Consume less or grow sustainably? Matching energy systems with Indigenous worldviews in Panama

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ABSTRACT
This article explores how energy systems, if reconceptualized and reordered to deliver greater equity, could exponentially improve livelihoods and livelihood pathways of Panama’s Ngäbe and Buglé communities which currently lack energy access. Inevitably, the choice of energy systems and related infrastructures will not only bring benefits, but also impose burdens on local ecosystems as well as communities living near project sites. In biodiversity-rich Indigenous contexts, including Panama’s comarcas, making informed decisions about energy systems that are yet to be developed, implies understanding the impacts and potential risks of embedding such technical systems into areas with high levels of biodiversity and species density, whose vulnerability will only increase with climate change. A conceptual framework used in the study combines energy justice research perspectives with the energy–water–food–climate nexus as an approach to local livelihood planning. This approach makes it possible to treat the concept of ‘energy’ within a broader framework of social–ecological systems and safe operating spaces, while applying it to a specific context (Ngäbe–Buglé comarca, Panama). In this way, the study extrapolates how energy justice issues co-relate with social–ecological inequities, and at the same time present risks for the future of the comarca, with implications for broader contexts.

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1. INTRODUCTION
Since Panama Canal’s independence in 2000, the country experienced two decades of uninterrupted economic growth exceeding economic growth rates in much of Latin America. At the same time, material, social and cultural well-being of marginalized rural Indigenous populations has for the most part not improved. The Covid pandemic only amplified pre-existing inequalities, manifesting in poor access to healthcare and vaccines, on the one hand, and, on the other, inadequate internet connectivity, precluding access to information,
medical help and online education during lockdowns. What emerged during the pandemic is the importance of access to electricity. While the country enjoys nearly universal access, extending access to remote Indigenous communities has been a challenge for a number of reasons.

Comarcas comprise Indigenous lands under a special jurisdiction with their own political administration. Similar to Panama’s provinces, they are further subdivided into districts, municipalities and townships, which in turn differ in electricity coverage, ranging from 4% in the Ngäbe–Buglé comarca to 96% in the province of Panamá (AECID, 2019). The capital of the Ngäbe–Buglé comarca, Llano Tugrí (Büabitdi in Ngäbe), is neither connected to the grid nor does it have a reliable distributed energy system.

This article explores how energy systems, if reconceptualized and reordered at present to deliver greater equity, could exponentially improve livelihoods and livelihood pathways of communities who currently lack access. Framed by considerations of energy justice (Sovacool et al., 2020), equitable Indigenous livelihoods are understood as resilient, to some extent self-reliant communities, able to respond to future climate risks, but also communities that continue to shape their own futures, by being able to both determine and implement the terms of their own development. By extension, the meaning of *equitable* here refers not only to distributive, procedural and recognition justice, which may improve the Indigenous citizenship status overall, but also capabilities to draw one’s own future within environmentally and ecologically *safe operating spaces* (Rockström et al., 2009). Capabilities and skills are considered key to enabling Indigenous communities to survive in their environment within environmental and ecological limits, and expand their livelihood prospects beyond current employment opportunities. At the national level, this approach to development would help meet both climate and sustainable development goals.

The introduction of energy systems in the *comarca* will implicate lifestyles and livelihoods in significant ways. If guided by anti-poverty policies, the energy policy will run a risk of appropriation, or misconceptualization of local livelihood discourse. When poverty is measured by purchasing power, consumption rates and monetary incomes, the category ‘poor’ may become interpreted in ways that fit predetermined energy policy objectives (*e.g.*, to satisfy new and increasing energy demand) rather than respond to local Indigenous contexts (*e.g.*, achieve and maintain energy sufficiency in alignment with local livelihood needs). At this critical juncture, energy futures are emerging that will either boost opportunities for self-determined, culturally and ecologically appropriate development, or deprive communities of access to local resources on which they depend (drinking water, fish, uncontaminated soil), eventually leading to collective displacement and out-migration. Research and policy questions that in this context arise are: Will such energy systems mirror the past experiences of uneven distribution of costs and benefits, or improve livelihoods and livelihood prospects for local communities who currently lack energy access? Will they be designed to facilitate small-scale, self-determined rural development within the energy–water–food–climate nexus, or preclude it? While answering these research questions, the findings inform about what can be done to prevent the existing inequities from being inscribed in policy designs and reproduced in the current energy planning in the Ngäbe–Buglé comarca.

The study builds upon the literature in sustainable rural development, energy justice and policy practice in Indigenous territories. By demonstrating the imbalance between costs and benefits of large-scale energy systems experienced by local communities, the study contributes to research in small-scale, context-specific energy planning in tropical zones. It concludes with a set of recommendations that can help policymakers and practitioners to conceptualize, innovate and/or implement small-scale energy systems that benefit both local communities and national climate policies.
2. CONCEPTUAL FRAMEWORK: THE NEXUS APPROACH IN ENERGY PLANNING

The study develops a conceptual framework that combines energy justice perspectives with energy–water–forest–food–climate nexus approaches in sustainable development. It uses nexus as a broader theoretical context necessary for the analysis of interdisciplinary phenomena, and energy justice for the articulation of complex categories, such as energy equity and livelihood security in the context of Indigenous development. This research design makes it possible to integrate phenomena that would otherwise be considered distinct into a higher order perspective, but at the same time illustrate how energy technology developers may configure the function of energy system crossing diverse domains, yet remaining focused on hyper-local, culturally unique setting.

Energy justice research and its three analytical categories of justice – procedural, distributional and recognition (Sovacool et al., 2017) – provide useful lenses through which decision-making contexts become better understood so that more equitable approaches can be implemented (Jenkins et al., 2020). When combined with the energy–water–forest–food–climate nexus, this sufficiently complex approach makes it possible to explicate how distributed energy systems can best serve local community needs and open up opportunities for self-determined, climate-compatible development for present and future generations on the comarca.

The nexus approach in the environmental science and sustainable development policy discourse is understood to be a conceptual tool used to capture the interlinkages between natural resource supply and human demand on the environment, with the aim of finding the necessary balance for environmental livelihood security. In this study, nexus refers to the interrelatedness between energy, water, forest and food, while accounting for projected impacts of climate change. Here, the nexus approach is theorized for purposes of envisioning a culturally and technologically appropriate energy system compatible with the unique social and ecological context of the comarca. Compared with sustainable development approaches that are configured based on top-down quantitative indicators measuring the achievement at the national, regional and global levels, the nexus-based livelihood discourse is shaped by bottom-up (or mid-level) approaches that aim to enhance people’s ability at the local level to maintain their resource base, thereby sustaining their ability to survive in their natural environments (Folke et al., 2003; Scoones, 2009), and subsist on often non-market-based environmental provisions. The range of human activities may have positive environmental/sustainability impacts (agro-biodiversity, inter-cropping, reforestation), or negative impacts (deforestation, monoculture and soil degradation, water depletion, salinization) (Biggs et al., 2015). These impacts can be assessed as a ‘footprint family’ indicator (ecological, carbon and water footprint combined) (Galli et al., 2012). Good outcomes of nexus policy approaches thus presuppose the enactment of transdisciplinary knowledge, cross-sectoral, coordinated policy action, and the continuous uptake of scientific knowledge, as well as capacity to integrate findings generated via post-assessments and monitoring.

3. MATERIALS AND METHODS

The study uses mixed-methods research (document analysis supplemented by qualitative research). Reliability and validity of research findings were ensured by drawing on multiple sources of evidence. The initial document analysis was followed by field research to validate and build upon the initial findings, during which participants’ responses were gathered and participant observations collected.
The document analysis comprised primary and secondary sources (English and Spanish), and included case study reviews, academic journal articles, ethnographic accounts, government reports, reports by non-governmental organizations (NGOs) working on behalf of Indigenous communities, as well as sources produced by Indigenous communities themselves, media articles and published interviews. The interpretation of results is framed by concepts of energy–water–food–climate nexus approach, and relates more broadly to social energy research. The combination of theoretical perspectives (energy justice and energy–water–forest–food–climate nexus) makes it possible to extrapolate how different dimensions of inequity become inscribed in current struggles for energy access, and how energy systems, when not embedded in the energy–water–forest–food–climate nexus, in fact reproduce or amplify such injustices.

Data gathered during field research are included in the supplemental data online.

4. RESULTS

The Indigenous comarcas are a home to 196,059 Indigenous peoples comprising seven distinct ethno-linguistic groups, altogether representing 47% of the total Indigenous population (Table 1). The remaining 221,500 reside in areas adjacent to the comarcas, or have out-migrated to towns or the capital city (Herrera, 2012). Indigenous communities living in remote comarcas still lack access to basic services including electricity, sanitation and drinking water. Majority of Ngäbe Buglé (85%) use wood for cooking, and suffer 2.3 times higher incidence rates of pneumonia than the national average. While self-identification and/or identity consciousness are a

| Category                          | Definition                                                                 | Description                                                                 |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| 'Indígena' and 'pueblos Indígenas' | Definitions formulated by Panama’s Consejo Nacional de Desarrollo Indígena, and extend to the Ngäbe, Kuna, Emberá, Buglé, Wounaan, Naso and Bribri who maintain their own social, cultural, political, religious or linguistic values. Criterion used: self-identification or identity consciousness | Panama’s Indigenous groups constitute 12.26% of the total population. The Ngäbe account for the largest group (63%), followed by the Kuna (19.28%), Emberá (7.5%), Buglé (5.97%), Wounaan (1.74%) and three other groups that altogether amount to less than 1% (Naso Tjër Di, Bribri and Bokota) (Dirección Nacional, 2010) |
| Comarca Ngäbe–Buglé               | Created by Ley 10, 1997 as an inalienable landholding created for the exclusive use of Ngäbe–Buglé communities. There are four additional Ngäbe townships (Annex areas) outside the comarca proper, located in the provinces of Chiriquí and Veraguas | Comprises 6814 km² (out of a total country area of 75,416.6875 km²). Located in western Panama, the comarca encompasses the Caribbean (Atlantic) side, 40% of which is covered by primary forest, and is divided from the Pacific side by the Cordillera de Talamanca |
| Political administration          | The country comprises 10 provinces, 77 districts and municipalities, three Indigenous comarcas at the level of the province (Guna Yala, Emberá and Ngäbe Buglé with their own governors), and two comarcas at the township level (Guna de Madungandí and Kuna de Wargandí), which are part of the 623 townships in all of Panama. The Ngäbe–Buglé participate in both national and local or Indigenous elections | In national elections, the Ngäbe–Buglé elect three members of Parliament (diputados) as well as nine mayors (alcaldes) (out of a national total of 81) and 68 representatives (representantes de corregimiento) (out of a national total of 679). All belong to a political party and administer the comarca in collaboration with a governor, who is also Ngäbe–Buglé and is appointed by the President of Panama |
fundamental criterion for determining the Indigenous identity, disagreements over representation persist, suggesting a tension between coherent, place-based community strategies and extra-local interests.

4.1. Core and periphery
The indigenous *comarca* geographically most distant from the core is a home to the largest indigenous group: the Ngäbe who represent 63% of the country indigenous population (Figure 1). However, 98.4% of Ngäbe–Buglé live below the national poverty line, of which 90% is extreme poverty. While 98% of people living in the capital enjoy access to electricity, in the *comarca* it is little over 4%.

The urban–rural divide manifests in several ways – as unequal opportunities, unequal access to public services including health and education, and unequal income – based on ethnicity, language, gender and age. The urban–*comarca* divide represents an additional layer of inequity, as the communities are ‘left to fend on their own’ with a disproportionately low number of

![Figure 1](https://creativecommons.org/licenses/by/4.0/)

**Figure 1.** Map of Panama and Ngäbe-Buglé Comarca. **A.** Tree cover and primary forest loss in Panama, 2013. Indigenous comarcas (grey), intact forest landscape (light green), tree cover loss (purple). Línea Chiriquí Grande, proposed electricity transmission line (red dotted line). **B.** Primary forest (dark green) (2001), and tree cover (light green) (2010) in the Ngäbe-Buglé Comarca. **C.** Between 2001 and 2020, Ngäbe-Buglé Comarca lost 37.9 kha of tree cover (pink), equivalent to a 6.7% decrease in tree cover since 2000, and 21.8Mt of CO2 missions. CHAN II hydroelectric power plant (red) which does not provide electricity for the comarca.
Source: Adapted from Global Forest Watch, Panama Deforestation Statistics, GFW globalforestwatch.org, with modifications.
health clinics, schools, training centres or employment opportunities. With limited access to justice, *comarcas* are at a high risk of exposure to a broad range of factors that negatively implicate Indigenous livelihoods, including, but not limited to, externalities resulting from extractive development.

**4.2. Climate in the energy–water–forest–food nexus**

It is anticipated that climate change will alter variability and streamflow water volumes, impacting green water availability, with implications for hydropower production (energy and forests), aquatic systems (water, food/fisheries), and agricultural production (food systems). Having the capacity to integrate local and extra-local knowledge of the nexus, and successfully communicate this knowledge to local communities, is a precondition for a socially acceptable and ecologically viable energy system on the *comarca*.

**4.3. Energy within the water–forest–food–climate nexus**

Even though the *comarca* and the surrounding area (Changuinola-Teribe watershed) concentrate most of the country hydropower potential, the Ngäbe–Buglé *comarca* has the lowest electrification coverage in the country (4%), followed by the *Comarca* Guna Yala (15%), and the *Comarca* Emberá (35%), which stands in sharp contrast to the electrification rate in the province of Panamá (94%) (INEC, 2010; AECID, 2019). While the number of rural households without electricity observe a declining trend across the country, in the Ngäbe–Buglé *comarca* it is estimated to be still rising (from 26,256 households in 2010 without electricity to 28,818 in 2017) (AECID, 2019). Access to electricity, particularly when provided via distributed power using renewable sources, can support livelihood alternatives that are not disruptive to the nexus; solar energy can be used to produce safe drinking water, small photovoltaic (PV) systems can improve small-scale local food production, while reducing the need to cut wood used for cooking or heating.

Relying on large-scale energy systems (fossil-fuel or hydropower) to supply *comarca*’s energy needs may run counter to climate science, as it poses a risk to the ecological systems along the watershed. Moreover, efforts to develop large-scale energy projects clashed with local preferences and cultural protocols, and are known to have resulted in violent conflict on the *comarca*. Energy development projects (e.g., Changuinola I and II) (Figure 1c) were locally perceived to be a venue for opening up the *comarca* to subsoil resource extraction (e.g., mining activities) and have been historically contested (Table 2).

**4.4. Forests within the energy–water–food–climate nexus**

The Indigenous *comarcas* of Panama contain an estimated 54% of the country’s primary forests, and as such are critical for the conservation of biodiversity (Sharma et al., 2016). Municipalities of Kankintú and Besiko (*Comarca* Ngäbe–Buglé) overlap with protected areas of Bosque Protector de Palo Seco (BPPS) (125,000 hectares), and the district of Ñokribo with Humedal de Importancia Internacional Damani Guariviera (24,089 hectares). Additionally, the *comarca* partially overlaps or contains other protected areas of both national and regional significance – Bastimentos Island National Marine Park (BINMP), RAMSAR sites (‘Wetlands of International Importance’), La Amistad International Park (PILA), and Areas Insulares (Islands in the Bocas del Toro Archipelago), some of which are Annex areas. Forests are essential to the proper functioning of the ecological systems – in the *comarca* and beyond (Peters et al., 2019). Among other things, they retain moisture and help provision fresh water supply in small streams, which becomes disrupted in deforested areas (Figure 1). For Ngäbe, primary forest – *kätogwá* in Ngäbere – is a resource that complements other aspects of Ngäbe livelihood strategies (Smith et al., 2017). Forests are valued for the multiple services they provide, including provisioning ecosystem services (e.g., firewood, food, house construction materials, medicines), and cultural
ecosystem services (e.g., traditional identity, sense of place, spirituality). Wild plant foods including palm heart, fruits, vines and ferns are harvested for consumption, such as mitra (Prestoea acuminata) and the fruits of the ñurun palm (Chamaedorea tepejilote) (Smith et al., 2017).

Deforestation rates in the Comarca Ngäbe–Buglé have been high (Vergara-Asenjo & Potvin, 2014), with a reported total loss of 21.8% between 1992 and 2000. Deforestation may be attributed to an informal customary forest tenure that grants individuals or small groups exclusive control over harvested resources in the forest, including the right to clear them for agriculture—all while these lands are part of the commons. Access to the resources is nonetheless highly uneven, as some households reportedly control large areas of primary forest, while others only have small, or no plots at all. Under this arrangement, deforestation is entirely in the hands of the informal plot harvester-owners (Smith et al., 2017). To prevent deforestation, actionable, effective policies need to be in place to disincentivize deforestation, and provide instead a range of other, sustainable and climate-compatible economic activities (beyond mining). With the proposed introduction of small-scale energy systems, more diverse sustainable development activities can reduce environmental pressures arising from the currently dominant logging or cattle ranching activities.

Table 2. Contested energy-related initiatives in or around the Ngäbe–Buglé comarca (partial account).

| Period | Energy project | Outcome |
|--------|----------------|---------|
| 1960s  | Attempts at copper mining (hydropower needed) | Opposed |
| 1981   | Hydroelectric plant on the Tabasará River planned (for Cerro Colorado Copper Mining) | Opposed |
| 1997   | Tabasará I and II hydroelectric plant planned | Opposed |
| 1990s  | Mining applications issued on 80% of the comarca | No local community consent |
| 2003   | Law 41 of 1998 (repeals legislation requiring consent for industrial and commercial use of resources) | Opposed |
| 2008–16| Barro Blanco hydroelectric plant under construction (Annex area) (20–28 MW) | Contested |
| 2011   | Chan I dam, completed despite ongoing litigation | 1000 people displaced |
| By 2012| 19 dams built or under construction in the comarca (Bocas Del Toro, Chiriquí and Veraguas provinces) | Community response unclear/not known |
| 2012   | Law 11 of 2012 prohibits mining in the comarca | Result of public pressure |
| 2014   | Chan II (224 MW) | Under concession, cancelled, then the concession reissued |
| 2018   | Acciona Micro Energia Foundation (AECID) plans to extend electricity access to 2500 households using off-grid solar (pay-as-you-go model for service provision) | Effort at engaging local communities in the preparatory phase, the extent of participation is unclear |
| 2019   | Interconnected system expansion plan (PESIN) underway focused on decarbonizing the current power matrix; third and fourth power lines under construction (adding 800 and 1280 MW) | Participation and inclusion in the planning phase are unclear; the project is contested by some communities |
4.5. Water within the energy–forest–food–climate nexus

Water used in electricity production marked a 435% increase between 2002 and 2017, compared with 61% increase in household consumption, while water used in agriculture declined by 37% in the same period (Figure 2). Dependence of hydropower energy generation on forests in the tropics has been explicated (Stickler et al., 2013). Moreover, large-scale energy projects, including dams and hydropower plants, have historically presented challenges for local livelihoods, disrupted inter- and intra-community relations, and often resulted in out-migration. Along watersheds, high levels of pesticide use in agriculture produced toxic landscapes and water contamination that pose severe health risks for local communities who depend on the access to water and fish for survival. Reported cases of water-related diseases have increased from 191,000 in 2008 to 271,000 in 2016 (MiAmbiente, 2019). Biological quality of water resources tested around the comarca (i.e., Volcán Barú) reported high levels of water contamination and species loss, attributed to pesticides use along the watersheds. In the six regions along the Chiriquí Viejo watershed, approximately 1500 individuals use contaminated or highly contaminated water. Lack of water and sewer systems pose additional concerns, since contaminated water is being discarded without prior treatment to the environment (Miller et al., 2017). Broad-scale water testing needs to be conducted to ensure safe water quality.

5. DISCUSSION

The nexus approach, combined with energy justice perspectives, is proposed to answer two related research questions. First, will the emerging energy systems on the comarca mirror the past experiences of uneven distribution of costs and benefits, or improve livelihoods and livelihood prospects for local communities who lack energy access? Second, will such a system boost opportunities for self-determined, culturally and ecologically appropriate development, or deprive communities of access to local resources on which they crucially depend, eventually resulting in collective displacement and out-migration? This conceptual framing makes it possible to demonstrate how large-scale energy systems, when disembodied from both energy justice and the ecological nexus, risk reproducing prior inequities and amplifying past injustices.
Because Ngäbe livelihoods are linked to the availability of water supply, some parts of the comarca rely on water from the Changuinola-Teribe watershed that has been since the 1970s exploited for its hydroelectric potential (Jordan, 2008). Data collected show that even as water use in electricity production increased nationally by 435% (2002–17) and in household consumption by 61% (Figure 2), Indigenous communities living in the vicinity of the hydrological source remain without electricity access, and in many areas without access to safe drinking water. The nearly universal access to electricity in the country’s capital contrasts with the 4% electricity coverage in the Ngäbe–Buglé comarca. Both water availability and water quality are of key concern in the comarca, since large water reservoirs in the tropics have been reportedly high methane emitters, disruptors of biogeochemical cycles and under high temperatures, a source of toxic blooms. A faster uptake of water co-management programmes on and around the comarca are needed to ensure sufficient supply of safe water for multiple uses on the comarca. Capacity needs to be built to support source water protection at a local scale, since comarca communities have no or limited resources to develop this capacity internally. This should imply all of the following: (1) protecting source water from contamination, (2) identifying sources and threats of contamination, (3) treating drinking water to meet the required standard and (4) consistently and continuously maintaining, monitoring and testing the water system, without reliance on private sector actors (Patrick, 2019).

The nexus approach can be applied in energy development policy when projects are scaled down, and when distributed energy systems and off-grid solutions become embedded in the energy–water–forest–food–climate nexus. Given the historical context of the comarca (Table 2), small-scale, ecologically compatible energy systems seem to be not only a culturally appropriate approach that can be linked to the Indigenous livelihood discourse, but also an economically more productive solution, by providing additional opportunities for more diversified bioeconomic activities in the area. When accounting for environmental, climate and energy justice concerns, small-scale rural approaches need to continue incorporating nexus-based ecological knowledge if they are meant to constitute viable and sustainable future trajectories. This implies prioritizing local livelihoods over energy or mining projects which result in an increased water footprint, and negatively impact local water provisioning. Other factors need to be considered in nexus approaches, such as the tensions between green water for humans versus nature. The choice of cattle farming, for example, will likely speed up the pace of deforestation and exacerbate green water scarcity.

Juxtaposed against the context of Indigenous comarcas, procedural energy justice would imply procedures and processes, to which equal access is guaranteed and realized (access to knowledge, information, full disclosure about projects planned on Indigenous territories; access to law; participation in decision-making, policy formulation, free, prior and informed consent – FPIC). Distributional justice in this context refers to a just distribution of costs and benefits of proposed energy projects, opportunities and capabilities; enforcement of non-discrimination to ensure both equitable benefit-sharing schemes and remedies for harms done. Recognition justice denotes the institutionalized and enforced recognition of the political and cultural diversity, which can either promote, or by contrast, disincentivize self-determined development. Without recognition justice, procedural and distributional justice for Indigenous communities cannot fully materialize.

When viewed from the perspective of rural livelihoods, developing energy systems in Indigenous territories based on energy justice considerations would favour designs based on sufficiency, but which would make it possible to enhance local livelihoods, and focus on supporting local (rural) needs and capabilities over the long term (sustainable farming and agroecology, fishing, silvopastoralism). If energy justice is framed by rural livelihood perspectives, valuation of natural assets should be concerned with satisfying local social and ecological needs, and prioritize community approaches built around small-scale livelihood
strategies. Put differently, what is needed is not to deprive Indigenous communities of natural resources and opportunities to pursue small-scale rural livelihoods into the future, but rather, provide them with support to sustain culturally appropriate development for decades to come. In the absence of an energy system based on clean renewables, livelihood prospects for sustainable local bio-economies remain slim.

While small-scale, renewable energy systems on the *comarca* will likely enhance future livelihoods of its population, fossil-fuel and/or large-scale energy systems are likely to exacerbate social and ecological inequities experienced by local communities living around the project sites. National policies and co-management plans that offer local communities opportunities to benefit from nexus approaches, would also benefit national climate strategies. This implies training, technical assistance, and support in project execution across the energy–water–food–climate nexus (see the supplemental data online). Lack of such programmes will likely incentivize the wrong type of economies (e.g., small-scale mining, pesticide overuse to guarantee yields, logging, and cattle grazing – all with negative impacts on the forests). Ironically, losing the forests would in the end undermine national interest, since forests guarantee the efficiency of water flows, thus the productive capacity of the large-scale hydropower plants in the area.

5.1. Limitations and implications for future research
Several questions have been opened up by this research, and remain unanswered, while others are not exhaustively answered, such as: Under which conditions can energy development become a vehicle by which Indigenous inequities become addressed and resolved – in the self-defined interest of the Indigenous communities? While the study focused on the importance of the local cultural and ecological context for the choice of energy systems that could improve rural Indigenous livelihoods, it did not account for other factors, such as horizontal inequalities, internal community division or intergenerational conflict. Other questions have exceeded the scope of the study and could not be substantively advanced, namely: Which assumptions should context-specific energy development discourse and practice rely on, if not economic growth, free markets, individualism? Or, are there broader social and economic developments and processes researchers should account for when envisioning energy trajectories in Indigenous territories? These questions, as well as data points generated in this study can be taken up by researchers in the future.

6. CONCLUSIONS
As demonstrated in this study, energy development projects, when not designed as part of the energy–water–forest–food–climate nexus, have historically had adverse effects on local communities by reducing the availability of livelihood-sustaining resources such as water or by disabling access to otherwise ‘free’ resources, in effect depriving affected communities of the right to self-determined development (i.e., own means of subsistence). By eroding the economic base – land and resources – the marginalized communities, those that the development practitioners are tasked with bringing out of poverty, are in fact sinking deeper into poverty. The nexus approach can thus be seen as a new economic–ecological rationality, based on prior concepts of small-scale rural livelihoods and planetary boundaries, which may be the preferred rationality from the perspective of local rural communities. This approach could be used in energy planning and focus on meeting the needs of local communities, in line with commitments to sustainable development goals and their internal coherence. By contrast, energy planning that accounts for neither the nexus approach nor the three dimensions of energy justice can halt or even reverse progress made in sustainable development.

Large-scale energy systems needed for industrial development of the expanding Latin American megacities and heavily populated urban areas, where 50% of Latin America’s Indigenous peoples reside, stand in sharp contrast to what can be imagined as an equitable energy
solutions (e.g., off-grid solar) for remote rural areas where the other half struggles to survive, often closely connected to land and the natural environment. In Indigenous comarcas that lack energy access, distributed power backed by energy storage can exponentially boost local livelihood capacity (i.e., small-scale rural development).

The task for energy developers, as suggested in this study, is not to shift communities from remote settings of the comarca to already built material environments with pre-existing energy systems, but to develop culturally appropriate, small-scale energy systems based on Indigenous worldviews and cultural protocols, while respecting ecological and climate compatibility. In this view, Indigenous lifestyles are not envisioned as needing to conform to the energy system; rather, energy technology solutions are to be designed (and incrementally innovated) to conform to Indigenous livelihood needs.

Importantly, since the comarcas do not yet have developed energy systems, it is of key importance that impartial technology assessment is conducted – before any such systems are introduced into the tropical, biodiversity-rich environment. The technology assessment process needs to ensure the prioritized energy technologies are suited to the comarca’s biodiversity-rich tropical environment (Bebbington et al., 2020), and at the same time least disruptive to its fragile ecological systems, which implies accounting for the interlinkages within the energy–water–forest–food–climate nexus.

Table 3. Recommendations for energy policymakers and practitioners.

| Approaches                              | Issues defined                                                                                                                                                                                                 | Solutions                                                                                           |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Urban versus rural energy               | In Indigenous comarcas, energy systems, including those that are yet to be designed, need to reflect specific cultural–ecological contexts and address local livelihood needs, with special attention paid to risks of contamination, resource depletion and biodiversity loss | This implies a choice of clean renewable energy technologies, and the polycentric, rather than centralized, nature of the energy infrastructure (distributed power) |
| National emission targets versus local livelihood needs | Past and present energy policies tend to focus on generating revenue and/or meeting national emission targets, which comes at a high cost to local communities | Carefully crafted energy policies based on a nexus-based approach, underpinned by procedural, distribution and recognition justice can benefit both national climate plans and simultaneously provide preconditions for culturally appropriate local bio-economies |
| Large versus small scale                | While hydropower is an indispensable source of clean renewable energy, the location and scale to a great extent determine whether the cost to local cultures and ecologies will outweigh benefits, and eventually undermine sustainability objectives of national economies | Biodiversity-rich, densely forested tropical zones require comprehensive, state-of-the-art technology assessment incorporating the latest scientific knowledge to determine the optimal design, scale and location of the energy infrastructure |
| Externally determined versus self-determined energy pathway | Residents of the comarca need to develop and exercise both agency (the ability to make their own choices) and capacity (the ability to implement them) in ways that are socially and ecologically sustainable | Both agency and capacity require specific capabilities, skills, training, and co-management to ensure the energy system is both socially acceptable and ecologically appropriate |
Developing local capacity in the energy–water–food–climate nexus is a precondition for good outcomes. Technical support will be needed to address knowledge gaps and to train local communities (e.g., maintain the energy systems, monitor hydrological systems, habitats and biodiversity, or co-pilot and co-manage conservation initiatives). Importantly, training and co-management programmes need to include building capacity to ensure the required standard of water quality is achieved, without reliance on private sector actors.

Additionally, political will is needed to negotiate shifts toward new (more ecological) practices that bring long-term benefits, but also sufficient short-term rewards so that communities are lifted out of condition of deprivation and achieve self-determined well-being (Table 3).

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