as supporting evidence.

Several HP types can serve as support to the arguments presented above. Firstly, Baba hydropower plant was built as a part of a multipurpose project and began its operation in 2013. According to the findings of (Briones-Hidrovo, Uche, and Martínez-Gracia 2017; Briones-

Hidrovo, Uche, and Martínez-Gracia 2019), this type of hydropower plant is not the best strategy for mitigation of climate change and conservation of ecosystems and biodiversity since it opposes environmental sustainability, *Buen Vivir* and the Rights of Nature (Constitution, 2008). Another dam-based hydropower example is the planned Santiago hydropower project of 3,600 MW, located on the Amazon slope (CELEC EP 2015). Based on the evidence of similar case studies, this project will incur disrupting and affecting the water basin, life cycle, structures and functions of terrestrial and aquatic ecosystems (Briones-Hidrovo, Uche, and Martínez-Gracia 2019; Intralawan et al. 2018) and will potentially lead to greenhouse gases emissions, mainly methane (Demarty and Bastien 2011; Abril et al. 2005; Hertwich 2013).

Secondly, the impacts on the water basin can already be seen due to the operation of Coca Codo Sinclair (regulated and diverted run-of-river scheme, 1,500 MW), the largest hydropower plant in Ecuador located on the Amazon slope. The Coca river is registering a severe erosion that modifies the basin's geomorphology and affects local communities (SNGRE 2020). In addition, the operation of this hydropower plant implies the withdrawal of sediments that have ecological consequences downstream in the Amazonian floodplains (Flecker et al. 2022).

Lastly, the construction of the Hidrotambo hydropower project (diverted run-off-river scheme, 30 MW) was stopped due to a constitutional review because it infringes the Rights of Nature (Corte Constitucional del Ecuador 2020). The complaining party (the local community) argued that the Hidrotambo project would dry up the river since 90% of the annual average water flow would be withdrawn. This would, therefore, affect the integrity of the river ecosystem, the access to water, and local ecotourism (Corte Constitucional del Ecuador 2020). Finally, it is worth adding that, contrary to what is expected, the socioeconomic benefits of hydropower may be a myth. In this line, (Mendieta-Vicuña and Esparcia 2022) found that Mazar-Dudas hydropower project (21 MW) in Ecuador was not compatible with sustainable

local development. Furthermore, according to (Faria et al. 2017), the positive economic effects of hydropower are short-lived. On the other hand, the hydropower investment can leave countries in debt, as is the case in Ecuador, which can be seen as a negative economic impact (Williams 2020).

5. Alternative to BAU-HPO

5.1. Towards a Buen Vivir-based hydropower development

BAU-HPO was found to be environmentally and even constitutionally inconsistent. Accordingly, a set of recommendations for future policymaking is proposed (Table 2). These recommendations are based on an environmentally low-impact and sustainable hydropower scenario (Opperman et al. 2019), which could constitute the basis of the *Buen Vivir-based* Hydropower Policy (BV-HPO). These recommendations follow the evidence found in the literature (e.g., (Thieme et al. 2021; Flecker et al. 2022; Almeida et al. 2019; Kuriqi et al. 2020), and they are consistent with the philosophy of *Buen Vivir* and the Ecuadorian constitutional framework. The idea is to rethink how hydro energy can be harnessed harmoniously with national environmental goals, local communities, ecosystems, and biodiversity.

For instance, (Gasparatos, Ahmed, and Voigt 2021) stressed that "*national policy frameworks need to encourage integrated planning and landscape-based approaches that search for the combination of renewable energy sources that has the fewest biodiversity trade-offs*". The authors also underlined that the design of policies must be guided based on the evidence to minimize trade-offs between renewable energy and biodiversity (Gasparatos, Ahmed, and Voigt 2021). In this same context, (Thieme et al. 2021) proposed a set of tested and proven solutions to navigate trade-offs associated with river conservation and dam development, including avoiding new dam hydropower construction, reduction of impact through strategic planning and dam removal to restore rivers.

Consequently, the first proposed recommendations (1 to 4) address environmental flow, size, and scheme (Table 2). In this sense, re-assessing the national hydropower potential following the dynamic environmental flows and climate change scenarios will lead to new size estimation of hydropower projects. These new sizes, combined with alternative schemes other than dam-based (e.g., run-off-river, diverted and non-diverted), will result in a new portfolio of hydropower projects. This way, it is suggested to emphasize medium, small, mini and micro-hydropower projects (from 5 kW to 100 MW[1]). This will affect and modify regulations, laws and plans (see Table S1). For instance, the technical standards should change the size classification of hydropower plants (currently, small hydropower are < 1 MW). Water Law must prioritize small hydropower projects (limited to 50 MW) while restricting large ones with emphasis on dam schemes (Table S1). Anyhow, hydropower projects will be automatically limited by applying dynamic environmental flows. Accordingly, the Energy Efficiency Plan must be revised and redrafted following the new goals. Furthermore, the re-assessment of the national hydropower potential based on the dynamic environmental flows will allow adapting the biocentric view aligning with the 2008 constitution of Ecuador.

Recommendation 5 is concerned with coupling hydropower with strategic river basin planning. Although Water laws and plans already envisage river basin management, hydraulic projects are not restricted. Therefore, Water laws and plans should emphasize river basin and ecosystem-based hydropower development. On the other hand, Water law and environmental and technical standards present drawbacks from a technical, ecological maintenance and restoration perspective. In this sense, recommendation 6 strongly encourages the application of new hydropower turbines technology (e.g., bulb turbines, Archimedean screw), aquatic biodiversity-friendly technologies (e.g., fish-friendly passage system), and nature-based

[1] Classification according to (IRENA 2012)

solutions (e.g., green infrastructure for flood mitigation) when possible. Thus, the impact on aquatic life in rivers could be strongly reduced, and even ecosystem restoration can be achieved.

It is also suggested to carry out a more holistic and depth environmental assessment as part of the overall sustainability assessment. In this respect, several biophysical indicators from different approaches could be considered (Recommendation 7). This will affect where hydropower projects can be deployed since climate change impact, ecosystem services and biodiversity are taken into account. Accordingly, the environmental standard for environmental license should ask for other environmental studies and indicators that prove the environmental sustainability of hydropower projects. Based on the requirements of new environmental sustainability indicators, the new hydropower projects could be contrasted with other low-carbon energy sources (Recommendation 8). This way, comparing environmental sustainability indicators of power generation projects can provide a bigger picture while supporting decision-making. Because of this, the national energy plan will be affected in terms of production and efficiency, for which a new future energy scenario should be analysed.

Recommendation 9 states that promoting hydropower development should satisfy basic needs and guarantee well-being. This means a comprehensive review of National Development and Energy Plans to seek the lowest trade-offs between electricity generation, resources, environmental impact and basic needs. Therefore, the energy demand should be redefined according to priorities and sectors. Lastly, the decommissioning of existing hydropower plants takes part in Recommendation 10. Water Law might include a transitional provision mentioning a specific period to remove existing dams or their redesign. This last recommendation could potentially lead to re-establish river's connectivity and restoration. However, national electricity generation will be affected which should also be considered part of energy scenarios within the National Energy Plan.

[Table 2 near here]

5.2. How does BAU-HPO compare to BV-HPO?

Several aspects can be highlighted of the BV-HPO compared with BAU-HPO. One aspect of BV-HPO is that it responds to the 2008 Ecuadorian constitution contrary to BAU-HPO that follows the socio-economic and political global agenda. In this sense, hydropower systems have been implemented worldwide unquestionably, following the ruling production-consumption pattern of the global economy while ignoring the socio-environmental impacts. Therefore, BV-HPO complies with what the 2008 Ecuadorian constitution states regarding the use and consumption of resources and the human-nature relationship. Constitutional compliance highlights a second key point: BV-HPO opposes to BAU-HPO, which means confronting the *status quo*. Hence, BV-HPO becomes a turning point in the energy generation sector and can set an example for other sectors. Thirdly, as it takes BV philosophy, BV-HPO entails breaking down the development paradigm. Hence, it will allow building a new human-nature relationship where fundamental values such as conviviality, caring, sharing and community are applied. The integrity of nature will be kept, which in turn means avoiding ecosystem services and biodiversity losses, contributing to the overall human well-being.

Four and last, BAU-HPO has a counterproductive and conflicting situation across social, economic, and environmental dimensions. Conversely, BV-HPO has a biocentric approach, so that it can make significant contributions in such dimensions. As a matter of fact, BV-HPO could be seen as an ally to achieve energy justice and a just transition. Energy justice and just transition are concerned with a just and equitable balance between politics, economics, and the environment (Villavicencio Calzadilla and Mauger 2018) and socioeconomic fairness and equity in post-carbon societies (McCauley and Heffron 2018), respectively. Therefore, BV-

HPO could lay the foundations for a just transition. The socio-environmental consequences of BV-HPO should be explored in future works.

6. Policy implications and final remarks

Through the proposed conceptual framework and the interplay between key elements that compose it, the environmental analysis of national BAU-HP policy exposes the urgent need for a radical shift of hydropower policy if the conservation of ecosystems and biodiversity, and climate change mitigation are to be accomplished in Ecuador. Accordingly, this implies complying with the constitutional framework. The suggested recommendations may lead to an environmental sustainability hydropower generation while avoiding socio-environmental conflicts and lawsuits and moving towards *Buen Vivir*. Therefore, a new hydropower policy approach (holistic, integrated) with a new philosophy (e.g., biocentric viewpoint, Buen Vivir, Rights of Nature) can bring about a paradigm shift in the power sector.

Nonetheless, implementing such recommendations would have several implications. As Ecuador still needs to substitute the 12% oil-based electricity generation and secure future energy demand, the hydro energy potential constraint would imply seeking electricity generation from other renewable energy sources, such as solar or geothermal (Moya, Paredes, and Kaparaju 2018). Accordingly, this would trigger several techno-economic and environmental challenges:

- To undertake new holistic environmental-economic trade-offs analysis and feasibility assessments for hydropower and other low-carbon combustion and combustion-free energy sources. Local communities' rights, the Rights of Nature, and *Buen Vivir* must be ensured.
- To redesign the national electric plan, including assessing new energy transmission infrastructure.

- To couple the national energy policy with environmental and water policies which in turn entails coupling future hydropower deployment with river basin planning and management.
- To guarantee funding availability and overcome financial issues.

Despite the implications, it may be an opportunity to diversify and strengthen the national power generation system, making it less vulnerable to climate change in the future. It is worth highlighting that the environmental sustainability of electricity generation should go hand in hand with strategies on energy efficiency and reduction in energy consumption. Finally, it is acknowledged that although such recommendations are consistent with the ongoing global socio-ecological and climate circumstances, they could be conflict arising. The recommendations may equally be applied elsewhere since it seeks to achieve environmental sustainability. The suggestions may be helpful to reform not only the current environmental and water laws but also the technical and environmental standards, as well as the procedures to obtain an environmental permit (see Supplementary Material).

Acknowledgement

We would like to thank to Lucía Belén Salazar Gómez for her valuable contribution.

Declaration of interests

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

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Table 1. Main constitutional articles addressing the Rights of Nature, Buen Vivir, biodiversity, and natural resources. Source: (Constitución de Ecuador 2008).

Title		**# Article**	**Key idea**
II Rights	Rights to *Buen Vivir*	12	Water, as a fundamental right, constitutes a strategic national patrimony for public use; it is inalienable, imprescriptible, non-attachable, and essential for life.
		14	The population has the right to live in a healthy, ecologically balanced environment, which guarantees sustainability and *Buen Vivir*. Conservation of ecosystems and biodiversity and prevention of environmental damage are of public interest.
	Rights of Nature	71	Nature has the right to be respected and the right to preservation and regeneration of life cycles, structure, and functions.
		72	Nature has the right to be restored.
		73	The State will apply precautionary and restrictive measures for activities that may lead to the extinction of species, the destruction of ecosystems, or the permanent alteration of natural cycles.
VII The regime of *Buen Vivir*	Biodiversity and natural resources	395	The State will promote sustainable, environmentally balanced development that preserves biodiversity and regeneration capacity of ecosystems, ensuring the satisfaction of needs of the present and future generations.
		396	The State will adopt the appropriate policies and measures that avoid adverse environmental impacts in cases where the damage to the environment is certain.
		400	The conservation of biodiversity is declared to be of public interest.
		404	The natural heritage of Ecuador, which is unique and invaluable, demands its protection, conservation, restoration, and promotion.
		411	The sustainability of ecosystems and human consumption is a priority in regard to water use.

		413	The State will promote energetic efficiency, development and use of environmentally clean technologies and practices, as well as diversified renewable energies of lower impact, without putting the food sovereignty, the ecological balance of ecosystems and the water rights at risk.
		414	The State will adopt adequate measures to mitigate climate change by limiting greenhouse gas emissions, deforestation, and air pollution.

Table 2. Recommendations for *Buen Vivir-based* hydropower policymaking in Ecuador

#	**Recommendation**	**Argument**	**Supporting reference**
1	Dynamic environmental flows should be adapted.	Adapting hydropower to hydrological dynamics will benefit ecosystems and biodiversity.	(Kuriqi et al. 2020; Kuriqi et al. 2019; Rosero-López et al. 2019; Fantin-Cruz et al. 2015; Laborde et al. 2020)
2	Re-assessing national hydropower potential based on dynamic environmental flows and climate change scenarios.	This will benefit ecosystems and biodiversity conservation.	(J. Zhang et al. 2014; Carvajal et al. 2017; Jager et al. 2015; Habersack et al. 2016)
3	New large hydropower projects should not be allowed. Small, mini and micro-projects should be promoted[1].	Large hydropower is detrimental to ecosystems and biodiversity conservation.	(J. Zhang et al. 2014; Intralawan et al. 2018; L.-X. Zhang, Pang, and Wang 2014; J. Zhang, Xu, and Li 2015; Zarfl et al. 2019; Gasparatos, Ahmed, and Voigt 2021)
4	New dam-based hydropower plants should not be allowed. Run-off-river schemes should be promoted.	Dam-based hydropower is detrimental to ecosystems, biodiversity, and climate change.	(Thieme et al. 2021; Intralawan et al. 2018; Barros et al. 2011; de Faria et al. 2015; Briones-Hidrovo, Uche, and Martínez-Gracia 2020; Zarfl et al. 2019; Wohlfahrt, Tomelleri, and Hammerle 2021)
5	Hydropower development should be integrated into river basin planning. The selection of the site should be checked.	Improvement on management of river basins.	(Couto and Olden 2018; Habersack et al. 2016; Laborde et al. 2020; Fantin-Cruz et al. 2015; Vasconcelos et al. 2021; Flecker et al. 2022; Gasparatos, Ahmed, and Voigt 2021)
6	Combining new hydropower turbines and aquatic biodiversity-friendly technologies with nature-based solutions.	Ecosystems and biodiversity can be preserved and restored.	(Chaudhari et al. 2021; Habersack et al. 2016)
7	Performing a holistic assessment with multiple biophysical indicators (e.g., Energy Return On Energy Investment, climate change, carbon and water footprint, water-carbon-energy nexus, balance and efficiency of ecosystem services, energy replacement cost, environmental sustainability index (emergy analysis), biodiversity impact, biocapacity impact, sediment transport, flow regulation, river connectivity).	This will create a more robust criterion for decision-making.	(Briones-Hidrovo, Uche, and Martínez-gracia 2021; Flecker et al. 2022)
8	The environmental performance of hydropower projects should be compared among different projects and to other low-carbon energy technologies in a holistic manner.	This will help to prioritize energy projects that maintain the integrity of ecosystems.	(Moya, Paredes, and Kaparaju 2018; Briones-Hidrovo, Uche, and Martínez-gracia 2021)

9	Hydro energy should be aligned with basic needs and well-being.	This will allow to understand the Nature-human being trade-off.	(Hickel 2020; Millward-Hopkins et al. 2020)
10	Removal and redesign of existing dams should be considered.	This will restore the river ecosystem and biodiversity.	(Thieme et al. 2021; Linares, Callisto, and Marques 2020)

[1]It has used the (IRENA 2012) classification of hydropower projects: large hydro >100 MW; medium hydro: from 20 to 100 MW; small hydro: from 1 to 20 MW; mini-hydro: from 100 kW to 1 MW; micro-hydro: from 5 kW to 100 kW.

Figures captions

-Figure 1. Description of the proposed conceptual framework applied for the analysis.

-Figure 2. Historic evolution of hydropower installed capacity in Ecuador. Own elaboration from (Consejo Nacional de Electricidad 2012; Ministerio de Energía y Recursos Naturales No Renovables 2019)

Figure 3. Map of the Hydropower plants and planned projects. Adapted from (ARCONEL 2015)

- Figure 4. Legal and environmental relational implications of hydropower policy