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"Leave no one behind". A power-capabilities-energy justice perspective on energy transition in remote rural communities in Cambodia

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A R T I C L E I N F O

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A B S T R A C T

Over the past two decades electricity access in Cambodia has increased considerably. The Electricity Authority of Cambodia has announced that the country expanded energy access from 34% in 2010 to 98% by mid-2022, but that 245 villages still lack access to the national distribution network due to their remoteness. For some of these villages, off-grid renewable energy systems have played a significant role in providing electricity access. However, connecting villages to the grid or providing them with off-grid renewable energy is not enough to overcome energy poverty and achieve people's well-being. In this paper we apply a power-capabilities-energy justice framework to analyse social justice concerning renewable energy and energy poverty in remote communities. Based on primary data collected through interviews and focus group discussions, and using a social network analysis (SNA) we approach capabilities and energy poverty in Cambodia as a relational process and we provide for the first time a through picture of social and power relations in the Cambodian energy sector. Our study finds that communities and vulnerable groups such as female-headed households, located in remote rural areas are suffering distributional energy injustice in that they have access to a limited range of energy services to fulfil basic capabilities, such as being in good health, being educated and socially connected. We also find that distributional energy injustice is closely connected to power relations and relationality aspects of the Cambodian energy sector, as well as a lack of recognition of different vulnerabilities in energy policies.

1. Introduction

One of the central, transformative, and universal values of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) is to "Leave no one behind" (LNOB). This represents the commitment by UN Member States to eradicate poverty, reduce rising inequalities and vulnerabilities, end discrimination, marginalisation, and exclusion that prevent people from accessing services, resources, and equal opportunities to development and well-being. According to the LNOB universal value, identifying inequalities requires looking at the multidimensional and intersectionality aspects of vulnerabilities, such as gender, geography, age, and the root causes that generate them, such as laws, policies, and social practices.[1] It is an overarching, universal value that all countries are required to implement in achieving the 17 SDGs, which are a call to action to "end poverty, protect the planet and improve the lives and prospects of everyone, everywhere".[2]

SDG 7 is about ensuring access to affordable, reliable, sustainable, and modern energy for all. Indeed, in the Agenda 2030 for Sustainable Development, lack of energy access is considered one of the main challenges that "hinder the achievement of economic and human development" (*ibid.*). Although in recent years energy access has been improving worldwide, regions and countries in Southeast Asia and Africa are still lagging. In Sub-Saharan Africa, more than 50% of the region's population still lacks access to electricity (UNCTAD, 2023). Even though in Southeast Asia around 95% of households have access to electricity for lighting and 70% use clean energy for cooking, these

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[1] UN Sustainable Development Group. Leave No One Behind (https://unsdg.un.org/2030-agenda/universal-values/leave-no-one-behind).
[2] UN Sustainable Development, The Sustainable Development Agenda (https://www.un.org/sustainabledevelopment/development-agenda/)

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shares remain low in Cambodia and Myanmar (IEA, 2022): Cambodia's electrification rate is the second-lowest among Southeast Asian countries (IEA, 2022). Despite progress being made in recent years, the International Energy Agency estimates that by 2030 1.3 million people mostly living in rural settlements in Cambodia and Myanmar will still have no access to reliable and affordable electricity (IEA, 2022).

Lower electrification rates in Cambodia than in other countries in Southeast Asia are associated with historical events. Three decades of civil war (1968–1998) have prevented the country from investing in energy infrastructures and electricity facilities (more details in Section 3). However, in the past two decades Cambodia has experienced significant economic growth that has allowed the country, with the help of international donors, to invest in new energy infrastructures, such as the construction of new power plants and the expansion of the electricity transmission network (World Bank, 2024). The Cambodian government has also attracted private investments in the power sector through the introduction of independent power producer (IPP) schemes. As a result, the Electricity Authority of Cambodia (EAC) has recently announced that energy access grew from 34% of all villages in 2010 to 98% by mid-2022. However, over 200 rural villages still lack access to the national grid due to their remoteness. These areas are considered Cambodia's 'last non-electrified frontier' (Chevillard, 2023; AMPERES, 2023). For some of them, off-grid renewable energy (RE) has played a significant role in providing electricity access. However, connecting villages to the grid or providing them with off-grid RE is not necessarily enough to overcome energy poverty and achieve people's well-being, as in Cambodia the rural–urban and gender divides, as well as energy reliability, safety and affordability remain challenging (Han et al., 2020; Han and Kimura, 2019; Khanna et al., 2019). In this context, the limitations of the energy poor to fulfil basic needs are reflected in their low energy consumption, struggle to pay connection fees, and challenges in procuring household wiring and appliances. In fact, even many households in 'electrified' villages in Cambodia lack electricity access (a condition known in the literature as being 'under-the-grid'). Energy poverty is around 33% nationwide and persists especially among the rural population (Han and Kimura, 2019). According to a study comparing energy poverty in the ASEAN region and India, Cambodia is the energy poorest (Khanna et al., 2019). The groups most vulnerable to energy poverty are female-headed and rural households (Han and Kimura, 2019).

The multidimensional nature of energy poverty requires to look at the problem from multiple perspectives, including reliability, safety and affordability, and how these aspects are linked to various forms of social (in)justice that hinder especially marginalised and vulnerable groups from adopting energy sources, and prevent access to fundamental energy services (Khanna et al., 2019). Looking at energy poverty from a social justice lens, inequalities of energy access are closely linked to energy justice and to power relations, which influence policy and practice and the governance process of energy decisions (Chipango, 2023).

In the literature that combines Sen and Nussbaum's capabilities approach (Sen, 1993; Nussbaum, 2011) with studies on energy poverty, energy poverty is defined in capabilities terms, as "an inability to realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services, and taking into account available reasonable alternative means of realising these capabilities" (Day et al., 2016: 260). Following this reasoning, the capability of a person to fulfil their needs related to energy access depends on a variety of factors, including personal characteristics and social/institutional arrangements. Therefore, capabilities can be affected as a direct or indirect result of individual (e.g., affordability, ability, gender), social/institutional (e.g., reliability of the energy produced and technological aspects, policy frameworks, financial support, due process and power relations) and environmental/geographical barriers (e.g., weather conditions, geographical location) (Middlemiss et al., 2019).

While much research has focused on analysing the relationship between capabilities, energy poverty and justice (Bartiaux et al., 2019; Arnaiz et al., 2018; Day et al., 2016; Lee et al., 2021; Groves et al., 2021; Melin et al., 2021, among others), focusing on "individual capabilities to what each individual is able to be or do" with respect to accessing or not accessing certain energy services (Chipango, 2023: 1), less research has explicitly looked at the linkages between energy poverty, capabilities, and power relations (Chipango, 2021; 2023). Chipango (2023: 1) argues that "energy poverty is socially constructed by prevailing social and political-economic relationships," and therefore a capabilities approach needs to focus on relationality aspects. In their work on social relations, capabilities and energy poverty, Middlemiss et al. (2019) show that social relations are fundamental to address energy poverty as people rely on friends, families and key agency workers for information, support and advice.

Drawing on this literature, we approach capabilities and energy poverty in Cambodia as a relational process. Through a social network analysis (SNA), we provide for the first time a through picture of social and power relations in the Cambodian energy sector. Besides providing additional empirical evidence to the existing studies, we also contribute by looking further into the relationality aspect at the intersection of power, capabilities, inequalities, and energy poverty.

The 'capabilities' approach, as further explained in the next sections, refers to the real opportunities or abilities that people have to achieve various 'functionings.' Robeyns (2011) defines capabilities as "the real freedoms that people have to achieve their potential doings and beings"; they are the ability to achieve determined 'functionings' (Sen, 1992). Capabilities are the states and activities that a person is able to be or do, such as being healthy, educated, or socially connected. In this work, we draw on a critical reading of the capabilities approach based on the assumption that power/politics and justice dimensions are central elements of energy poverty. By applying a power-capabilities-energy justice framework we analyse how different actors, policies and practices influence specific functionings and, consequently, some capabilities of the energy poor. The power/politics and justice lenses give the opportunity to move away from a simple account of the materiality of energy and energy systems by offering a normative basis that combines material interventions with relationality aspects (Balmaceda et al., 2019), namely the web of social and political relations to evaluate what constitutes a just energy transition. We base our analysis on a qualitative approach using primary data collected through interviews and focus group discussions.

In the following sections, we define our power-capabilities-energy justice conceptual framework by first discussing some key concepts of Sen and Nussbaum's capabilities approach; then, we examine the hybridisations of this approach with the energy poverty and the energy justice literature. After discussing issues of energy affordability, safety and reliability in the case study area, and our research methods, we describe our findings in terms of power relations and social network analysis, and we connect them with local issues of capabilities. Finally, we draw together our findings within an energy justice framework and conclude with policy recommendations.

2. Energy, social justice, and capabilities

2.1. Social justice and development: The capabilities approach

Sen's capabilities approach emphasises the importance of evaluating people's well-being based on their actual capabilities to achieve the functionings they value, rather than solely on their income or wealth. Functionings and capabilities relate to both freedom of choice and what people can achieve and do. Sen argues that enhancing people's capabilities should be the primary goal of development, and that policies and programs should be designed to increase people's opportunities to achieve the functionings they value (Sen, 1993; Nussbaum, 2011). As Sen observes: "The capability approach to a person's advantage is concerned with evaluating it in terms of his or her actual ability to achieve various valuable functionings as a part of living" more than its actual quantitative value (Sen, 1993: 31).

Drawing on Sen, Corvino et al. (2021) further distinguish among three different parameters that can be adopted as measures of wellbeing and informational bases of justice: realised achievements, means to achieve, and freedoms to achieve (Sen, 1992, 1999). Nussbaum (2000) further develops the capabilities approach by identifying a list of ten core capabilities that are necessary for people to live a dignified life, such as the capability to live a healthy life, to engage in meaningful work, and to participate in political decision-making. She argues that these capabilities are essential for human flourishing and that policies and programs should be designed to ensure that all people can achieve them. Nussbaum's core human capabilities have been applied to energy systems, resulting in a variety of 'energy capabilities' as discussed in the next sub-section (Hillerbrand, 2018; Hillerbrand and Goldammer, 2018; Pellicer-Sifres et al., 2021).

A growing number of studies, including by Nussbaum herself, have been investigating the capabilities approach in relation to intersectionality and gender. Nussbaum (1999) has emphasised how many of her 'core' capabilities were often not enjoyed equally by individuals belonging to different genders. In 2014, she co-edited a volume on capabilities, gender, and equality, highlighting the contribution of capabilities approach to gender studies and feminist economics (Comim and Nussbaum, 2014). Energy-related studies on capabilities and gender have also been increasing in number over the last five years: as with our study, a considerable number of them have focused on Global South countries, as we show in the next subsection.

2.2. The capabilities approach and its relationship with energy poverty, power, and energy justice

The literature has showed that the capability framework is a useful approach for analysing the relationship between energy poverty and social justice as it allows to look at how unequal access to energy services relates to social inequalities and influences people's capabilities to fulfil their needs (Bartiaux et al 2019; Chipango, 2021; Arnaiz et al., 2018; Day et al., 2016; Lee et al., 2021; Groves et al., 2021; Melin et al. 2021). According to this literature, access to energy per se is not necessarily enough to overcome energy poverty and achieve people's wellbeing, and the energy services accessed and the real opportunity to perform important capabilities for "meeting their needs" are more significant (Chipango, 2021: 447).

In relation to energy poverty, access to reliable energy services throughout the year is fundamental to fulfil elementary capabilities such as being in good health, being well-nourished, engaging in meaningful work, being educated (Day et al., 2016; Middlemiss et al., 2019; Frigo et al., 2021).

Energy use and access are strongly related to gender issues, and to the lack of opportunities for women's empowerment in energy decision-making (Moniruzzaman and Day, 2020). In this respect, Gill-Wiehl et al. (2022) have studied off-grid solar energy in rural Tanzania and argued that despite women and low-income households experiencing a disproportionate burden of energy poverty, many electrification plans do not take those aspects into account.

These intersecting inequalities require looking at energy systems through a social justice lens. In this respect, the energy justice literature has identified eight principles that are important in relation to equity in energy provision: availability, affordability, due process, information, prudence, intergenerational equity, intragenerational equity, and responsibility (Sovacool, 2013). Three of these principles are analysed in this article, namely availability (and reliability), affordability, and due process.

Despite the criticism the energy justice concept has received (e.g., for the theoretical and practical implications of its origins in the Western liberal philosophical tradition) (Pellegrini-Masini et al., 2020), energy justice and its formulations are proving a fertile framework for hybridisations, including with the capabilities approach (Wood and Roelich, 2019; Velasco-Herrejon and Bauwens, 2020). In 2021, a special issue of the *Journal of Human Development and Capabilities* was published on the connections between these two approaches (Melin et al., 2021), and it is easy to see common ground: for example, the energy justice principle of availability is related, among other factors, to the reliability of the energy services; this, in turn, refers to the opportunity to rely on an adequate amount of (uninterrupted) energy sources throughout the year to fulfil elementary capabilities and basic needs (Frigo et al., 2021).

In relation to power relations, social and institutional arrangements in connection with the capabilities approach, Chipango (2021) investigates the relationship between energy poverty, social suffering and a lack of capabilities, and argues that "capabilities are a function of power relations" (Chipango, 2021: 448; on this point, see also Groves et al., 2021). She also argues that Sen's capabilities framework is "insufficient to conceptualise a multidimensional phenomenon such as energy poverty" (Chipango, 2023: 2). She points out to the need to achieve a better understanding of "how policy could be an enabler or constraint in addressing energy poverty" (Chipango 2021: 463) and therefore favour or hinder the capability of the energy poor to achieve valuable functionings. Other scholars suggest that social relations and institutional choices by powerful actors may constrain or enable access to modern energy resources and result in unequal allocations, exclusion and discrimination of certain groups of people (Pachauri and Rao, 2013).

Based on this argumentation, in this paper we apply a power-capabilities-energy justice framework to look at power relations and how social positioning affects capability deprivation. We look at vertical power relations as the main driver of socio-ecological changes in poor and remote rural areas (Bryant, 1998). Vertical power relations are defined as "relations of power exercised by actors external to a community" (Ramcilovic-Suominen and Kotilainen, 2020: 3) and may include governments with power to design and impose policies, regulations and rules on the communities, as well as international development partners, civil society organisations or other external agencies, which influence communities through providing funding, technical support, advice and information. We therefore focus on policies, decision-making procedures (due process), the web of social relations and actors' positionality (Moon, 2019) to illustrate how institutional forms of power may enable remote communities in Cambodia to access energy resources, or constrain their access, and therefore may result in (un)intended effects on their capabilities by reinforcing existing inequalities and marginality (Ahlborg and Nightingale, 2018). To analyse power relations, we use SNA as an approach for investigating social structures (Zhang, 2010), and more specifically the social network of energy governance in Cambodia. Such an analysis is meant to identify key actors, their links and influence, to gain a better understanding of governance in relation to energy access, social justice, and capabilities. To contextualise the application of our power-capabilities-energy justice framework, in the next section we provide a sketch of the Cambodian power sector.

3. Energy policies and targets in the Cambodian power sector

In Cambodia, until the late 1990s, local energy generation was on a relatively small scale, and was mostly from diesel and oil generators (Mika et al, 2021). Electricity imported from neighbouring countries accounted for most of the supply. Distribution covered mainly urban areas, with a few exceptions in rural areas (Chhay & Yamazaki, 2021). The low electrification rate in Cambodia was linked to historical events. Three decades of civil war (1968–1998) have prevented the country from investing in energy infrastructures and many electricity facilities, including generation, transmission and distribution systems were destroyed during the Khmer Rouge regime (1975–1979). After peace was restored in 1998, access to electricity in rural areas accounted for 5.4% (Chhay & Yamazaki, 2021). In 2001, an Electricity Law was passed that promoted private ownership of energy facilities to attract private investors and help the country with the development of the power sector. Today both the government-owned company Electricité du Cambodge (EDC), private Independent Power Producers (IPPs) and private Rural Electricity Enterprises (REEs) produce and distribute electricity in Cambodia.

In recent years Cambodia has experienced remarkable economic growth. The World Bank estimated an average annual economic growth rate of 7.6% between 1995 and 2019 (World Bank, 2024). As a result, investments in energy infrastructures have increased and at present Cambodia is generating much more of its own electricity, mainly from hydropower dams (52.4% of its electricity production) and coal-fired plants (35.9%),[3] although electricity imports are still significant, with net imports covering 29% of the demand in 2021 (IEA, 2021). Despite improvements, problems of efficiency, affordability and reliability remain prominent (Mika et al., 2021). The presence of private enterprises, such as IPPs and REEs responsible of the production and distribution of electricity, is considered one of the main causes of the high electricity prices and low energy reliability in Cambodia, especially in rural areas (see also Section 4.2).

To better understand energy transition in the country, in the remaining of this section we provide an overview of the main policies, plans and strategies related to the energy sector in Cambodia since the promulgation of the Electricity Law in 2001. These refer to energy efficiency, rural electrification and development plans, carbon neutrality, RE deployment and specific roadmaps and regulations for solar electrification (Table 1) (Electricité du Cambodge, 2020a, 2020b).

The Power Development Plan (PDP) of Cambodia includes the strategy for the country's energy sector for the period from 2022 to 2040. The plan's main aims are: to meet growing electricity demand while ensuring the security, reliability, and affordability of energy supply; to improve efficiency and reduce emissions through the deployment of RE. These objectives also underpin the National Policy and Strategic Plan for Green Growth (2013–2030), and Cambodia's Nationally Determined Contributions (NDC) as part of the country's commitments to the United Nations Framework Convention on Climate Change (Ministry of Mines and Energy, 2022).

The energy targets included in the plan are set to maximise the deployment of domestic RE, especially solar energy, as well as improve energy efficiency (Table 1), while excluding the development of additional coal plants and hydro dams on the Mekong River (Ministry of Mines and Energy, 2022). The plan therefore recognises the importance of transitioning from fossil fuels to renewable sources to achieve the overall 42% emission reductions by 2030 as set in the long-term strategy for carbon neutrality by 2050 (Kingdom of Cambodia, 2021) and at the same time avoid environmental and social impacts of large dam construction (Ministry of Mines and Energy, 2022). However, despite the Government's announcement of a 10-year moratorium on mainstream dams (from 2020 to 2030) (Ratcliffe, 2020), in 2020 it has completed feasibility studies for the construction of new dams and is reconsidering the construction of large dams along the Mekong River, as in the case of Stung Treng dam (Sivutha, 2022).

Regarding coal plants, as said, in 2021 the Ministry of Mines and Energy announced that Cambodia would not build new such plants; however, the installed power capacity of the Power Development Plan (PDP) in 2022 shows that if all the approved/planned coal power plants were built, coal plant capacity would be almost doubling (from 1,216 MW to 2,266 MW). Moreover, only 15.8% of the 56.3% RE facilities to be realised by 2030 is non-hydro, and that is far below the RE target recommended by ASEAN (Ministry of Mines and Energy, 2022).

The deployment of non-hydro RE, such as solar energy, presents some challenges: unclear regulatory frameworks on tariff structures and grid integration, the lack of policy support such as feed-in-tariff, net metering, or green certificates, high upfront costs, and the presence of Power Purchase Agreements (PPA) to be signed with EDC,[4] to allow

Table 1
Summary of energy policies, targets, and financing environment in Cambodia.

Energy related policies and strategies	• Electricity Law (2001) • Rural Electrification Master Plan (2006) • National Policy on Rural Electrification by Renewable Energy (2007) • Power Development Plan (PDP) (2022–2040) • National Climate Change Strategic Plan (2014–2023) • Long-term strategy for carbon neutrality by 2050 (2021) • Energy Efficiency and Conservation Master Plan of Cambodia (2020) • National Policy and Strategic Plan for Green Growth (2013–2030) • National Strategic Development Plan (2019–2023) • Cambodia Basic Energy Plan (2019) • National Energy Efficiency Policy 2022–2030 • Cambodia EV roadmap (2022) • GOV Regulation on General Conditions for connecting Solar PV Generation sources (2018) • Principles for Permitting the Use of Rooftop Solar Power in Cambodia (Ministry of Mine and Energy, 2023)
Fossil fuel and RE target(s)	According to PDP 2022–2040, the domestic installed capacity supply mix in 2030 will be: • 2,266 MW of Coal (40.4%), 1,558 MW of Hydro (27.7%), 490 MW of Fuel Oil (8.7%), 1,005 MW of Solar PV (17.9%), 200 MW of Battery Energy Storage System (BESS) (3.6%), 98 MW of Biomass (1.7%) • 3,095 MW of power imports from Laos, 700 MW of power imports from Thailand • 1,215 MW of capacity saved through the adoption of energy efficiency measures. By 2040: • to 2,266 MW of Coal (21.4%), 2,973 MW of Hydro (21.4%), 490 MW of Fuel Oil (4.6%), 900 MW of natural gas (8.5%), 3,155 MW of Solar PV (29.8%), 420 MW of BESS (5.8%), 198 MW of Biomass (1.9%) • 3,095 MW of power imports from Laos, 1,000 MW of power imports from Thailand • the equivalent of 2,205 MW of capacity saved through the adoption of energy efficiency measures.
Feed-in tariffs, net metering and green certificates	• No feed-in tariff (FIT) for grid-connected RE systems to sell to grid • No net metering, no net billing policy or green certificates
Financing support for the poor	• Rural Electrification Fund (2020) – Electricité du Cambodge (EDC) provides financing support for the operation of the Renewable Energy Fund and the implementation of three programs (Power to the Poor (P2P); Solar Home System (SHS); Assistance to Develop Electricity Infrastructure in Rural Areas (EDC, 2020). • Programme to subsidise low-income households: the subsidy amounts to 380 Riels/kWh from 1kWh to 10 kWh of monthly consumption; to 480 Riels/kWh from 11kWh to 50 kWh; to 610 Riels/kWh from 51kWh to 200 kWh; and to 730 Riels/kWh for a monthly consumption that exceeds 200 kWh).

Source: Authors' elaboration.

[3] IEA Countries – Cambodia. Energy mix – Electricity generation mix, Cambodia, 2021 (https://www.iea.org/countries/cambodia)

[4] EDC is co-owned by the Ministry of Mines and Energy and the Ministry of Economy and Finance. It is a vertically integrated power utility responsible for the generation, transmission and distribution of electricity in the country. More details on its functions are provided in paragraph 6.2.

excess production (over 50%) to be fed into the grid, have constrained the private sector and international investors from scaling up solar energy and increasing the share of RE use in urban areas (Han, 2015; GIZ, 2021). To tackle some of the above issues, the Ministry of Mines and Energy has recently issued new regulations, aimed at fostering the installation of rooftop solar PV systems by lowering the price of solar electricity. However, the new regulations do not introduce net metering, net billing policies or feed-in-tariffs, which are still not allowed in Cambodia (Ministry of Mines and Energy, 2023). Therefore, owners of PV systems are not incentivised to feed the grid with the surplus power produced. The new regulation has also been criticised for not being clear enough in terms of the final cost that PV owners will pay to EDC (Santos, 2023).

Regarding the deployment of off-grid solar energy in rural areas, the government has implemented a Rural Electrification Fund (REF) to support the electrification of remote rural communities using solar home systems (SHS), as well as to assist the development of electricity infrastructures and the expansion of the national grid in rural areas, as indicated in Table 1 (Electricité Du Cambodge, 2020a, 2020b). The REF, which represents the main policy measure for the achievement of universal energy access in remote rural communities, is further analysed in Section 4.2.

This section has outlined a description of the Cambodian energy policies and strategies to achieve clean energy transition and universal energy access, providing context for a critical analysis of issues of energy access, energy affordability and reliability in remote rural communities, which we conduct in the next section.

4. Affordability, safety, and reliability of energy access in Cambodia

4.1. Energy access: The rural–urban and gender divide

Over the last decade, in response to a significant growth in energy demand (+19% yearly average between 2012 and 2021), the government has invested in the development of the power system infrastructure with the objective of achieving universal electricity access (Ministry of Mines and Energy, 2022). As mentioned in the Introduction, electricity access has reached 98% of the villages in Cambodia, however, over 200 remotely located villages are still not reached by the grid. These villages are home to Cambodia's most vulnerable communities, due to high poverty rates, high incidence of malnutrition, and the presence of indigenous groups and ethnic minorities (Gadde and Va, 2023).

Looking at household-level data, the latest Cambodia Demographic and Health Survey 2021–2022 shows that in rural areas 12% of the households still lack electricity access (National Institute of Statistics et al., 2023). Almost half of Cambodian households use clean fuels and technologies for cooking (79% in urban areas and 34% in rural areas), and the remaining 50% rely primarily on solid fuels for cooking – mainly firewood (43%) and charcoal (6%).[5] The most used clean technology is LPG/natural gas stove (47%), followed by electric stove (3%) and solar cooker (1%). Nearly half of households using solid fuels for cooking use a three-stone stove or open fire (*ibid.*).

In terms of lighting, electricity is the most widely used clean energy source. However, only 50% of the household population primarily relies on clean sources for both cooking and lighting (*ibid.*).

If we look at gender aspects, female-headed households are more dependent on solid fuels for cooking and have on average fewer hours of electricity supply a day than male-headed households (*ibid.*). They also rely more on off-grid, intermittent energy: this is mainly due to the affordability of connection to the grid and to monthly fees (World Bank, 2018). In Cambodia, as discussed above, energy access in remote rural areas and across genders remain challenging, as do energy reliability and affordability (Han and Kimura, 2019). We discuss this point in the next subsection.

4.2. Energy affordability and reliability

Although the Cambodian government has recently introduced a programme to subsidise low-income households depending on the amount of electricity consumed, tariffs remain among Southeast Asia's highest (GIZ, 2021). The introduction of REF in 2004 intended to palliate this phenomenon, as did in 2012 the establishment of EDC's "Department of Rural Electrification Fund" (Electricité du Cambodge, 2022). In 2018, through REF, the Government launched four programs for more inclusive electrical coverage for the rural poor: a) "Power to the Poor (P2P)" provides subsidies and interest-free loans to poor rural households to meet the costs for connection fees, materials and equipment and labour for installation; b) "Program for Solar Home Systems (SHS)" provides assistance to remote households located in villages with no grid access, to reduce the cost of the purchase and installation of SHSs; c) a third program facilitates access to electricity for agricultural irrigation uses with reduced tariffs; d) a final program reduces tariffs and provide interest-free loans to REEs (Electricité du Cambodge, 2022).

In 2021, REF installed a total of 9,933 SHSs in rural households and electrified 868 villages[6]; 1,258 households received subsidies to pay for grid connection; and 62 villages benefitted from the Solar Water Pump Innovation Grant Program 2021, aimed at providing electricity for agricultural irrigation uses (Electricité du Cambodge, 2022).

Despite the above initiatives, energy poverty is still widespread, especially in rural areas. Han and Kimura (2019) describe two types of energy poverty in Cambodia: i) grid-connected citizens having access to modern energy technologies but are constrained in the consumption of energy by affordability reasons; ii) remote rural communities, who are not connected to the national grid, and for whom electricity access is very limited. Both electrified and off-grid communities usually rely on different energy sources, such as solar, rechargeable car batteries, kerosene, firewood and other traditional fuels for lighting and cooking (Mika et al., 2021). Since there is no unified electricity tariff in Cambodia, in areas supplied by REEs electricity tariffs are highly volatile due to fluctuating fuel prices, and electricity price can range from $0.65/kWh to $0.90/kWh. For electricity from rechargeable car batteries and diesel generators, the cost averages $1.00/kWh (ADB, 2018a; Han, 2015).

In relation to reliability, approximately two-thirds of the households connected to the national grid experience frequent power shortages, or in the case of off-grid households using SHSs they cannot produce enough energy to fulfil their basic needs due to poor technological standards, the highly dependence of solar energy on climatic conditions coupled with unaffordability of solar battery storage systems for poor households (Sem et al., 2022).

[5] Clean cooking fuels and technologies include: electric stoves, solar cookers, liquefied petroleum gas (LPG)/natural gas stoves, piped natural gas stoves, and biogas stoves. Clean lighting fuels and technologies include: electricity, solar lanterns, battery-powered or rechargeable flashlights/torches/lanterns, and biogas lamps. Here 'clean' is to be intended as 'not producing smoke'.

[6] Of these, 4,995 households were provided with 80Wp SHSs; 3,998 households, with 200Wp SHSs; and 940 households with 325Wp SHSs (Department of the Rural Electrification Fund, 2022).

[7] Poor level 1 households have more difficult living conditions (poorer) than poor level 2. Those households are classified as poor level 1 or 2 according to their score cards (values added to their possession: type of house, size of land, motorbike or car possessed, TV, etc.), calculated by the Ministry of Planning officials who measure the level of poverty in each household. More information can be found in The Identification of Poor Households Programme (IDPoor) at: About the Identification of Poor Households Programme in Cambodia | IDPoor: http://idpoor.gov.kh/en/about/.

According to a report published by the Parliamentary Institute of Cambodia (PIC) in 2019, around 69% of users reported unpredictable power shortages and 33% experience safety issues in relation to appliance damage due to unstable voltage (Marabona, 2019).

5. Research approach: methods, study area and context

5.1. Case study area, semi-structured interviews and focus group discussions

The research methods applied in the empirical study consist of fieldwork in remote rural communities located in the Stung Treng region, which is one of the poorest regions in Cambodia with 16.6% of the population in severe poverty, high incidence of child malnutrition (29%) and the lowest electrification rate in the country −74.2% of villages electrified with 33 villages remaining to be electrified (Oxford Poverty and Human Development Initiative, 2023; Gadde and Va, 2023; World Vision Cambodia, 2023). We also conducted ten semi-structured interviews on energy access and off-grid RE in Cambodia with representatives from the business sector, international organisations & NGOs, international donors, local NGOs, government, academia, and think tanks. A list of the actors interviewed, and their role is provided in Table 2. The fieldwork was carried out in February 2023.

The main purpose of the interviews conducted with key actors indicated in Table 2 was to explore the main challenges and opportunities of off-grid renewable energy from a social justice perspective. We used semi-structured questions organised around broad themes such as energy access, distribution, reliability, and affordability, barriers, challenges and opportunities for off-grid RE, energy policies and practices, to prompt discussion, leaving to the interviewer the opportunity to explore specific themes or responses further. Themes were tailored to the different interviewees. For example, in interviews with government officers, we focused on policies and practices, energy infrastructures, future energy plans, energy access and distribution of energy services, collaboration/involvement of the government with international and local actors, including international organizations, civil society organizations (CSOs), and communities. We also asked interviewees to identify the main actors involved in the energy sector in the country, their linkages, influence, and power for our SNA.

Communities and interviewees were selected, and interviews conducted in collaboration with the local partner MyVillage, a local NGO working with marginalized and vulnerable communities in different provinces in north-east Cambodia (Stung Treng, Ratanakiri, and Mondulkiri provinces).

To explore local challenges regarding energy access, social justice, and capabilities, including aspects related to the gender divide, we conducted three focus group discussions (FGDs) with two remote communities, Koh Sampeay and Koh Snaeng, located in Siem Bouk District, part of Stung Treng Province in north-east Cambodia (Fig. 1). Topics discussed during FGDs referred to past and current experiences with energy access by community members, challenges and opportunities in relation to access to off-grid renewable energy and impacts on their capabilities, their needs and priorities, reliability and affordability of energy, expectations. In relation to capabilities, we did not ask community members to discuss specific capabilities as defined in the literature; instead, we inferred the capabilities that they valued based on their responses during FGDs (these are further discussed in the results Section 6.1).

In Koh Sampeay we conducted one mixed focus group discussion (FGD) with men and women. This was due to community members preference toward one mixed FGD instead of conducting two separate FGDs. In Koh Snaeng we conducted two FGDs with community members, one with men and one with women. Details of the people involved in FGDs are provided in Table 3.

The two villages have access to different types of energy sources depending on their location. Koh Sampeay, located on land, has been recently reached by the national grid: therefore, most of the households have access to it for lighting and cooking. However, six poor households, three of which have access to small SHSs (70 A), still lack connection to the grid (Table 4). In relation to the use of RE, off-grid solar energy is mainly used for public lighting and by some of the households not connected to the grid, while one family uses the energy produced by a mini-hydro device (Table 3). In terms of water supply for irrigation and

Table 2
Key interviewed actors.

Classification	Key actor	Description
Business	Pteah Baitong small community projects – Clean energy company (Clean energy expert)	Provides clean energy technologies, e.g. solar powered irrigation pump, designed for smallholders farmers
International organisations/ international NGOs	UNDP – United Nations Development Programme (Energy specialist)	Promotes RE in Cambodia working with government ministries and local NGOs. Promotes energy access through the implementation of solar mini-grid systems in remote areas. Provides financial support
	Oxfam – Cambodia program (Policy expert)	Supports community research and advocacy for sustainable resource management and provides small grant to local NGOs for small renewable energy projects (mainly solar), provides support to NGOs and local organisation to help the communities to raise their voices in relation to the impacts of energy transitions (such as hydropower)
International donors	ADB – Asian Development Bank (Clean Energy Specialist)	Provides financial support, feasibility studies, safeguards analyses for large and community-based RE projects
Local NGOs	CRDT – Cambodia Rural Development Team (Expert on RE programmes implementation)	Local NGO which provides financial and technical support to local communities for the implementation of community-based RE projects
	EnergyLab – Cambodia (RE and solar energy expert)	Raise awareness and develop knowledge related to Clean Energy. Evidence-based advocacy. Initiate and/or guide Clean Energy policies, instruments, and regulations to stimulate RE demands
Government	EAC – Electricity Authority of Cambodia (4 experts from the General Department of Transmission and Sub-transmission and Data and Dissemination Department)	Responsible for managing and administering the provision of electric power in Cambodia
	MEF – Ministry of Economy and Finance (4 experts from the General Department of Policy)	Implements and contributes to the government's economic and financial policy with regard to financing and investment for the development and scaling-up of RE
Academia and Think Tank	ITC, Institute of Technology of Cambodia (2 academics with expertise on energy)	Provide technical support to government, international organisations, CSO and conduct research on renewable energy
	ERIA – Economic Research Institute for ASEAN and East Asia (Energy Economist)	

Source: Authors' elaboration (we conducted ten interviews in total, some interviews involved more than one person, for a total of 17 participants).

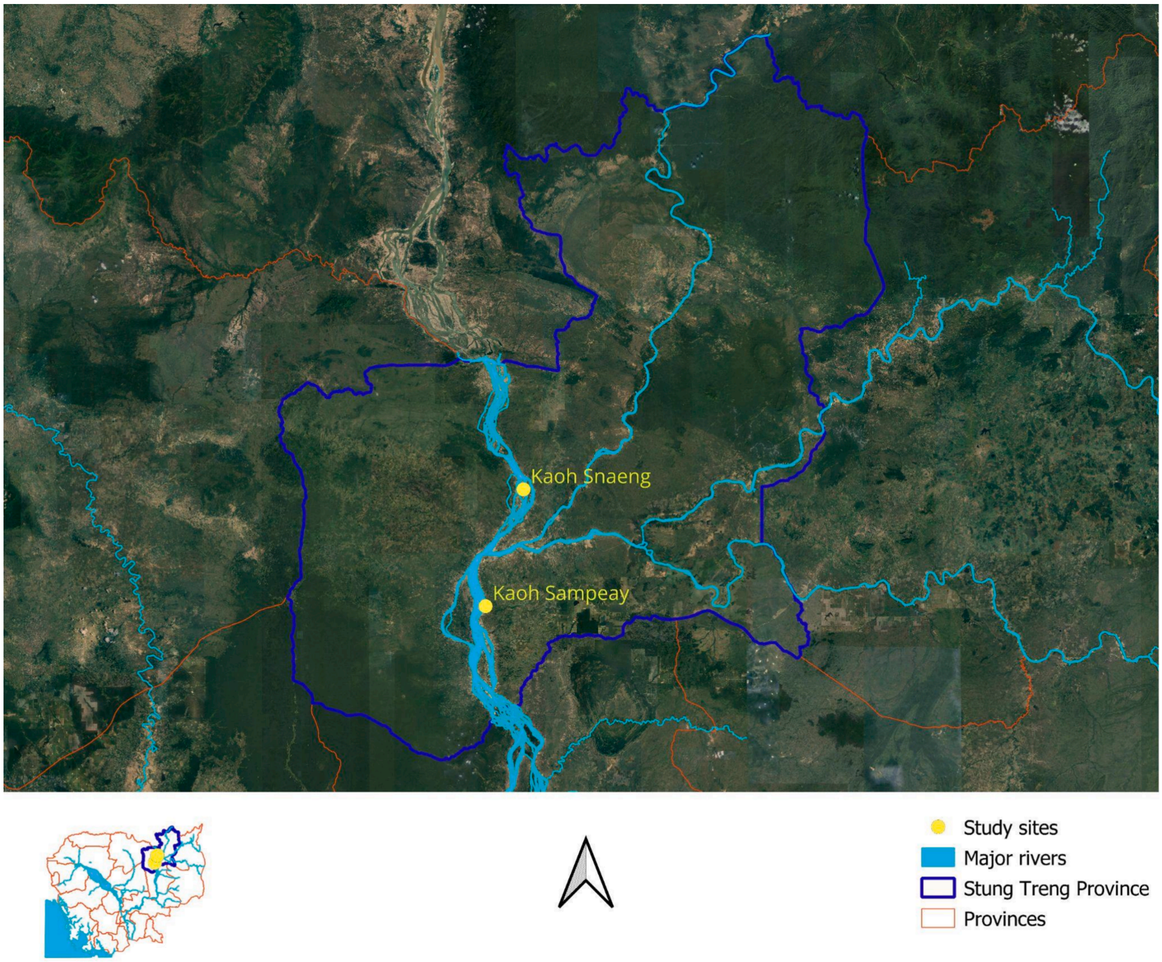

Fig. 1. Map of Cambodia with study locations in Stung Treng Province.

Table 3
Details of FGDs.

Location	N. of community members	age range	sex	Main occupations/ livelihoods	Energy access	Type of RE
Koh Sampeay Village	7 (4 men, and 3 women)	30–80	Mixed men and women	Farmer, fishermen	Hydropower, solar energy and national grid	Mini-hydro (1 family); solar street lights (for public lighting only); Solar Home Systems (SHS)
Koh Snaeng (FGD with men)	10	25–70	Men	Farmer, police, fisherman, boat driver	Solar energy	Solar Home Systems (SHS)
Koh Snaeng (FGD with women)	6	24–53	Women	Farmer, Housewife	Solar energy	Solar Home Systems (SHS)

Source: Authors' elaboration.

personal use, villagers have access to a community water system.

Koh Snaeng, located on an island in the Mekong River, is not reached by the grid. Villagers use two different types of off-grid solar home systems, small scale (70 A) and medium scale (200 A), for lighting and cooking. Most of the households, especially the poorer ones and female-headed ones, use small scale SHSs (Table 5). In terms of water supply for irrigation and personal use villagers use engines for pumping water from the Mekong River. Most of the villagers in both Koh Sampeay and Koh Snaeng rely on fishing and farming (rice and vegetables), livestock farming, and collection of non-wood forest products for both self-consumption and sale on the local market.

The material collected during interviews and FGDs was analysed using qualitative thematic analysis (Vaismoradi et al., 2013). We focused on statements on access, capabilities, reliability, and affordability. We aimed to distinguish the responses depending on social parameters, such as gender and poverty levels. We present the results of the analysis in Section 6.1.

5.2. Social network analysis

Our SNA maps out a complete network of actors that have been identified to directly or indirectly influence energy governance, energy access and renewable energy in Cambodia. It provides a first empirically informed analysis of the social complexity and web of social interactions linked to energy transitions in the country. To analyse influential or central actors in the network we use degree and betweenness centrality indexes (further explained below).

To undertake this analysis, we used primary qualitative data, directly collected through semi-structured interviews from key informants (listed in Table 2), whom we had previously identified through secondary

Table 4
Koh Sampeay Village.

	Total	Number of HHs connected to national grid	Number of HHs without connection to the national grid
Total number of people	1360		
Total number of households	381		
Total houses	365	359	6
Men	527		
Women	833		
Poor level 1 households (very poor)	8	5	3 (without connection)
Poor level 2 households (poor)	26	23	3 (connected to SHSs)
Elderly people	0		
Female headed households	150	150	

Source: Authors' elaboration (HH stands for 'household').

Table 5
Koh Snaeng Village.

	Total	Types of solar Use small scale (70 A) solar home system	Use large scale (200 A) solar home system
Total number of people	1230		
Total number of households	270		
Total number of houses	210	110	100
Men	665		
Women	565		
Poor level 1 households (very poor)[7]	25	25	
Poor level 2 households (poor)	39	39	
Elder persons	1	1	
Female-headed households	5	5	

Source: Authors' elaboration.

data sources, and based on the expertise of the research team. We used the Net-Map® tool to map out the data provided by the key informants interviewed (Schiffer and Hauck 2010, Hauck et al. 2016).

We used the Social Network Visualizer® (SocNetV) software for visualisation and data analysis of the social network (SocNetV, 2023). The structure of the network is analysed looking at the network's size and density. The density index is used to analyse the cohesion of a network: it provides a measure of a network's connectivity. It ranges from 0 to 1, where values close to 0 show less connectivity and values close to 1 show high connectivity, and therefore a greater ability to share information and resources, and collaborate (Stein et al., 2011; Kharanagh et al., 2020).

The actors' influence/power is analysed by looking at how central or peripheral the actors are in the network. Two measures of this parameter are degree centrality, i.e., the number of connections an actor has in the network, inward (in-degree centrality) and outward (out-degree centrality) links to other actors, and betweenness centrality, i.e., how many times an actor acts as a bridge between the two other actors. The relationship between power and degree centrality indexes has been long demonstrated (Ding and Liu, 2011; Hansen et al., 2012; Brass and Krackhardt, 2012), and a positive relationship exists between centrality and influence. In-degree centrality indicates the importance of an actor in a network, which is measured by the number of links received from other actors, while out-degree centrality, which is measured by the number of outward links from one actor to other actors, represents influence and effectiveness of an actor (Uddin et al., 2017). With respect to betweenness centrality, actors with a higher value act as connectors and have the ability to control information flow, resources and actors inside the network (Kharanagh et al., 2020; SocNetV, 2023).

In the next section we present and discuss the results of the FGDs and interviews carried out during fieldwork (Section 6.1) and of the SNA (Sections 6.2 and 6.3).

6. Results

6.1. Voices from the ground: Issues of energy accessibility, affordability, reliability, and equity

Analysis of the data collected from interviews and focus group discussions with the local population reveals, issues of accessibility, affordability, reliability and equity. Interviews with the local communities and CSOs, reveal problems with the cost of storing energy in batteries connected to solar installations: high upfront costs, which have implications in terms of equity and affordability, as not all rural households can afford to buy such batteries. Consequently, particularly during the rainy season, the lack of such batteries prevents the little energy generated by the sun from being stored and used, resulting in lack of electricity access for those households, except on sunny days.

In terms of equity, reliability and affordability of off-grid solar systems, an expert from Oxfam also confirmed that:

> "Solar energy in communities is unreliable, it is not possible for them to rely on just one energy source if they want to scale-up their activities and satisfy basic needs such as pumping water for agriculture and personal use, or using an efficient cookstove, especially during the rainy season when there is less sunlight available. Only richer families can afford to buy batteries to store the solar energy produced and use it when sunlight is scarce."

There are also problems related to energy efficiency, blackouts, and technological failures. Respondents from the communities mentioned problems related to the durability of SHSs and failures (the systems tend to malfunction and break, obliging users that can afford it to buy new ones). Even when malfunctioning does not force the purchase of a new one, there remains the problem of dependence on the outside world to repair the devices: a problem that is related to poor capacity building and training of the local population and the repairers of the SHSs are not available or cannot fix the broken system in the remote areas. During FGDs with men in Koh Snaeng, one villager claimed: "When the systems were broken, the repairers from the solar company came but could not fix them". Therefore, those who could afford it, had to buy a new one. In terms of training and capacity building, during FGD with men in Koh Snaeng, participants mentioned that one villager received training from EDC to fix the system; however, another villager said: "My house had solar system errors and he [the trained villager] came but could not fix them. His skill was limited." Villagers also mentioned that when problems arise, they are on their own, they feel disconnected, as the relationship with those in power is limited to the provision of subsidies to buy SHSs. This highlights relationality problems between the local population and the government.

Villagers using the small solar technology are heavily reliant on fuelwood for cooking. They would mention that the 70A solar system can only be used for "4 lighting bulbs, phone charging, a little bit for fan or flat TV for about 1h," while the 200A systems could also be used for cooking. Nevertheless, some households using the 200A systems also experienced solar system errors that prevented the use of electric rice cookers.

Regarding the amount of energy produced, there are clear differences: while wealthier households, usually larger farmers, have the economic capacity to afford the use of several energy sources, at different times of the day and year, this is not the case for less affluent households. For example, wealthier households, in addition to the use of solar panels and firewood, also make use of diesel batteries to compensate for lower energy production from SHS depending on the type of activities they need to perform, for example for cooking or using water pumps for irrigation and personal use. This practice is known as 'fuel stacking' (in which new cooking technologies and fuels are added, without abandoning the traditional systems) (Masera et al., 2000: 2084; Yadav et al., 2021; Mika et al., 2021). In some cases, villagers share the costs of the technology used to pump the water for personal use and irrigation, as well as the costs of the use of alternative energy technology and fuels:

> "People use the gasoline generator to pump the water (only about 20% to 30% of the total villagers could afford to buy the pumping machine). The villagers can share the costs, some bought the water tube, some bought the pumping machine, and some bought the gasoline generator. So, they worked to pump the water as a team. Some households carried water using a water tank from the river because they did not have money to buy the pumping machine or the gasoline generator".

Despite all the difficulties experienced with the solar systems, during FGDs with men and women in Koh Snaeng, the villagers said these have improved their condition: "We are happier with solar, before we used kerosene lamp, and car batteries that needed to be charged every 3 days or every week. But now we use solar by ourselves, no need to pay like before". Another villager stated: "Before, we needed to carry the battery on our shoulders to the car battery charging shop far from home. So, it is more convenient using solar – we just install the solar at home and charge the phone at home, no need to carry anything far away from home". However, as discussed above, reliability of the energy produced due to weather conditions, systems failures and the affordability of using different technologies and fuels makes access to electricity in rural areas to perform basic needs challenging. The difficulty of using rice cookers and efficient cookstoves due to the instability of the energy produced with SHSs was mentioned as one of the main issues experienced in the communities with implications on health and the ability to free up time for other tasks "the use of rice cookers would reduce indoor smoke and I would have time to do other activities" (respondent from FGDs with women in Koh Snaeng). Even though these circumstances affect all villagers, the most vulnerable groups, such as poor and female-headed households, are mostly affected as they can only afford solar systems with limited capacity, as indicated in Table 5.

In the new regulation on solar PV installation, the Government makes a clear statement saying that "consumers who use solar energy, [...] must invest in battery energy storage system to store the energy for use during hours that have low or no solar radiation or use the electricity supply from national grid as a supplement" (Ministry of Mines and Energy, 2023: 1). However, poor families in marginalised rural areas not connected to the grid, such as in Koh Snaeng, cannot afford to buy battery energy storage, and no policy measures are in place to provide differentiated support and alternative energy technology to vulnerable families. In interviews, the respondent from the Economic Research Institute for ASEAN and East Asia (ERIA) argued that "in Cambodia the REF funding scheme of SHSs has been effective to provide off-grid renewable energy access to remote communities; however, on a small scale and with only modest subsidies".

In terms of who is benefiting more from the adoption of off-grid solar energy, the respondent from Oxfam argued: "This will benefit mostly big or middle farmers who can afford to buy better technology and bigger and more reliable solar panels and that have the means to pay for maintenance, operation and repair in case of damages. For small farmers it is a challenge to buy solar panels with enough capacity to pump water for irrigation, it is too costly for them".

Problems of affordability and energy access are also present in villages connected to the national grid, such as in Koh Sampeay, where during FGDs villagers mentioned "difficulties for the community in paying for the electricity bill every month," and as a result six families are not yet connected to the grid (Table 4), and others struggle to pay.

Moreover, one villager mentioned that those connected to the national grid often experience blackouts: "Recently, we experienced blackouts very often like two to four times per day, especially during nighttime." Locals also maintain that the provision of solar energy could help the community obtaining continuous energy access during power cuts: "[...] if the government subsidies projects like 'One house, one solar light' in our village, when the national grid is off (black out), we can still use our own solar light". This statement highlights the need for the villagers to rely on different sources of electricity to be able to perform essential activities. The importance for poor rural households to rely on a portfolio of different fuels, traditional fuels along with modern ones, depending on costs, availability, and reliability, has also been demonstrated by research conducted in other rural contexts in developing countries (Yadav et al., 2021). These studies have shown that the 'one size fits all' policy approach to energy transitions is not adequate to respond to the multidimensional aspects of energy poverty in marginalised rural areas.

Linking results from the interviews with specific (energy) capabilities (Nussbaum, 2000; Frigo et al., 2021; Day et al., 2016), the above issues with energy access, energy affordability, reliability and efficiency mentioned during interviews and FGDs constrained community members' capabilities in various ways: (i) *engaging in meaningful work and being well-nourished* is affected by a reduced access to water for irrigation practices for food production and agricultural activities; (ii) *being in good health* is affected by indoor air pollution caused by the use of fuelwood; (iii) *being well-educated and socially connected* is impaired by a reduced ability to light their house, charge their phones, use a computer for longer hours, use electric rice cookers for a better distribution of daily activities such as chores and extended leisure and study times. A summary of these consequences is shown in Table 6.

Looking into the relationality aspect at the intersection of power, capabilities, inequalities, and energy poverty, in the next section we present the results of the SNA to analyse how positionality and power of different actors, as well as policies and practices influence energy inequalities and capability deprivation in the study area. As specified in Section 2.2 we look in particular at vertical power relations, which include governments with power to design and impose policies, as well as international development partners, civil society organisations or other external agencies, which influence communities through funding, technical support, advice and information.

6.2. Social network analysis results

6.2.1. Energy governance, energy access and off-grid renewable energy

The SNA was used to identify and analyse (a) groups of actors at regional and local levels, (b) the interplay between actors at different levels, national and local, and (c) the actors' influence/power. In particular, we mapped the local dynamics and power relations between

Table 6
Capabilities and energy services in the study area.

Capabilities	Energy services
being in good health	difficult to use electric cooker and modern cooking stoves – use of fuelwood and problems of indoor air pollution; not enough energy to use water pumps –limited access to water for personal use
engage in meaningful work and being well-nourished	not enough energy to use water pumps – limited access to water for irrigation practices for food production and agricultural activities
being well-educated and socially connected	not enough energy to light the house, charging their phones and use a computer for longer hours

Source: Authors' elaboration based on FGDs and (energy) capabilities as discussed in Nussbaum, 2000; Frigo et al., 2021; Day et al., 2016.

the different actors looking at flows of (1) knowledge/information, (2) money transfer (subsidies, investments, loans etc.), (3) recommendations/advice, (4) technical support/technology transfer, (5) control, authorization and approval. Table 7 shows the links used in the social network.

To identify the actors, during semi-structured interviews, we asked interviewees with expertise in the Cambodian energy sector (listed in Table 2) to name all actors they believe influence energy governance, energy access and renewable energy in Cambodia. 23 actors were identified as indicated in Table 8. The actors were grouped in eight categories, namely: institutions, business sector, international organisations & NGOs, local NGOs and CSOs, research, local communities, and international donors.

Figure 2 shows the complete network of actors that have been identified to directly or indirectly influence energy governance, energy access and renewable energy in Cambodia, which provides a first empirically informed analysis of the social complexity and web of social interactions between the different actors involved.

Before going into the details of the power and influence of the different actors, here we provide an explanation of their different roles and responsibilities within the network, in terms of knowledge and information exchange, local support, technology and money transfer, control, authorization and approval, definition of policies and strategies.

The key energy institutions of the Cambodian energy sector are the Ministry of Mines and Energy (MME), the Electricity Authority of Cambodia (EAC), the Ministry of Economy and Finance (MEF) and Electricité du Cambodge (EDC). Other Ministries such as the Ministry of Public Works and Transport (MOWT), the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of Rural Development (MRD) play a marginal role, as they mainly provide information and define and implement policies and regulations on specific cross-sectoral energy aspects. For example, MAFF is responsible for the management of wood-fuel and the production of biofuels. MoE reviews and approves Environmental Impact Assessments (EIAs) and Environmental Management Plans (EMP) for all energy related projects and is responsible for the definition of climate change strategic plans including in relation of the decarbonisation of the energy sector and readiness for climate change, and defines the road map for achieving Sustainable Development Goals, including Goal 7 on energy access. The MME defines government policy, strategies, plans, and technical standards for the energy sector, which before publication must be approved by the Royal Government of Cambodia (RGC). It is responsible for the development and publication of the Power Development Plan of Cambodia, electricity trade with neighbouring countries, big energy investment projects and the management of rural electrification (Han, 2015). The EAC is an autonomous agency that regulates the electricity sector and has the responsibility to issue rules, regulations, and procedures on power market operations, award licences, set tariffs, resolve disputes between producers, suppliers, and consumers, and to review energy planning and finance. EDC is co-owned by MME and MEF. It is a vertically integrated power utility responsible for the generation, transmission, and distribution of electricity in areas assigned to it by the EAC. Most of EDC's electricity is sold in urban areas, such as Phnom Penh and the main provincial towns. EDC's mandate also covers the extension of local grids

Table 7
Links between actors.

Links	Description
1	Knowledge, information exchange, complaints/requests
2	Money transfer (grants, loans, services payments, funds, subsidies, technology transfer payments etc.)
3	Recommendations, advice (policies, strategies, technical advice etc.)
4	Technical support, technology transfer (technical support through research, transfer of technology including installation and technical support)
5	Control, authorization, approval

Source: Authors' elaboration.

Table 8
Actors identified in the social network analysis.

Name of actor	Type of actor	Network code	Description
Central Government	State Agency	1	Oversees and approves all processes and activities of the Ministries, define RE laws, strategies and roadmaps
Ministry of Economy and Finance (MEF)	State Agency	2	Implements and contributes to the government's economic and financial policy also with regard to financing and investment plan for the development and scaling-up of renewable energy
Ministry of Mines and Energy (MME)	State Agency	3	setting and administering government policies, strategies, and planning in the power sector
Ministry of the Environment (MoE)	State Agency	4	In charge of environmental protection including protected areas, national wildlife sanctuary (about 7.5 mil ha or 41 % of the total country area of Cambodia), and advocate for green development, carbon neutral, and renewable energy
Ministry of Agriculture, Forestry and Fisheries (MAFF)	State Agency	5	MAFF is responsible for governing activities of agriculture, forestry and the fishery industry in Cambodia.
Ministry of Rural Development (MRD)	State Agency	6	MRD governs development of rural areas of Cambodia, including rural road rehabilitation and construction, rural clean water and sanitation, policies, etc.
Ministry of Public Works and Transport (MPWT)	State Agency	7	Governs the transportation, communication and technology, including export, import, internet, digital government initiatives, etc.
Council for the Development of Cambodia (CDC)	State Agency	8	promote and facilitate foreign and local investments, provide information, review and monitor investment projects, support policy dialogue with the government through biannual Government-Private Sector Forum
Electricité du Cambodge (EDC)	State Agency	9	It operates specified generation facilities, purchases electricity from sources available at present and in

(continued on next page)

Table 8 (*continued*)

Name of actor	Type of actor	Network code	Description
			future, to plan, develop and operate the transmission system and to distribute electricity in its authorised Distribution areas. Through the Department of Rural Electrification Fund EDC manages the Rural Electrification Fund (REF) established by the RGC and MME.
Electricity Authority of Cambodia (EAC)	State Agency	10	responsible for regulating the electricity industry and has the duties of licensing, tariff setting, solving the disputes between producers/ suppliers and consumers, setting up the uniform accounting standards, enforcing regulation, reviewing of planning and financing performance
Int. Organisations/ NGO	International organisations/ international NGOs	11	research and advocacy for renewable energy development; provide fundings, such as small grant to local NGOs for the development of community renewable energy projects (such as solar, mini-hydro, biomass); provide support to NGOs and local organisations to help the communities to raise their voices in relation to the impacts of energy transitions (such as hydropower); provide capacity building to local organisations
Consultants	Business	12	Provide technical support to international organisations, NGOs, the Government, international donors, CSOs
Local communities	People	13	Adopt RE technologies, provide information to CSOs, local authorities and the government in relation to electricity access in the community and complaints, buy RE technology from SMEs and pay electricity to REEs and PECs when connected to the national grid. Receive funds (subsidies) from EDC through the REF for the adoption of RE technology.
CSOs	Local NGOs and civil society organizations	14	Support local communities for the development of RE projects through technical support, information and knowledge exchange. They facilitate the flow of information between local communities, the government and local authorities also in relation to complaints.
Academy/Think Tank	Research	15	Provide technical support to international organisations, NGOs, the Government, international donors, CSOs. Conduct research on RE.
Prov. Departments	State Agency	16	Sub-national levels, decentralised power and administration system from all Ministries at the national level to the sub-national levels.
Prov. Gov. Representatives	State Agency	17	Having political power in law formulation, promulgate the laws, particularly in voting to elect to withdraw the Prime Minister, if the PM has seriously violated the country's laws.
Local Authorities/ Local community committees	State Agency	18	Local authorities include village chiefs, commune councils, and local police. Local community committees (e.g. community forestry committee, water user community, Community of fishery, etc.) are the representatives of the villagers in the communities, who get elected by the villagers.
Development Banks	International donors	19	Invest and provide financial support (through loans and grants), feasibility studies, safeguards analyses with regard to RE projects (both large and small scale)
Private investor/large enterprise	Business	20	Large enterprises investing in RE infrastructure and technology
Small/Medium Enterprises (SMEs)	Business	21	Small and medium enterprises investing in RE infrastructure and technology
Independent Power Producers (IPPs)	Business	22	Private companies that received a licence from EAC to generate electricity and sell it to EDC

(*continued on next page*)

Table 8 (*continued*)

Name of actor	Type of actor	Network code	Description
Rural Electricity Enterprises (REEs) and Provincial Electricity Companies (PECs)	Business	23	Private-owned electricity providers who get a licence from EAC to provide power outside the main economic centres (mainly in rural areas)

Source: Authors' elaboration.

of private energy producers and their integration into the national grid, as well as further extension of the grid to rural areas. To facilitate rural electrification, which involves large capital costs and a low payback, the government provides financial support and subsidies to EDC. Since 2012 EDC has also been responsible for the management of the Rural Electrification Fund (REF).

In relation to power distribution at the local level and outside of the main economic centres, private-owned companies and electricity providers play a crucial role, especially in relation to rural electrification. These are Independent Power Producers (IPPs), Rural Electricity Enterprises (REEs) and Provincial Electricity Companies (PECs), which are licensed by EAC to provide power in provincial and rural areas. All power generators, suppliers, and distributors must be licensed by the EAC. However, interviewees mentioned that the provision of electricity services from isolated, REE-operated systems is extremely fragmented, generally unreliable and of poor quality: supplies are intermittent and energy distribution losses are high. Coupled with high electricity costs, this severely curtails the quality of life of people located in remote rural areas (ADB, 2018b; GIZ, 2021).

Development partners and international donors have also played an important role in the Cambodian power sector, initially by investing in the expansion of high-voltage transmission lines, and since 2014 also in the national grid expansion of medium- and low-voltage sub-transmission and distribution lines, which are crucial for bringing grid electricity to rural areas. They also support investments in off-grid solar energy and capacity building (ADB, 2018b). In relation to this, during interviews, the EAC stressed the fact that the scale-up of off-grid solar electrification in remote villages is a matter of international donors' involvement, as it depends on them funding projects in rural areas. This was confirmed by the Oxfam interviewee, who argued that "the government sees the development of solar energy as something voluntary which relies heavily on external donors support, with inadequate support from the government." He added: "There is a lack of support from the government to scale-up renewable energy adoption. There is a lack of business models and a lot of competition between different middle energy providers who buy electricity from EDC and sell it at sometimes unaffordable prices to the communities." Moreover, according to senior officials of the MME, it would take another ten years for the government to provide electricity to the villages left behind by the electrification plans of the country. Electrification of those villages mainly rely on international financial institutions and private investments companies to provide off-grid solar energy for a period on a temporary basis (Sothear, 2023).

EAC also recommends international donors to install solar systems that can be easily connected to the national grid when this will be extended to all areas in the country (interviewee from EAC). However, interviewees from Oxfam, UNDP and the Institute of Technology of Cambodia also mentioned that this is problematic for international donors as there is no clarity from the government as for what type of systems are allowed, and there is uncertainty in terms of when certain rural areas will be connected to the grid (that may take up to ten years as indicated by MME).

In terms of electrification and energy development priorities, the PDP 2022–2040 provides some possible solutions for further developing sub-transmission lines and distribution lines to reach un-electrified villages; however, the strategies formulated in Cambodia's PDP are vague without an indication of a concreate action and investment plan (Ministry of Mines and Energy, 2022; Sothear, 2023).

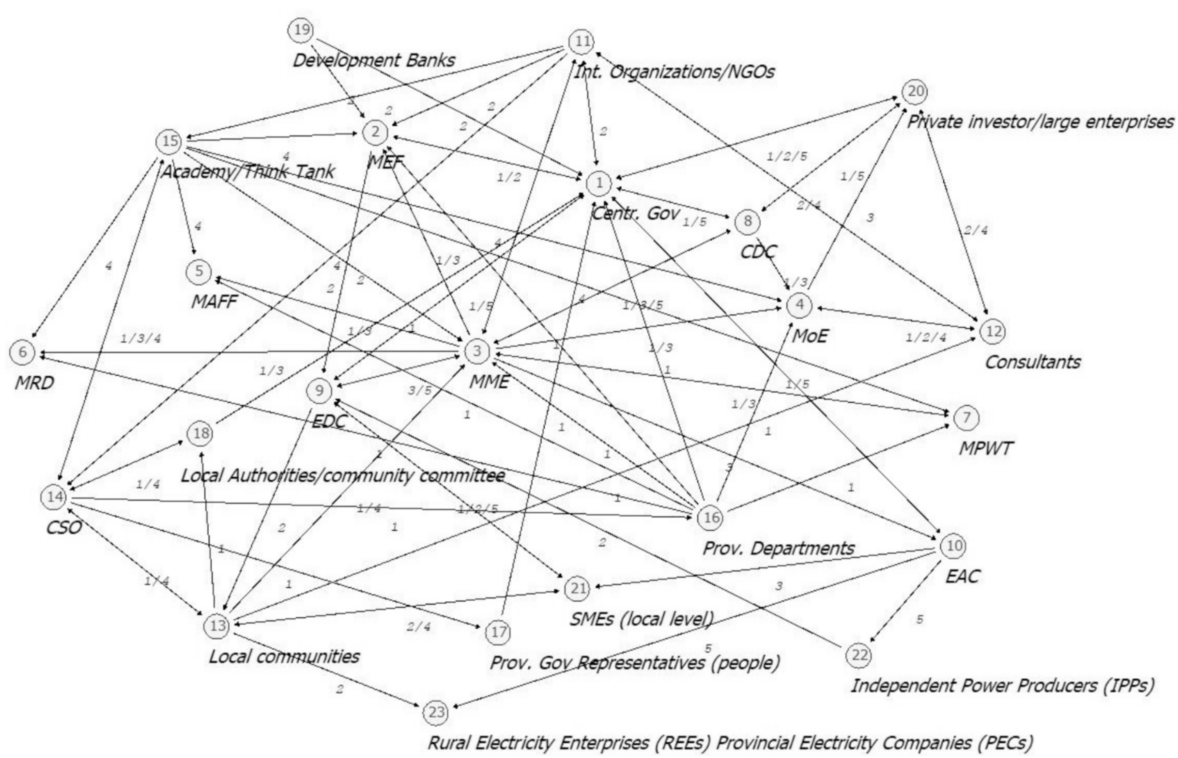

Fig. 2. Social network: energy governance, energy access and renewable energy in Cambodia (The numbers of the edges refer to the links described in Table 7). Type: Directed; Nodes: 23; Links/ties: 77; Density: 0.15.

Local NGOs and CSOs provide support to local communities for the development of off-grid RE projects through technical support, information and knowledge exchange. They facilitate the flow of information between local communities, the government (such as provincial departments and provincial government representatives) and local authorities, and provide support for the preparation of complaints and requests to the local and central governments. For example, in relation to the decision-making process regarding the provision of solar off-grid to the communities, the process follows a bottom-up approach, in which communities supported by CSOs make a request to the local community committee and ask them to have the solar panel request included in the community investment plan. This request is then sent by the local community committee to the central government which decides if it can be included in the central government investment plan on energy provision. The extension of the national grid follows instead a top-down approach, in which the government makes decisions in collaboration with provincial departments but without prior consultation with the communities (from interviews with CSOs).

Advice and technical support through research and transfer of technology to local NGOs and the Government are provided by external consultants (usually international), academia and think tanks, as well as by international organisations. These actors are crucial for the energy transition as local knowledge and expertise is limited (CIF, 2020). Financial support for the deployment of renewable energy is mainly provided by international donors and development banks, such as the Asian Development Bank and the UN Development Program, as well as private investors such as large enterprises. Funding is provided mainly through grants and loans to support projects both at the local – e.g., through the REF and other SHS projects – and at national level – e.g., for the construction of large renewable energy projects (from interview with ADB).

In the next section we analyse power relations, influence, and power of the different actors.

6.2.2. Relationality, influence and power: Network density and centrality

Degree and betweenness centrality indexes were used to identify influential or central actors in the network. Figure 3 shows the SNA results (nodes' numbers identify the actors listed in Table 7). Whereas degree centrality helps to identify actors that have many ties to other actors, betweenness centrality makes it possible to identify actors that sit in-between many others, thus potentially playing a key role in the network as they can control information flow, resources and actors inside the network. They act as mediators between different actors (Freeman, 2002).

In terms of the structure of the network, the actors identified were linked through 77 ties in total, resulting in a low network density of 0.15 (the existing number of ties divided by the possible number of ties), which suggests that actors are loosely connected. This disconnection is particularly evident if we look at actors acting at different levels, national and local.

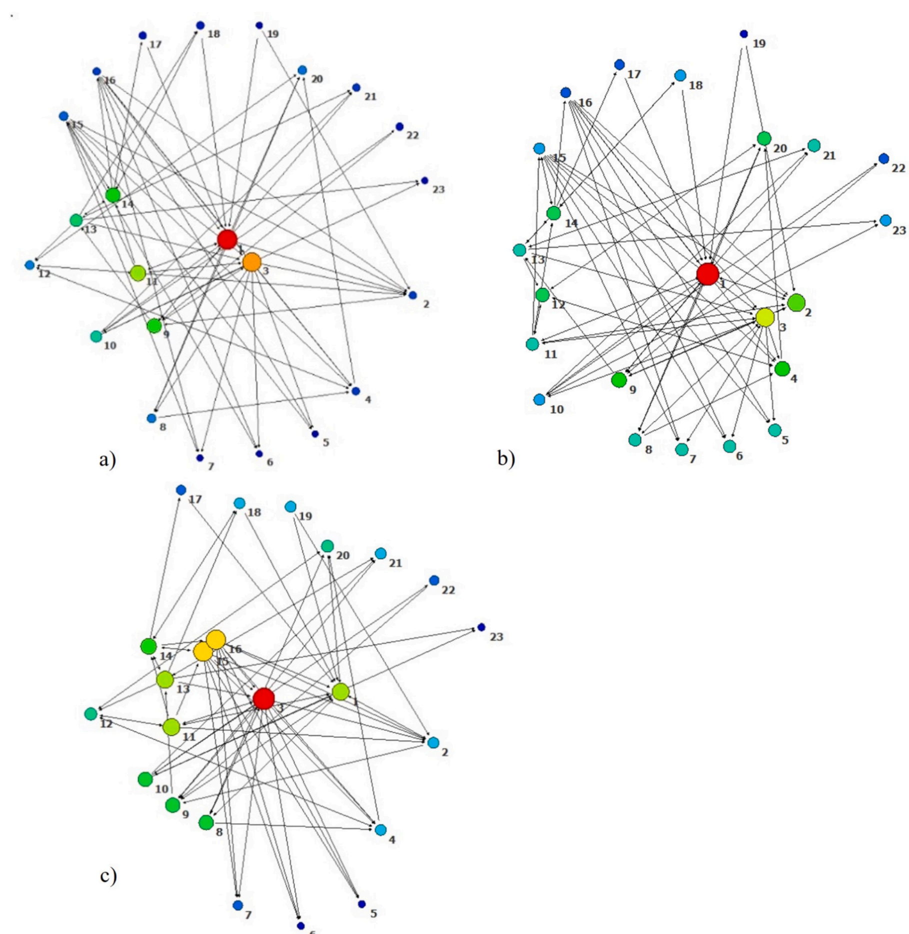

Fig. 3. The social network based on (a) betweenness centrality, (b) in-degree (prestige) centrality and (c) out-degree centrality. Actor positions, colours and sizes reflect their betweenness, in-degree and out-degree centrality in the network. Actors closer to the centre of the graph and with greater size have greater centrality. The colour indicates clusters of actors showing the same centrality in the network (see Appendix 1 for results on Betweenness Centrality, In-degree (prestige) Centrality and Out-degree Centrality for each actor). The graphic elaborations and the degree centrality values were realised with the software Social Network Visualizer® (SocNetV) (SocNetV, 2023).

Not surprisingly, the most central actors at the national level (among the highest betweenness and centrality indexes) are the national government and the MME for their decision-making power, control, and authorization role and for the definition of energy policies and strategies, as explained in the previous section. At the local level, the most central actors are local CSOs, for their role in providing technical support, advice and information and for their interaction with communities on a regular basis, as well as in bridging communities and government representatives. Though CSOs have no decision-making power in the energy sector, they can influence local communities' decisions – for example, in terms of technology adoption and the participation of local households to the REF programme – and therefore also have a weight in the deployment of off-grid renewable energy and energy access in rural communities. They work in close collaboration with local community committees to provide local technical support and to facilitate the exchange of information and knowledge between the communities, community committees and the central government. However, their support to local communities is constrained by national energy policies and funding provided by the central government and sometimes through financial support from international organizations (interviewees from CRDT and EnergyLab).

International organisations also have a high betweenness centrality index, suggesting that even if their decision-making power is limited, they influence the network as they act as 'brokers' creating links between other actors at different levels that would otherwise have poorer connections. International organisations have connections with different actors both at the national and local levels, such as with local CSOs, by financially supporting the development of small and large-scale renewable energy projects and off-grid solar energy. This result was confirmed during the interview with the Oxfam representative, who argued that:

> "The role of CSOs and international donors is crucial to support energy access and renewable energy transition in rural and remote areas. They are involved in decentralised solar systems and in projects to empower local people. However, decentralised energy hasn't been very successful so far due to not enough involvement from the government".

7. Concluding discussion

Applying a power-capabilities-energy justice framework this paper has shown how distributional energy (in)justice, in relation to the ability of people to perform essential activities, is closely connected to vertical power relations, relationality aspects, such as failed relationships between the central government and local realities, and compounded by a lack of recognition in energy policies of local vulnerability. To enhance energy justice and equal opportunities to development in remote rural areas, we close this article by discussing some implications of our results.

First, the findings of our analysis show that communities located in the remote rural field study area are suffering from distributional energy injustice in that they have access to a limited range of energy services to achieve essential capabilities. Misrecognition in energy policy-making of certain subjects of justice (such as female-headed households), of their needs and vulnerabilities, can result in an increased marginality, exclusion from accessing energy services, and inability of performing essential capabilities (Sovacool and Dworkin, 2015; Pachauri and Rao, 2013), such as being in good health, engaging in meaningful work, being well-educated and socially connected, as shown by the results of the FGDs.

Second, looking at the results of the SNA and into the relationality aspect at the intersection of power, capabilities and inequalities, mechanisms of exclusion from energy policies and interventions can be found in the strong reliance of remote rural areas for accessing energy services, on the goodwill of international organisations, CSOs and international donors that provide much-needed local support, as well as on the private initiatives of villagers and community committees.

At the same time, the presence of key bridging actors in the network such as international organisations provide a promising foundation for developing stronger relations between the local and national levels on energy decisions (Laborgne, 2023), but improvement will depend upon a commitment by the Government to devolving more decision-making power and resources to local actors, such as community committees and CSOs.

Ongoing efforts in Cambodia to achieve universal energy access and a just energy transition as enshrined in the universal value of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) to "Leave no one behind" (LNOB), must be accelerated.

Concrete measures could include shifting power and resources towards local organisations, as well as those working on the frontlines. This would allow a better recognition and empowerment of disadvantaged groups to develop and build the foundation for a more just energy transition and energy access in remote rural areas (Cloke et al., 2017).

Expanding the scope of local actors to manage, operationalise and oversee off-grid solar energy systems in remote rural communities can help to reduce the burden of energy access for the most vulnerable households by investing in a more equitable local energy distribution, for example by establishing an affordable electricity price for those more in need and allowing all community members to access the SHS systems of the same quality, as well as successfully operating and maintaining the system in case of failures (Munro et al., 2023). As lack of affordable energy storage emerged as quite an important issue in our results, aided provision of, or subsidy for battery purchase, could be an additional measure. Giving more power and resources to local institutions could also help the creation of participatory mechanisms that involve the local population in the decision-making process at the level of village committees for a better recognition of different vulnerabilities and the design of more adequate policy responses as demonstrated by other local initiatives on community-energy (Gadde and Va, 2023).

Towards this end, energy justice must be improved beyond the development of general policy frameworks (Sovacool and Dworkin, 2015). In relation to our study, effective policies to respond to energy poverty in remote communities in Cambodia should consist of a combination of specific measures tailored to the different challenges arising in communities, as defined by their capabilities. Greater investments in grid extension, capacity building for the villagers to be able to cope with system failures, energy storage and financially supporting multiple fuel use (fuelwood, solar energy, gasoline, etc.) (i.e., fuel switching) (Masera et al., 2020), are essential to ensure a more equitable access to energy services for all community members. The need for the local population to be able to switch between modern and traditional fuels to perform essential activities (lighting, cooking, water pumping, etc.) was confirmed during focus group discussions. Nevertheless, not all households reached by this study can afford to rely on different fuels, and that reproduces inequalities across households with different vulnerabilities and endowments.

As the MME announced, it would take another ten years for the government to provide access to the national grid to the villages left behind by the electrification plans of the country (Sothear, 2023). Until then, an energy justice and relational approach to energy transition is crucial to reduce rising inequalities and vulnerabilities, that prevent people from accessing equal opportunities to development and well-being (Chipango et al., 2023; Siciliano et al., 2021).

In this study the analysis of energy poverty and capabilities was site-specific, further research is needed to shed light on the capabilities and intersectionality aspects of the energy challenges that exist across different marginalised and vulnerable groups in remote communities in Cambodia, for example indigenous groups and ethnic minorities.

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CRediT authorship contribution statement

Giuseppina Siciliano: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Roberto Cantoni:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Pichdara Lonn:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Data curation, Conceptualization. **Narith Por:** Writing – review & editing, Supervision, Project administration, Data curation. **Solany Kry:** Writing – review & editing, Supervision, Data curation. **Chimmor Morn:** Writing – review & editing, Supervision, Data curation. **Ham Oudom:** Writing – review & editing, Conceptualization.

Declaration of competing interest

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.

Data availability

Data will be made available on request.

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Appendix 1

Social Network Analysis results on Betweenness Centrality, In-degree (Prestige) Centrality and Out-degree Centrality.
Degree centrality values were calculated with the software Social Network Visualizer® (SocNetV) (SocNetV, 2023).
Table A1. Betweenness Centrality (BC).

Node↕	Label↕	BC↕	BC'↕	%BC'↕
1	Central Government	113.5	0.2	24.6
3	MME	96.5	0.2	20.9
11	Int. Organisations	74.0	0.2	16.0
9	EDC	62.3	0.1	13.5
14	CSO	59.0	0.1	12.8
13	Local communities	43.0	0.1	9.3
10	EAC	35.8	0.1	7.8
12	Consultants	17.1	0.0	3.7
8	CDC	16.0	0.0	3.5
20	Private investors	15.4	0.0	3.3
15	Academy/Think Tanks	12.7	0.0	2.8
16	Prov. Department	7.1	0.0	1.5
2	MEF	6.8	0.0	1.5
4	MoE	6.3	0.0	1.4
21	SMEs	6.0	0.0	1.3
18	Local Authorities	2.3	0.0	0.5
17	Prov. Gov Representatives	1.3	0.0	0.3
22	Independent Power producers	0.9	0.0	0.2
5	MAFF	0.0	0.0	0.0
6	MRD	0.0	0.0	0.0
7	MPWT	0.0	0.0	0.0
19	Development Banks	0.0	0.0	0.0
23	REEs and PECs	0.0	0.0	0.0

BC' is the standardised index (BC divided by (N-1)(N-2)/2 in symmetric nets or (N-1)(N-2) otherwise.
Table A2. In-degree (Prestige) Centrality.

Node↕	Label↕	DP↕	DP'↕	%DP'↕
1	Central Government	10.0	0.5	45.5
3	MME	7.0	0.3	31.8
2	MEF	6.0	0.3	27.3
4	MoE	5.0	0.2	22.7
9	EDC	5.0	0.2	22.7
12	Consultants	4.0	0.2	18.2
14	CSO	4.0	0.2	18.2
20	Private investors	4.0	0.2	18.2
5	MAFF	3.0	0.1	13.6
6	MRD	3.0	0.1	13.6
7	MPWT	3.0	0.1	13.6
8	CDC	3.0	0.1	13.6
11	Int. Organisations	3.0	0.1	13.6
13	Local communities	3.0	0.1	13.6

(continued on next page)

(*continued*)

Node↕	Label↕	DP↕	DP'↕	%DP'↕
21	SMEs	3.0	0.1	13.6
10	EAC	2.0	0.1	9.1
15	Academy/Think Tanks	2.0	0.1	9.1
18	Local Authorities	2.0	0.1	9.1
23	REEs and PECs	2.0	0.1	9.1
16	Prov. Department	1.0	0.0	4.5
17	Prov. Gov Representatives	1.0	0.0	4.5
22	Independent Power producers	1.0	0.0	4.5
19	Development Banks	0.0	0.0	0.0

The DP index, also known as In-Degree Centrality, of a node u is the sum of inbound edges to that node from all adjacent nodes. DP' is the standardized index (DP divided by N-1).

Table A3. Out-degree Centrality.

Node↕	Label↕	DC↕	DC'↕	%DC'↕
3	MME	9.0	0.4	40.9
15	Academy/Think Tanks	7.0	0.3	31.8
16	Prov. Departments	7.0	0.3	31.8
1	Centr. Gov	6.0	0.3	27.3
11	Int. Organisations	6.0	0.3	27.3
13	Local communities	6.0	0.3	27.3
14	CSO	5.0	0.2	22.7
8	CDC	4.0	0.2	18.2
9	EDC	4.0	0.2	18.2
10	EAC	4.0	0.2	18.2
12	Consultants	3.0	0.1	13.6
20	Private investors	3.0	0.1	13.6
2	MEF	2.0	0.1	9.1
4	MoE	2.0	0.1	9.1
18	Local Authorities	2.0	0.1	9.1
19	Development Banks	2.0	0.1	9.1
21	SMEs	2.0	0.1	9.1
7	MPWT	1.0	0.0	4.5
17	Prov. Gov Representatives	1.0	0.0	4.5
22	Independent Power producers	1.0	0.0	4.5
5	MAFF	0.0	0.0	0.0
6	MRD	0.0	0.0	0.0
23	REEs and PECs	0.0	0.0	0.0

In directed networks, the index is the sum of outbound arcs from node u to all adjacent nodes (also called "out-Degree Centrality"). DC' is the standardized index (DC divided by N-1 (non-valued nets) or by sumDC (valued nets).

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