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Expectations and perceptions of rural electrification: A comparison of the providers' and beneficiaries' cognitive maps in Rural Sumba, Indonesia

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ABSTRACT

The 17 United Nations Sustainable Development Goals (SDG) provide a global common vision for development that achieves equality and equity. SDG 7 on energy has motivated development actors worldwide to promote universal electricity access through rural electrification projects. However, implementing technological interventions in rural areas can be challenging due to differences in worldviews between implementing agencies and cultural communities in which the beneficiaries are embedded. These differences increase complexity of both technology and knowledge transfer as it involves a negotiation of meaning and an adjustment of norms. This study aims to investigate the influence of long-existing cultural practices on the knowledge transfer process for implementation of a renewable energy rural electricity project on Sumba Island in Indonesia. The development actors' expectations and the beneficiaries' perceptions are compared to explore the extent to which knowledge has been transferred. We employ a semi-quantitative method called fuzzy cognitive maps (FCM) to obtain a comparable measurement that is qualitatively explainable. This method enables us to generate a simple statistical analysis based on sixteen key informant interviews. We also generate a belief-based model to predict the electricity access outcomes if the beneficiaries remained on the current level of knowledge. The analysis revealed differences between the providers' expectations and perceptions of the beneficiaries, which helps to explain why predicted electricity access outcomes do not meet expectations. The qualitative analysis also enables us to identify barriers to achieving SDG7 on Sumba Island. We argue that the subsistence nature of beneficiaries' economic practices limits expectations of becoming business entrepreneurs who can pay for electricity tariffs.

Introduction

United Nations Sustainable Development Goal (SDG) 7 on ensuring access to affordable, reliable, sustainable and modern energy has triggered implementation of numerous electrification projects worldwide. In 2019 the value of donor-funded electricity-related projects globally reached more than 206 billion USD (OECD, 2020). The actual investment is probably much greater as this value does not include the contribution of multilateral and private donors or the efforts of national governments in electrifying their regions. The political desire to increase levels of electrification stems from the discourse of electricity as a symbol of development; hence unelectrified regions need to be connected [1]. The global electrification movement and progress to achievement of SDG 7 is significantly enabled by recent technological advances and cost reductions in decentralised renewable energy generation. This has facilitated development actors to tackle two policy agendas simultaneously: delivering modern clean energy services and addressing climate change concerns [2,3]. As a result, the primary beneficiaries of electrification projects are regions in which electricity access has been absent or limited [4].

Knowledge transfer is an essential component of effective introduction of electricity to remote rural areas as the recipient actors may be embedded in a different worldview to the development actors imposing the technology. On one hand, the developmentalists promote technocentric economically-driven ideas that are shrouded by market ideology because the installation, operation and maintenance costs of the technology needs to paid for through electricity access tariffs; while on the other hand, the beneficiaries have a perception of technology shaped by shared traditional cultural practices [5–7]. As Stephenson et al. [7] stated, cultures shape electricity behaviour by altering people's

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definition of, and decisions toward, technological artefacts. Supporting this argument, researchers have provided explanations on the interrelation of worldview and electricity behaviour, in many different cultural contexts such as rural Romania [8], Zambia [9], and Kenya [10].

Indonesia is facing similar issues to many other countries as it works towards high levels of electrification access. The difficulty of electrifying rural areas is exacerbated by a lack of understanding of the socio-historical context in the implementation sites [11]. This has led to unsustainable powerplant operations and supply-demand mismatch [12]. The research presented here addresses this phenomenon by revealing some differences (and similarities) in knowledge from both the supply and demand sides. We utilise a semi-quantitative method called fuzzy cognitive map (FCM) to explore the question of how the providers (supply side) and beneficiaries (demand side) perceive the arrival of electricity in rural Indonesia and why those perceptions arise.

The FCM method has been widely applied in a variety of sectors addressing sustainability issues. The relevance of this method in the field of sustainability Is due the involvement of various domains of actors in achieving the seventeen widely divergent but interlinked Sustainable Development Goals. FCM has been used by researchers to compare stakeholder's perceptions [13], predict policy impacts [14], support collaborative governance [15], and simulate scenarios [16,17]. This research, applies FCM to implementation of the SDGs by addressing the topic of knowledge transfer. We argue that this issue is particularly relevant for translating the narration of sustainability concepts at the community level. An externally imposed sustainability discourse, such as the technical intervention of increasing access to electricity, is translated by external providers into the expected outcomes of sustainable development goals. In contrast, the extant knowledge and cultural context of the project's beneficiaries shapes the way the recipient communities perceive sustainability narration. By comparing both perceptions, we hope that this research contributes to understanding the extent to which knowledge has been transferred effectively to the beneficiaries.

The paper is organised into several sections. After the introduction, we review the theoretical background for our case study and its position in the current body of knowledge. In the third section, we explain the methodology, including data collection and analysis, and the description of our case study. The next section contains the results, which are followed by a discussion of the relevance to the current body of literature. The final section is a conclusion.

Literature review: the influence of worldview on knowledge transfer

Technological intervention is just one part of the system configuration of SDG 7 implementation. The term configuration refers to the alignment of a multifaceted set of variables that fulfil a purpose [18]. In this sense, technology has meaningful interaction with other sets of variables within the configuration [19]. Geels [15] provides an example of the role of heterogeneous elements in supporting the function of transportation technology in addition to the technological artefact. They include the related regulations, infrastructures, cultural behaviour, and markets. The case of the Danish island of Samsø provides an example of how configuration of land-use and demographic change contribute to the success of renewable energy implementation [20]. Conversely, the failure to understand non-technical variables such as community entrepreneurship and market linkage has led to the failure of a supply of rural technologies and services to transform agricultural practices in Ethiopia [21].

Achieving a working configuration requires collaboration between various social groups under a mutual understanding of common goals [19]. This brings the issue of knowledge transfer to the forefront of implementation activities. Knowledge construction emerges through activities embedded within a specific socio-historical context and constrained by material matters [22]. Transferring knowledge is not only a matter of information transmission as it also involves a negotiation of meaning and creating a commonality [6]. Consequently, such activities are problematic when participants are embedded in conflicting worldviews with differing perceptions of institutional change, socio-economic transformation and personal behaviour [6,23].

Research on knowledge transfer of technological intervention has primarily taken place in rural areas in which a particular worldview is rooted and practised amongst communities, for example rural coastal China [24]; rural sub-Saharan Africa [21]; rural Ghana [6]; coastal rural areas of Sabah, Philippines, and Sulawesi [25]; and rural Karnataka, India [26]. Researchers have provided empirical evidence on how belief-based practices contain some components that are against the global development discourse (see Table 1). For example, Clifton &

Table 1
Research highlighting differences of perception in rural development.

Author(s)	Regions	Methods	Themes	Highlighted influencing factors
Alemu & Adesina [21]	Four districts in the north Ethiopia	Statistical analysis based on cross-sectional survey data	Establishing non-farm household enterprises	• Biased development policies • Long-existed farming experience • Household land ownership
Halbrendt et al. [27]	Central mid-hill region in Nepal	Fuzzy cognitive maps	Impacts of conservation agriculture	• Ecological condition around the communities • long-existing agricultural experience
Gaus et al. [23]	Catchment basin of River Hasliaare in Bern, Switzerland	Qualitative and quantitative description of mental model	Integrated watershed management	• actor's ecological beliefs, meaning, and objectives related to floods, mudflows, and hydropower
Wu et al. [28]	China	Correlation analysis based on panel data set across China	China national innovation system policies	• Government budget on research and development • Rural geographical location • Educational disparity amongst rural regions
Slavova & Metiu [6]	Rural Ghana	Ethnography	Agricultural development	• Community rituals as a symbolic actions of the societies
Clifton & Majors [25]	Bajau communities	Descriptive qualitative	Fishing and conservation	• Community perceptions toward environmental decline • Spiritual belief on fish as a resource
Taylor & Bhasme [26]	Rural Karnataka, India		Agricultural technology transfer	• Model farmers as local conduits for program adoption • Power and influence of the model farmer

Majors [25] reveal that, despite its lack of sustainability and condemnation by fisheries experts, the blast fishing method has an essential social role within south-east Asian Bajau communities in supporting their catch-sharing behaviour. Similarly in rural Ghana, the existing farmers' agricultural perspective has hindered deployment of science-based agronomical knowledge as well as market-orientated agricultural practices introduced by development actors [6].

When technological implementation is being imposed on rural communities, the external knowledge of technical experts can become 'a language of domination' over existing indigenous insights. This domination leads to technological outcomes diffusing uni-directionally into the rural communities through technical advice, training, tools, and infrastructure. Moreover, it also creates binary labels used to describe members of the communities in which people enthusiastic about uptake of the technology are classified as 'progressive' whereas others are 'traditionalists' [29]. On the side of the recipients, during the development and knowledge transfer process they become equipped with knowledge constructed by particular values and materiality [5,6] and this shapes how they perceive technology. The outsiders who bring in the technology and associated knowledge often struggle to understand the community's perspectives of reality and development concepts and fail to recognise their culturally determined developmental needs as they live within a different value system [30].

By appreciating that the application of knowledge is contextually embedded and shifts from one context to another [5], this research complements the current body of literature by addressing the interrelation between knowledge and worldview in the context of electricity provision in rural Sumba, Indonesia. The research aims to contribute to empirical debates of how an established knowledge system might absorb, reject or influence technology-related knowledge transfer. Moreover, this research also demonstrates the application of FCM to addressing such issues. By taking advantage of the semi-quantitative nature of FCM, this research provides a quantitative measure of the extent to which knowledge is transferred and so helps to elucidate the barriers accordingly.

Material and methods

Indonesia consists of more than 75,000 villages of widely varying cultural traditions [31], so local perception of technological intervention is a prominent question in Indonesian rural development. Numerous development agencies have communicated the concept of technology-based rationality through diverse rural development agendas, including the rural electricity program [3]. However, despite problems that have emerged due to differences in the perception of development, even to the extent of complete failure of expensive technical interventions, the routine application of methods that measure differences between local knowledge and development discourses in Indonesia are still lacking. The current body of literature is primarily qualitative with general quantitative descriptions and limited validated empirical models (e.g. [32–34]). To the best of our knowledge there have been very few studies on predicting the influence of perception differences on efforts to achieve SDG7.

Research context: Sumba Island, Indonesia

Sumba Island is one of the larger islands in eastern Indonesia (see Fig. 1) and is considered to be a less-developed area in the Indonesia archipelago [35]. In 2010, only 24.5% of Sumba households had access to electricity, while 20% of communities lived below the poverty level [36]. The level of development influenced the non-governmental international development organization Hivos and the Indonesia Government to select Sumba as an 'iconic island' for promotion and implementation of electrification with power generated from the abundant natural resources [37]. The initiative attracted support from various organisations, including national to local governments, NGOs, state-owned companies, the private sector, and aid donors. The status of Sumba as an iconic island was institutionalised by the enactment of the Ministry of Energy and Mineral Resources Decree No. 3051 K/30/MEM/2015 as well as the coordination actions of various actors [38]. The goal is to create access to renewable energy electricity for all 650,000 of Sumba's inhabitants by 2025.

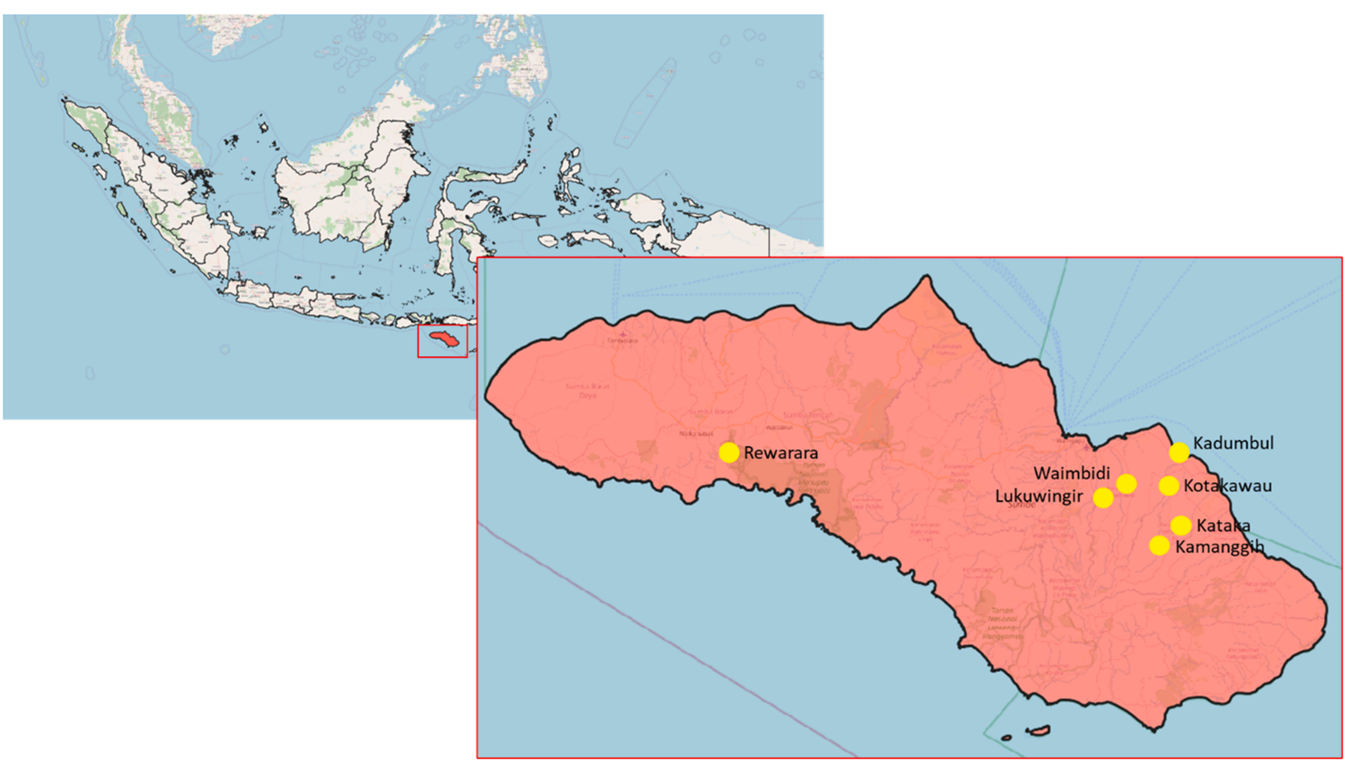

Fig. 1. Sumba Island and location of villages mentioned in the text.

By 2018, 9.3MW of renewable energy generation had been installed with a potential output of 42.2 GWh [12]. Solar photovoltaic powerplants dominate in terms of the number of units installed, with 18,782 units producing more than 7 million kWh. The micro-hydro powerplants have the largest energy capacity. They generate around 34.5 million kWh by using 22 power plants. More importantly, the electrification rates have increased by up to 50.9% in 2018, and the contribution of renewable energy to overall electricity supply reached 20.9% [12]. However, despite installation of powerplants and increased household electrification, numerous households are still experiencing limited and intermittent electricity supply with access only sufficient for lightbulbs and phone-charging capacity [39].

The fuzzy cognitive mapping method

In this study, we utilise the mental model approach that is visualised by fuzzy cognitive maps (FCM). A mental model refers to a cognitive representation of actual issues and associated relationships in people's minds [40]. A person or a group of people develop their mental model by processing accessible information from experiences, as well as obtained information into a set of causal relationships in their mind [41]. By applying this method, we can have a better understanding on where perceived differences originate and develop a predictive model accordingly [27,42]. Gaus et al. [41] revealed that people's mental models are interlinked with decision-making perspectives by filtering incoming information, shaping the meaning, and forming shared beliefs. A mental model-orientated investigation allows us to systematically reveal and analyse an actor's perspectives on specific issues.

FCM is an analytical and visualisation method of the mental model. It is a semi-quantitative mapping technique originally developed by Kosko [43] to create a structural image of people's knowledge in a data-poor situation. Specifically, the FCM quantifies intra-variable relationships within cognitive maps (CM) using fuzzy values ranging from 0 to 1 that are assigned a relationship direction represented by "+" or "-" symbols; or alternatively, utilising linguistic values to define the strength of causal relations elicited from experts [44]. The method involves stakeholders with diverse perspectives or perceptions of certain phenomena; hence it is essential to elucidate the subjective aspects of problems. FCM is particularly useful when variables influencing an actor's behaviour are hard to be pre-identified, there is inadequate statistical data, and no simple answer is available [42].

The main advantages of FCM are the ability to represent various perspectives in an integrated manner addressing specific issues [45]. This representation is beneficial for linking and visualising seemingly disparate concepts for understanding complex situations and working towards a problem-solving consensus [46,47]. The semi-quantitative nature of FCM brings together the advantage of qualitative and quantitative approaches. In this way the technique combines the ability to capture complex issues whilst maintaining consistency and reliability [48]. It provides a practical measurement of people's perspectives and enables comparison between individuals [49] and so creates a quantitative basis for a rich-qualitative narration. This feature enables FCM to provide a good foundation for collaborative problem-solving and decision-making [15,50]. Recognising the existence of different perspectives is essential for designing an effective participatory process. By using FCM, actors can represent their current understanding, learn from each other, and critically reflect on their existing beliefs [51]. Such application has benefitted researchers in highlighting diverse perspectives in various fields, for example water services [15], disaster management [52], environmental management [46,53], and agriculture [27,54].

Another prominent feature of FCM is to develop belief-based policy simulations. It generally asks "what-if" questions and predicts the system direction under different conditions or policy options [42]. This simulation feature of FCM helps to analyse system behaviour and estimate possible scenarios in the future. This belief-based simulation has been used by researchers in various domains. Goswami et al. [55], for instance, apply this feature in predicting the results of Covid-19 policies on smallholder farmers in India, whereas Solana-Gutiérrez et al. [54] utilise it in modelling river management scenarios. In exploring issues association with the sustainable development goals, FCM has been used to contribute to formulating strategies [17], gathering expert knowledge [13], and exploring inter-sectoral nexus [56]. For example, Ameli et al. [17] utilised FCM to develop strategies for achieving SDGs in three different COVID-19 outbreak scenarios; and Aravindakshan et al. [13] collated farmer's knowledge for formulating priorities in farming methods in the context of achieving SDG2.

Data collection and analysis

This research utilises stakeholder's statements obtained by conducting interviews for constructing the FCM. The data collection was conducted in February-April 2021 during constraints imposed in response to the Covid-19 pandemic and complied with Indonesia's social restriction policy at that time. Most interviews were conducted individually in either public or cross-ventilated rooms with limited numbers of participants. This practice can also avoid bias arising from power relations within the community, as hierarchical strata exist amongst traditional Sumbanese communities (see Fathoni et al. [57]). To accommodate limited literacy of some of the beneficiaries, we standardised the edge's weight into either "significant" or "not significant". Although the literacy constraint was not present on the provider's side, this was applied equally to all respondents to simplify the comparison process.

A total of sixteen experts were interviewed, representing both providers and beneficiaries. The interviews included five providers, with representatives from NGOs, provincial and local government bodies directly involved in the Sumba Iconic Island projects. Eleven beneficiaries were interviewed, comprising village agents who had contributed socially or technically to any related programs. The beneficiaries included individuals with a range of roles within the community such as priests, community organizers, technicians, and managers of village cooperatives. The data collection processes adhered to the ethical approval obtained for this research from the Research Ethics Committee of the first and second authors' institution. Consent from the interviewees was obtained, with a formal process for providers' informants through a series of research permit letters, and verbal consent obtained from the beneficiaries prior to the interviews.

The stakeholders were selected using two methods: predetermination based on reviewing relevant reports and literature (e.g. [12,58,59]), and snowball sampling during the fieldwork. The pre-determination method was chosen to simplify the fieldwork process and provide an understanding of each stakeholder's role in electricity projects. This method is more applicable for identifying providers rather than beneficiaries since most electricity projects are well-documented. Apart from identifying the stakeholders' roles in the project, the distribution domain of the stakeholders was also taken into account. This ensured that stakeholders from various levels of government bodies and non-government entities were represented. Considering the distribution domain also allowed for inclusion of stakeholders with multiple roles within the electricity project, such as central government as the enabler and initiator, provincial government as a technical regulator, and NGOs involved as funders, technical operators, and inter-institutional intermediaries. Additionally, the snowball sampling method was employed to ensure the inclusion of as many relevant parties as possible, particularly amongst the beneficiaries. This method involved identifying initial actors and then asking them to recommend other relevant actors, thus expanding the network of stakeholders involved in the research.

We selected seven villages on the basis of three criteria: 1) The village had to have a self-managed off-grid powerplant, 2) the sample included both successful and unsuccessful cases, and 3) a variety of renewable power plants were covered. We conducted interviews in the following villages: Kamanggih (10 kW of wind powerplant), Kadumbul (approx. 0.2 kW of wind powerplant), Waimbidi (22 kW micro-hydro powerplant; same powerplant with Lukuwingir), Kataka (20 kW of solar PV), Lukuwingir (22 kW micro-hydro powerplant; same powerplant with Waimbidi), Kotakawau (2.5 kW of micro-hydro powerplant), and Rewarara (1.6 MW micro-hydro powerplant).

All interviews were conducted in Bahasa-Indonesia. During the interviews, all informants were asked a general question: "What variables or things come to mind when I mention electricity?" This open-ended question aimed to identify variables related to electricity without influencing the respondents' answers. All variables mentioned were noted for the purpose of subsequent questions. In the second-layer question respondents were asked to clarify the meaning of the variables mentioned and were prompted to explain the causal relationships amongst these variables. In cases where informants had difficulty describing the relationships, the field team provided non-relevant examples of inter-variable causal relationships to help them understand and describe the relationships. The clarification for each relationship mentioned was based on the respondents' descriptions, such as asking if there was a relationship between variables A and B, what kind of relationship it was, and whether it was significant. There was no specific time limit for the interviews, although the process generally took around 30 min. The interview was considered finished when the interviewers believed that the information provided was saturated. The interviews were recorded and transcribed to ensure that no information was overlooked. The causal diagrams created during the interviews were preserved as supporting information for further analysis.

In order to develop individual cognitive maps, the informant's explanations are transformed into numerical data in the form of n x n adjacency matrix where n is the number of variables mentioned by the informants. As for the relationships between variables, we translated it into the relation's weight. If the relation is considered 'significant", we put the weight 0.67 and if "not significant, we put 0.33 as the weight. In terms of the direction, the "+" represents a positive relationship amongst variables, whereas the "-" is the opposite. In total, we developed sixteen individual maps consisting of 128 different variables.

The individual cognitive maps were aggregated into two maps representing the providers and beneficiaries social groups. This step was taken to visually condense the information and allow for direct comparisons between the two maps. Given the limitations imposed by the COVID-19 restrictions, using a participatory approach for formulating cognitive maps was not possible. Therefore, the categorisation was done by the researchers. We were aware that at this point that bias from our own views into the analysis was possible. To minimise bias the researchers took the precaution of presenting their findings to several respondents before finalizing the results. This step allowed for feedback and validation from the stakeholders involved, ensuring that the aggregation of the maps was relevant and accurately addressed the phenomena. The meeting with the respondents also provided a space for mutual discussion and further refinement of the findings, thereby promoting a collaborative approach to the research process.

In combining the maps, the presence of opposite signs in the connections decreased the weight of those connections, while agreement reinforced the causal relationship [42]. For instance, if variable A was found to have a relationship with variable B in multiple individual maps, the weight of the connection was determined by averaging the net values of those connections. The process of simplifying the variables was conducted qualitatively by subjectively grouping variables into categories. For example, some respondents mentioned various types of businesses they were involved in or observed, such as wood processing, mechanics, and shops. In order to aggregate the information, these variables were combined into a single category called "small business". Similarly, variables related to the "use of appliances" category were created by combining mentioned variables such as "use of computer," "watch television," "refrigerator," and "handphone" that were all associated with the use of different appliances.

After aggregation, the simplified maps consisted of 31 aggregated variables. These variables are generally associated with three themes: the accelerators or barriers of the sustainability of powerplants; the benefit of direct application of electricity in people's life's (level one); and the outcomes or benefit level two that represents the derived benefit of electricity application (Table 2). Figs. 2 and 3 are diagramatic representations of the relationships between all variables. The edges on both maps indicate the total values where the red line indicates negative-sum connections, while the blue line reflects positive-sum connections.

We utilise two steps of analysis: structural comparison of the aggregated cognitive maps and belief-based simulation. The first step is conducted by comparing the graph data of both matrixes (Table 3) including the number of receivers and transmitters, the map densities, and degree of centrality of each variable in both maps. The belief-based simulation is used to predict the outcome of policy intervention, particularly for the beneficiaries. This was done by clamping variables that related to the desired scenario [42]. Usually, this feature of FCM is utilised to do an inter-comparison between two or more scenario simulations. Solana-Gutierrez et al. [60] for example, generate different river restoration scenarios using the FCM simulation; whereas, Ameli et al. [17] simulate five proposed SDG strategies in COVID-19 outbreak situations. In this research, FCM simulation is applied to two scenarios: improvement of electricity connection by extending the daily supply; and enhancing the diversity of appliances. These scenarios are based on the research conducted by Wen et al. [39] who explored the willingness to pay (WTP) of the Sumba community. Their research highlighted the Sumba community's WTP for supply extension and increased usability of electricity [39].

The main question addressed in this simulation is: "What will happen to the community if the providers improve the quality of the electricity

Table 2
Categories of the variables in the aggregated cognitive map. Benefit level one is direct application of electricity in people's lives.

Categories	Providers	Beneficiaries	Short description
Accelerators/ barriers of the sustainability of powerplants	Land availability, capacity to maintain, renewable sources, community awareness, network quality, trust to officials, monthly payment	Community awareness, renewable sources, church supports, monthly payment	Factors that influence the operation of the power plant, both in the construction phase and in operation and maintenance
Benefits level one	Use of appliances, lighting, expenses	Use of appliances, lighting, expenses	The application of electricity in people's daily life
Outcomes or benefits level two	Women empowerment, productivity, agricultural activities, water supply, weaving, children studying, cultural events, threats to livelihood security, community cohesion, New job, public facilities, environmental protection, daily needs, entertainment, access to information, quality of life, small business, more income	Laziness, water supply, security threat, women empowerment, entertainment, social media, children studying, public facilities, access to information, weaving, daily needs, productivity, agricultural activities, small business, more income, cultural events, quality of life	Outcomes of the benefit level one. Advantages or disadvantages that are triggered by the benefit level one

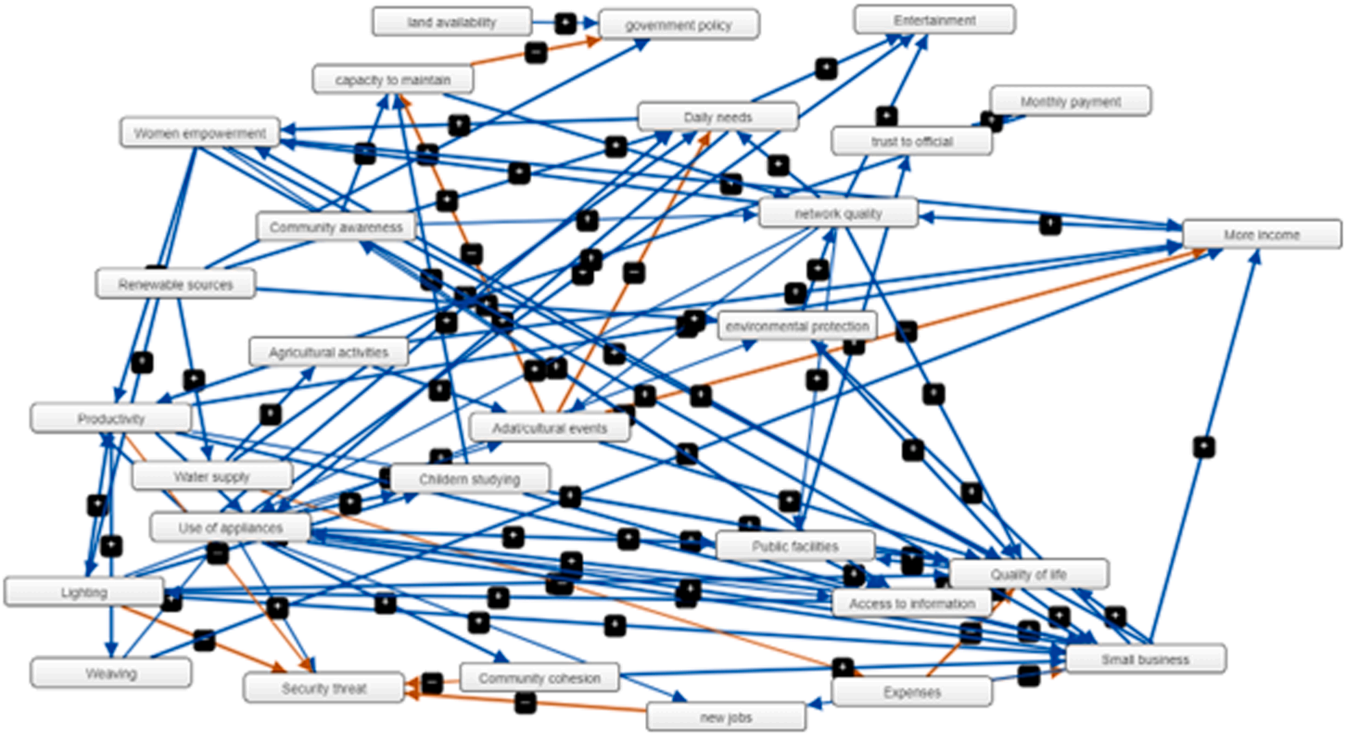

Fig. 2. The aggregated mental model of the providers.

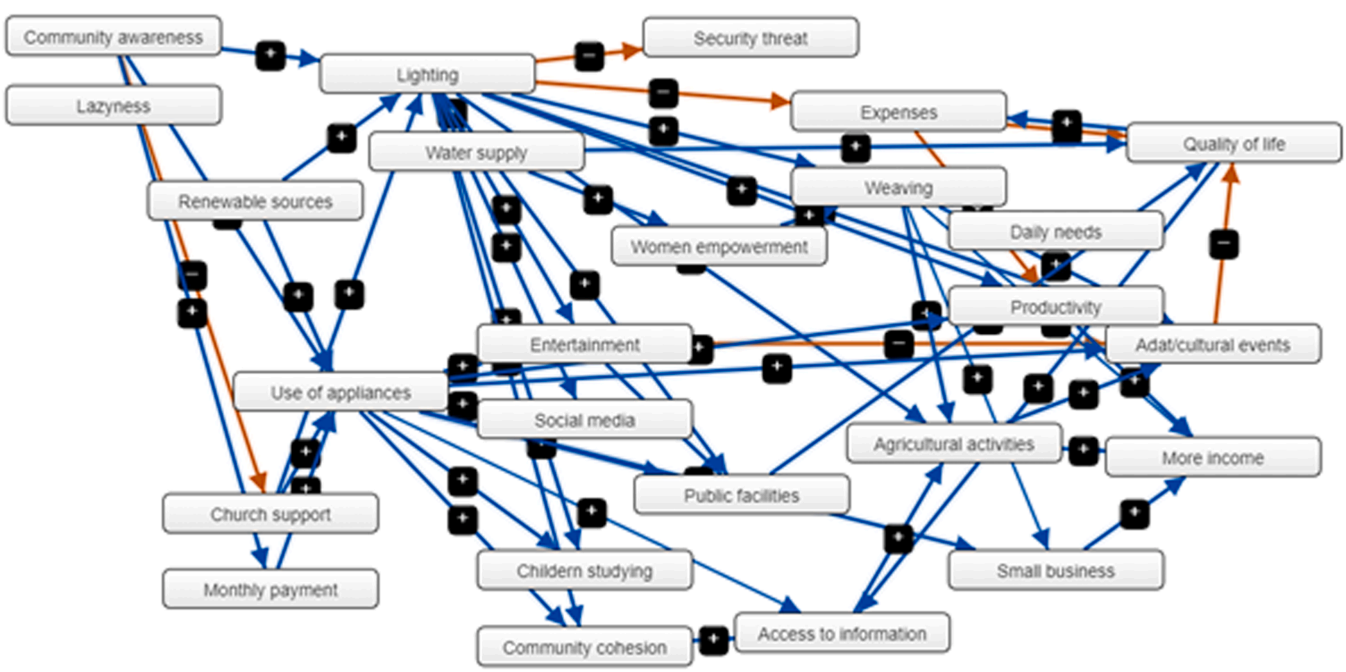

Fig. 3. The aggregated mental model of the beneficiaries.

connection?" To conduct the analysis, including visualizing the cognitive maps, a free web-based software called Mental modeller (www.mentalmodeler.com) was utilized. Mental modeller is a computer-based FCM tool that enables researchers to develop models, generate statistical attributes, and formulate model-based scenarios [44].

Results

Different beliefs about electricity

The cognitive maps indicated both similarities and differences in how electricity is framed through dynamic connections between variables amongst the social groups. The diagrammatic representations in Figs. 2 and 3 show the aggregated mental model of providers and beneficiaries. Generally, both parties believe that electricity triggers

Table 3
Descriptive statistics of the structure of both cognitive maps.

	Providers	Beneficiaries
Total variables	29	25
Total connections	89	52
Density	0.11	0.09
Connection per components	3.07	2.08
Number of transmitters	2	2
Number of receivers	3	5
Number of ordinary	24	17
Complexity	1.5	2.5

positive impacts on other variables as indicated by the blue line majority and the "+" symbol that dominates both graphs. In other words, both parties shared a similar optimism toward the rural electricity program. By looking at both graphs, it is clearly visible that the providers are better at associating electricity with other variables and the more complicated graph structure indicates this with a significantly larger number of connections. In contrast, the beneficiaries have simpler causal thinking as indicated by a smaller number of variables and connections.

The exploration involves some structural attributes of both cognitive maps, such as the number of transmitters, receivers, and ordinary variables, the density, complexity, and the variable's centrality. Each model forms specific patterns that enable us to determine how stakeholders view the system [42]. While the number of variables are similar, Fig. 2 has significantly more connections, leading to a denser map. On the other hand, Fig. 3 has more receiver variables, while the number of transmitters is equivalent to the providers' map.

The differences in density index between the providers' map and the beneficiaries' map indicate variations in the perception and understanding of the expected impact of electricity. The providers' map, with its higher density, suggests that the providers have a better grasp of the causal relationships and interconnections amongst variables related to electricity benefits. They are able to articulate a broader spectrum of benefits and understand how changes in one variable can have a significant impact on multiple variables. On the other hand, the beneficiaries' map exhibits lower density, indicating a less interconnected understanding of the variables and their relationships. This suggests that the beneficiaries may have a limited understanding of the potential benefits of electricity or may not be able to articulate the causal relationships as effectively as the providers.

The larger number of receiver variables on the beneficiaries' map indicates that electricity is perceived to have more outcomes than initially expected by the providers. Moreover, a larger number of receiver variables on the beneficiaries' map indicates that the electricity has more perceived outcomes than the providers expected. According to both maps, there are three expected outcomes: 1) reducing threats to livelihood security, 2) more entertainment, 3) government policy support. The perceived outcomes include: 1) reducing threats to livelihood security, 2) the use of social media, 3) more income, 4) children studying at night, 5) fulfilling daily needs.

Degree of centrality is also useful to examine as it shows which variables are the most central in both systems. Centrality refers to a number of variables that are directly connected. A variable with a high degree of centrality can be considered important [61]. In the Sumba case, differences in belief systems are also reflected in the different variables considered central, as shown in Fig. 4. Generally, the providers' map has more degree centrality in the majority of variables. It shows the providers' optimism toward electricity as they expect a more comprehensive benefit of electricity. A larger value of centrality means that variables are more connected; therefore, an improvement of a certain variable due to electricity can stimulate the enhancement of many other variables.

In terms of the most pivotal variables, there is a disagreement between both parties. The providers see the "use of appliances", people's "quality of life", and the existence of small businesses as the most central variables, with the centrality values 9.18, 8.36, and 8.7, respectively. In contrast, the beneficiaries consider "lighting" and the "use of appliances"

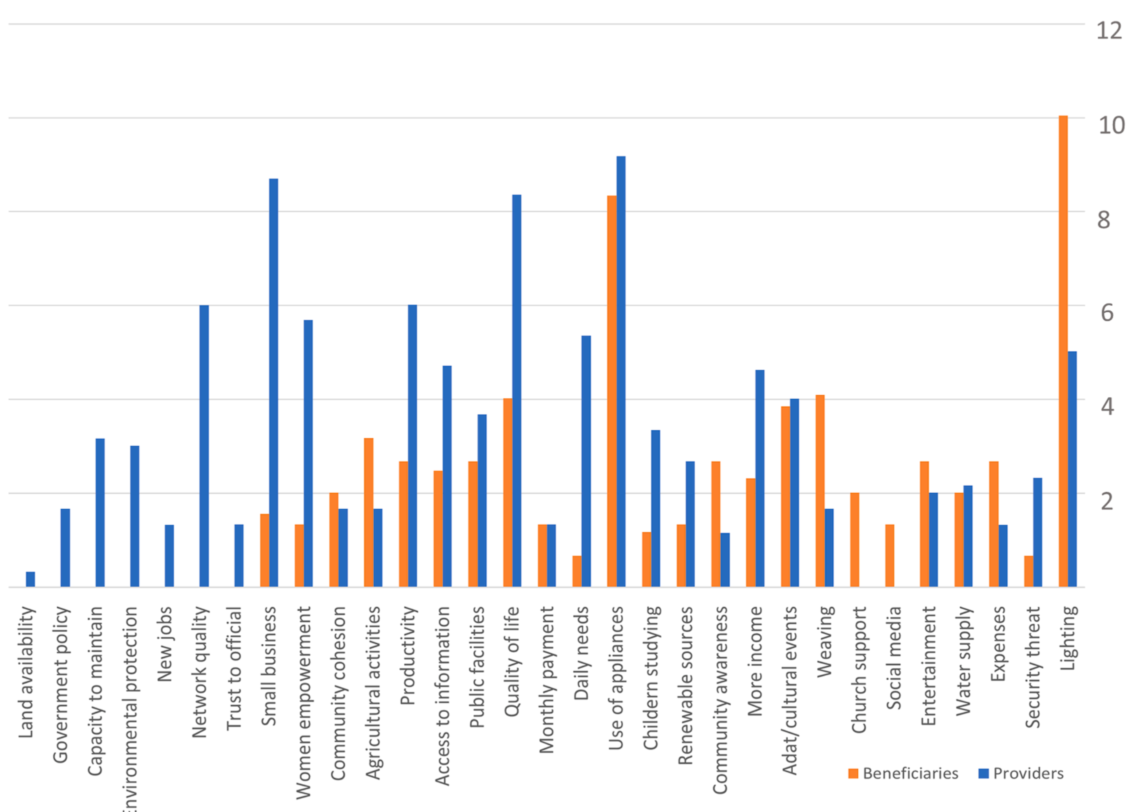

Fig. 4. Comparison of degree of centrality of variables for providers and beneficiaries.

as the most important variable within the whole structure of the cognitive maps, with centrality values of 10.05 and 8.34, respectively.

Improved quality scenario

In the scenario involving improvement of electricity quality, which includes an increase in the duration of supply and more generation capacity, two specific scenarios are chosen based on their relevance to the Sumba community [39]. For the improvement of the duration of supply, the clamping method is applied to the variable "lighting" because most of rural Sumba is connected to a lighting-only access to electricity. By selecting this variable, the aim is to include areas where the primary improvement with increased electricity duration would be in lighting. In the second scenario of increasing the capacity of generation, the clamping method is applied to the variable "use of appliances" since the rise in capacity would enable the community to utilise more appliances. This variable is chosen to explore potential changes in appliance usage with increased generation capacity.

Figs. 5 and 6 show the predicted changes if the improvement of electricity quality is provided and show the predicted benefits for beneficiaries (Fig. 5) and the benefits expected by providers (Fig. 6) under this condition. The result of this model is a value between 0 and 1. The number indicates the estimated increase or decrease of other variables when the lighting and use of appliances are increased to the maximum value of 1.

Generally, the simulations on both cognitive maps show that the beneficiaries' map is more sensitive to intervention. Based on the beneficiaries' map, the extension of electricity duration is estimated to trigger several variables in which “productivity” is the most affected variable (Fig. 5). Whereas the variable of “children studying”, weaving”, and “water supply” are the second most affected. On the other hand, under the same scenario, the providers' cognitive map has a more limited responses with the variable “children studying” is the most increased. Furthermore, for the second clamping scenario (Fig. 6), the beneficiaries' map has five most-affected variables: “small business”, “community cohesion”, “productivity”, “social media”, and “entertainment”. Whereas the variables “daily needs” and “entertainment” are two variables that are estimated to increase according to the providers' map.

In general, the simulations on both cognitive maps indicate that the beneficiaries' map is more sensitive to intervention compared to the providers' map. Based on the beneficiaries' map, the extension of electricity duration is estimated to have a significant impact on several variables, with "productivity" being the most affected variable (Fig. 5). Additionally, variables such as "children studying," "weaving," and "water supply" are also notably influenced. In contrast, under the same scenario, the providers' cognitive map shows more limited responses, with the variable "children studying" being the most increased. Moving to the second clamping scenario (Fig. 6), the beneficiaries' map reveals five most-affected variables: "small business," "community cohesion," "productivity," "social media," and "entertainment." On the other hand, according to the providers' map, the variables "daily needs" and "entertainment" are estimated to increase. These findings suggest that the interventions have a greater impact on the variables in the beneficiaries' map, indicating a more significant change in their perception and behaviour in response to the improvement in electricity duration and generation capacity.

The results indicate that the beneficiaries believe that improving the duration of electricity access will be a primary factor for increasing their productivity. The additional working hours made possible by improved lighting will have a significant impact on their weaving activities and enable their children to study at night, making these variables the second most affected in the first scenario. Interestingly, in this scenario, the providers believe that increasing the duration of lighting alone is not sufficient to trigger a significant impact on the community. According to their cognitive map, the most substantial influence of increased electricity duration is enabling children to study at night, while other variables require more comprehensive interventions to be affected. This suggests that the providers perceive the need for a holistic approach to bring changes in various aspects of the community's well-being beyond just extending the duration of lighting.

Results from the providers' simulation also apply to the second clamping simulation, while the beneficiaries' results highlight some additional points of influence. According to the providers' map, encouraging the use of diverse appliances will provide the community

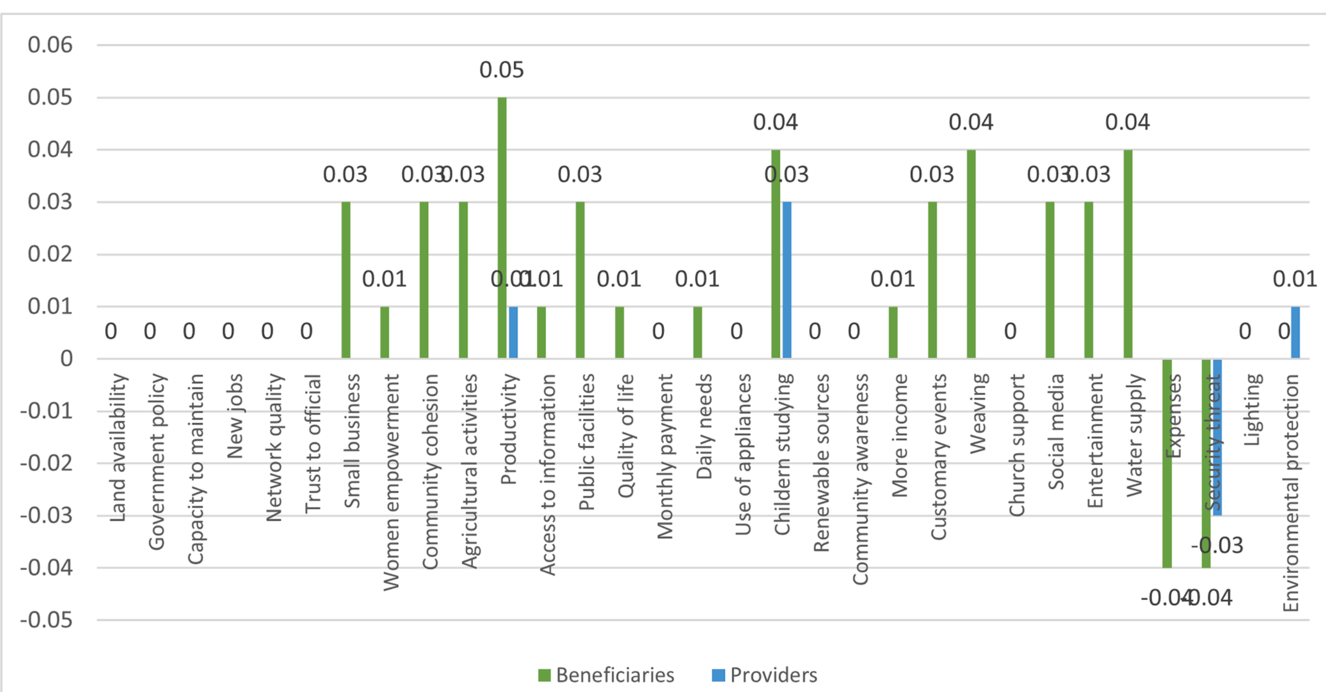

Fig. 5. The result of belief-based prediction on both cognitive maps if the variables of “lighting” is clamped.

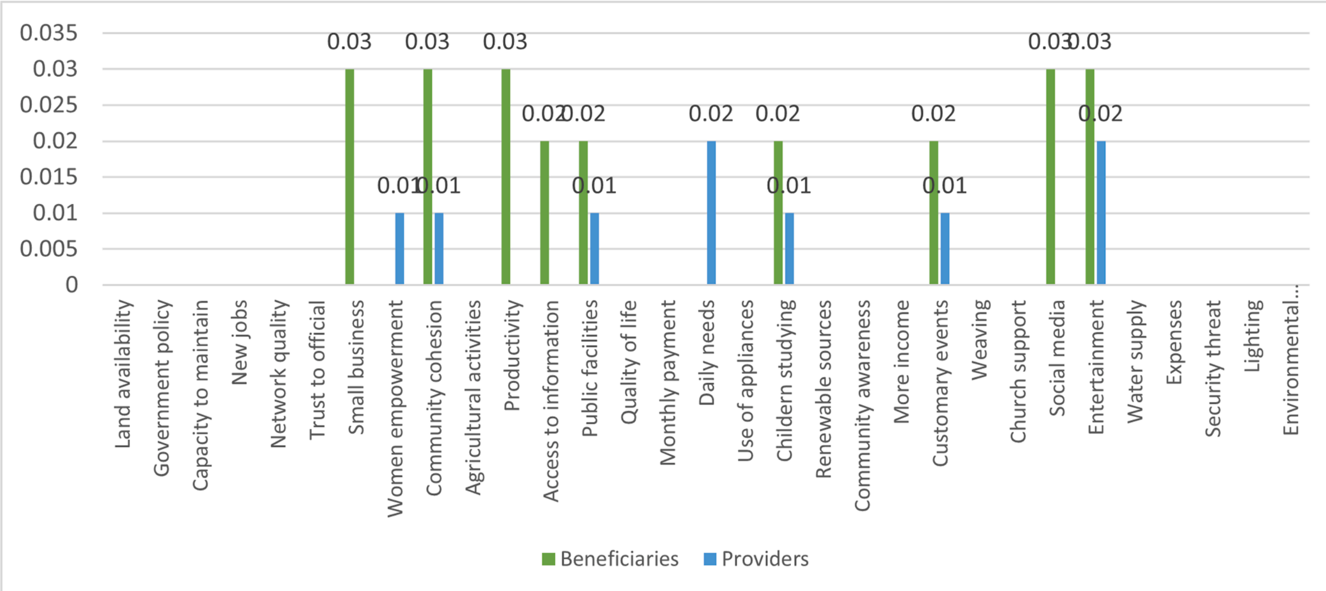

Fig. 6. The result of belief-based prediction on both cognitive maps if the variables of "use of appliances" is clamped.

with access to fulfilment of their daily needs and to be entertained. This includes introducing more efficient cooking practices by using a rice cooker instead of a traditional stove, and increasing their entertainment activities through the use of television, radio, and smartphones. On the other hand, according to the beneficiaries' map, while there is also emphasis on entertainment impacts, the beneficiaries also believe that by utilising diverse appliances they can establish new businesses as well as just being more productive. They see opportunities to diversify their livelihoods, such as using a fridge to sell cold drinks or utilizing mechanical tools to create furniture. However, in both scenarios the influence of increasing the quality of electricity connection to the variable "more income" is observed to be limited.

Discussion

The application of FCM has enabled us to explore different perceptions and expectations from two groups, providers and beneficiaries of electricity access, with different cultural embedding. The centrality analysis (Fig. 4) indicates dissimilarities. On one side, the providers promote a global discourse of electricity with a focus on modernity, productivity, and profits [1]; while the beneficiaries' cognitive maps represent the direct benefits of electricity of lighting and the use of appliances as the most significant variables.

The providers' expectation is based on their common concept of how electricity could impact people's lives and assumes a certain causality of future outcomes. Our analysis captured this causality and found that the providers have a common understanding that electricity is a trigger of economic productivity and hence a catalyst of prosperity. This concept is illustrated in the implementing agency's project vision statement and during the interview process:

> "*... ensuring the provision and utilisation of new and renewable energy sources that can* ***encourage*** *an inclusive and gender-just* ***economy*** *in order to* ***improve the welfare*** *of the people of the island of Sumba*" (SII Development Team, 2012: 3)

> "*... actually electricity is just a tool. Our goal is people's* ***economy****, so we actually want to* ***improve the welfare*** *of rural communities and isolated areas*" – Interview with IBEKA, 2021

This concept is guided by a rationality-based logic which emphasises the ability of electricity to encourage small businesses and productivity through the utilisation of appliances. This idea is also triggered by the necessity to generate profit to fund the operation and maintenance of powerplant. The providers convey the message through events in which they induce beneficiaries through reasoning or argument [62]. In the case of Sumba, our providers' informants reveal that before establishing a powerplant there were a series of meetings to explain the rules of the game, including each party's responsibilities, potential benefits, and operational and management issues.

On the other side, the beneficiaries' perceived concept is more straightforward. They emphasise 'lighting' and 'use of appliances' as the most central variables as these benefits enable them to do things they could not do before, such as night studies and daily household tasks. This is due to their limited access to participate in broader discursive activities and the educational background of beneficiaries [27]. Some of their statements illustrate this finding by emphasising lighting and the ability to use appliances as the benefits generated by electricity

> "*for lighting, for children studying at night, watching TV and charging cellphones*" – interview with a beneficiary in Kamanggih village, 2021

> "*I use it for lighting and charging the cellphone. In this village, finally, the children can study at night, even though there are only 2 or 3 lightbulbs, but the house is bright. To charge cellphone too and listen to music*" – interview with a beneficiary in Kotakawau Village, 2021

The differences between two parties in perceiving technologies affect the knowledge transfer success [6]. The ability to effectively articulate the benefits of electricity can indeed influence the performance of both the providers and the beneficiaries in sustaining the power plants. The study by Marlow et al. [63] emphasises the significance of the quality of conversation in determining group performance. In the context of electricity provision in Sumba, the differences in articulating the benefits of electricity between the providers and the beneficiaries represents the communities' expected performances and their fulfilment level. The unsustained operation of power plants and the unaccommodated needs of the communities in Sumba can be seen as indicators of the degree of successful knowledge transfer. If the knowledge about the benefits and utilization of electricity has not been effectively transferred to the beneficiaries, it can result in challenges in operating and maintaining the power plants, as well as addressing the specific needs and requirements of the communities.

However, we argue that our comparison on the map's density

(Section 4.1) shows that the providers' ability to engage in broader discursive practices with academics, practitioners, and policymakers contributes to their deeper understanding and ability to explain the benefits of electricity. In contrast, the isolated nature of the community, both spatially and informatively, may hinder their involvement in such conversations and limit their access to knowledge and information about the potential benefits of electricity. Despite these differences, the insignificant difference in density values suggests that both providers and beneficiaries are engaged in conversations about electricity benefits, albeit to varying degrees. This implies that the transfer of knowledge from the providers to the beneficiaries has occurred to some extent, even if not perfectly perceived by the community.

Despite the differences in articulating the importance of rural electrification as well as perceiving the pivotal variables (Section 4.1), interestingly, the simulation results show that the beneficiaries have more expectation in obtaining electricity benefits than the providers. We found that the beneficiaries believe that increasing electricity duration will improve people's productivity through more weaving time, whereas increasing the capacity of connection will trigger more business. On the other side, the provider's simulation does not result in as many benefits as the beneficiaries. We argue that this phenomena is associated with the more straightforward and simpler structure of beneficiaries' maps with the variable “lighting” and “use of appliances” more central..

The results indicate that while scenario 1 is predicted to increase productive time for weaving and scenario 2 is predicted to enable people to establish more businesses, these activities may not necessarily lead to a significant rise in household income. This observation can be attributed to the fact that agricultural practices dominate the livelihoods of the Sumba community, with other businesses serving as secondary sources of income. Several factors contribute to the limited impact of electricity on household income. Firstly, the social and cultural significance of weaving products may not translate directly into increased market demand or higher prices for these products. Additionally, the limited market access and economic opportunities within the community also pose challenges for expanding businesses and generating substantial income. While the cognitive maps suggest a narrative alignment between the providers' ambitions of electricity's economic benefits and the beneficiaries' perception of productive use, practical factors such as market size and people's business orientation hinder the materialisation of these benefits into income generators.

Moreover, we also argue that the long-existing practice of subsistence economy influences their entrepreneurial practices. Like other “survival entrepreneurs", the beneficiaries tend to stick to familiar-traditional ways over profit-maximising but potentially risky opportunities [64]. Their 'safety-first' principle has decreased their tendency to adopt new practices as their traditional methods have been proven to supply sufficient for the household's minimum necessities. Although almost all of our beneficiaries' informants stated that electricity had enabled them to establish a new business, the majority of these are side businesses in addition to their agricultural activities, as stated by one of our informants:

> "*The husband goes down to the field, the wife too. The husband works in the garden, and the wife works as well. When going back home, it is impossible for a man to weave, but women weave (at night)*" – Interview with a beneficiary in Kataka, 2021

The above statement illustrates that farming is their main source of income as it consumes most of their time, whereas the business (weaving) is done (by women) when they finish farming for the day; and electricity has enabled them to work at night.

Like most Sumbanese, our beneficiary informants primarily rely on livestock and agriculture as their primary source of livelihood. Both practices have similar cultural orientations of survival and social. Given the lack of agricultural infrastructures, both livestock-raising and farming activities in Sumba depend largely on nature and, hence, uncertainty. Almost all agricultural areas in Sumba are rainfed rice fields and so there is only one harvest annually. In some cases, when there is heavy rain or pest attacks during the harvest season, farmers experience crop failure, as happened in 1998 [65] and 2009 [66]. Regarding the livestock-raising activities, most households in Sumba have at least one animal, such as horses, buffalos, and pigs. However, the high demand for livestock for customary purposes and the need for investment in education have hindered them from being business entrepreneurs, as stated by one of our informants:

> "*If, for example, they have a child who wants to be registered (to a school) and at the same time, there is a need for customary (adat) events, of course, they prefer the customary. Because they do not want to break their relationship with their relatives. They prefer to sacrifice their child's necessities rather than his family in the village*" – Interview with a beneficiary in Kamanggih, 2021

These Sumbanese customary cultural practises are rooted in risk-sharing mechanisms, such as crop yield-sharing and barter, that enable them to maintain their traditions whilst being economically self-sufficient.

The existing Sumba literature supports our findings. Fowler [67] revealed the concept of *cari hidup* (seeking livelihood) of Sumbanese women. According to the research, Sumbanese women are involved in intra-island trade by either selling agricultural products collected from villages or trading commodities from market to market. However, they make little profit (around 0.01 USD per item) and this is immediately used for necessities [67]. Kusumastuti et al. [68] also emphasised the survival-mindedness of East Sumba residents by stating that they would be content if they were able to afford food for a day; hence it becomes a challenge to establish rural businesses. Some researchers highlight the need for continuous external assistance due to low encouragement of the community to adopt externally-determined policies and technological innovations [69,70]. Kusumastuti et al. [68] highlight this phenomenon by stating that the communities have a "myopic view of life" (p. 5) and lack of motivation and capabilities to sustain a business; after investigating a household-based food processing industry in East Sumba Regency where only 18 out of 440 business groups survived.

Conclusions

This research illuminates two different beliefs about electricity from two different culturally-embedded actor groups. The application of FCM provides quantified results as a basis of explaining how people's worldview and environmental condition influence their energy-related decision by constraining certain variables and enabling others. Our FCM results confirm the difference between two parties in articulating the benefits of electricity and hence affecting the expected and perceived electricity behaviour. However, the beneficiaries have optimism as showed in our simulation results; as they expect themselves to be more productive if more quality of connection is provided.

Furthermore, our findings also show that cultural and market barriers, particularly related to conservative agricultural practices and the high demand for livestock, have limited the beneficiaries' ability to fully exploit the productivity gains offered by electricity. The adherence to long-existing cultural behaviours and the uncertainties associated with agricultural practices in rural Sumba have influenced the priorities of the community, with agricultural activities taking precedence over entrepreneurial pursuits. This highlights the complexity of knowledge transfer in situations where actors have different worldviews and deep-rooted practices [5,6]. Thus, in our case, transferring the providers' expectations is not as simple as delivering information. Instead, it involves an adjustment of norms and values triggering their current economic practices. These findings align with existing literature on knowledge transfer, which emphasizes the challenges of transferring expectations and adjusting worldviews between different actors. It highlights the importance of considering cultural and contextual factors when designing interventions and strategies aimed at promoting economic development and leveraging the benefits of electricity provision.

Lastly, whilst we focus on the similarities/differences of perception, a discussion about how these perceptions shape energy behaviour is beyond the scope of this research. We also argue that despite the findings of this study aligning with other empirical cases, these results are context-specific and not generalisable. People with a shared belief system adapt and adjust their norms in response to global circumstances uniquely; hence, context-specific research is necessary. However, the application of FCM for exploring the similarities or differences of different belief systems is relevant beyond our case. We believe that utilising FCM to generate sensible and comparable evidence on how targeted groups perceive issues provides useful information for formulating policy deployment strategies.

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Declaration of Competing Interest

On behalf of the co-authors, I, Hafidz Wibisono, confirms that there is no conflict of interest in this manuscript

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