

## Review

# Energy Supply System Modeling Tools Integrating Sustainable Livelihoods Approach—Contribution to Sustainable Development in Remote Communities: A Review

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**Abstract:** The fulfillment of the sustainable development goals of the United Nations (UN) in remote communities undoubtedly goes through the consequent development of the energy supply system (ESS). Structuring a procedure for modeling the ESS, according to development requirements, is vital for decision making. This publication reviews the main methods for designing local development programs that apply a sustainable livelihoods approach and a group of modeling tools for ESS. The necessary criteria are verified to structure a model that integrates the expectations of sustainable development, through the indicators of sustainable livelihoods (SLs), with the requirements of the ESS and the use of available renewable energy resources. In the review carried out, it is found that the methods of analysis and planning of sustainable local development are disconnected from the models for energy planning. On the other hand, the relationship of the indicators for calculating SLs with the characteristics and behavior of energy demand with respect to time is verified. The main criteria, parameters, and optimization methods necessary for the design and expansion of ESS in hard-to-reach areas are also discussed. Lastly, the necessary elements are proposed to be validated through a future study case for the dimensioning and expansion of ESS in hard-to-reach communities, integrating the analysis of development programs based on SLs.

**Keywords:** sustainable livelihoods; energy management; isolated microgrids; renewable energy; energy system optimization



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## 1. Introduction

The sustainable development goals (SDGs) promote the need for greater efforts in the research of sustainable energy projects. The inclusion of affordable and clean energy for all is a clear demonstration of the correlation between access to energy and sustainable development, as it modernizes people’s lives, facilitating connectivity, improving health systems, and optimizing production, among other things.

To determine compliance with the SDGs, the United Nations Statistical Commission pertaining to the 2030 Agenda for Sustainable Development proposed an indicator framework [1]. The indicators proposed by United Nations (UN) do not allow establishing the relationship between energy demand coverage and the development of remote communities. Dawodu et al. [2] and Yang et al. [3] enounced the postulate that “what is not measured cannot be controlled”. Developing a system of indicators to establish this relationship, taking into account the work that UN has provided with regard to methodologies to measure development, would be a contribution to the measurement of sustainable development [1].

Studies conducted by Léga et al. [4] suggest the need for research efforts to model energy supply systems (ESSs), according to the requirements posed by the evolution of development for a community with difficult access. This is due to the fact that existing decision support tools for the design and expansion of off-grid generation systems based on renewable energies contain limitations in the social criteria used in short (hourly) and long-term (yearly) planning [5].

Sustainable livelihoods (SLs) have been a fundamental tool for evaluating development projects in communities, taking into consideration their sustainable development by the Department for International Development (DFID) of the United Kingdom [6,7]. Flora et al. [8] proposed an expanded methodology using DFID's livelihoods approach as a way to carry out an evaluation of communities with a greater focus on their cultural and political capitals.

Energy planning is the process of developing policies to help guide the future of a local, national, regional, or even global energy system. The discipline of energy planning takes into consideration political, social, and environmental aspects and is carried out taking into account historical data collected from previous energy plans of the country under review. The planning effort involves finding a set of sources and conversion devices to meet the energy requirements/demands of all tasks in one way.

Mukisa et al. [9] researched models to critically examine the predominant factors in the sustainability of microgrids using temporality criteria. This work presented a model for interpretive analysis of the Sustainable Livelihoods Approach for the implementation of alternative energy technologies in Uganda according to the modeling of the enabling factors for each capital and the relationship of the indicators. Hence, this paper raised the need to define the criteria, variables, parameters, and solvers needed to structure a model that integrates the expectations of sustainable development using SLs with the expansion of the ESS, taking as a reference Ringkjøb et al. [5].

This investigation focuses on the review of research on energy supply systems that integrate the SLs with system requirements and the exploitation of available renewable energy resources, as well as the consequent sizing or expansion of the energy supply system. This allows us to structure a procedure for modeling the energy supply system, according to the requirements posed by the development evolution planned for a remote community.

The organization of the article is as follows: Section 2 provides a literature review of SL indicators based on 47 papers. The papers selected integrate the sustainable livelihoods approach into development projects that include energy systems. Moreover, some references include the modeling of ESSs for remote communities. Section 3 presents energy planning models applicable to energy supply systems in remote communities. Section 4 discusses the findings and forthcoming work derived from this review. Lastly, in Section 5, the conclusions on the findings of this paper are presented.

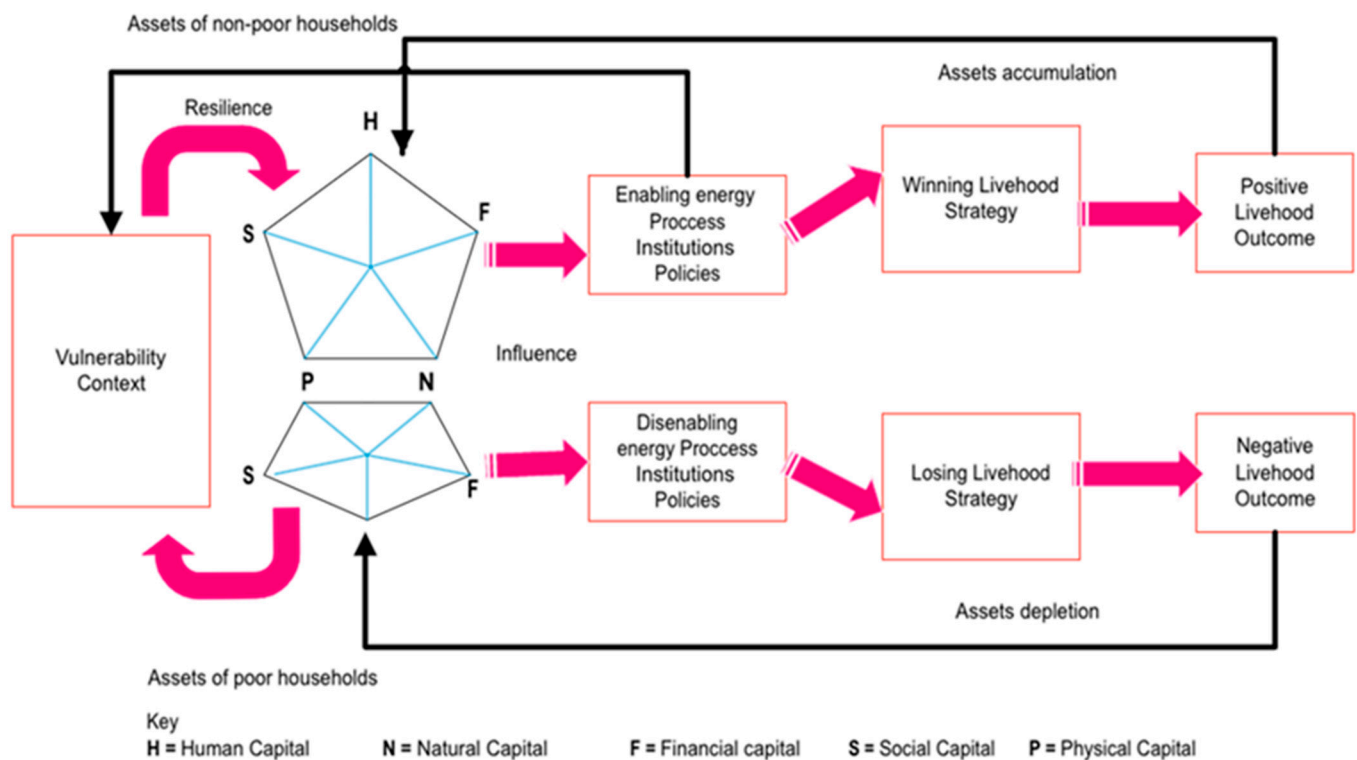
## 2. Sustainable Livelihoods Approach Indicators

The term “sustainable livelihoods (SLs)” was first used by Robert Chambers in the mid-1980s. These can be defined as the capabilities, assets (both material and social resources), and activities needed to live. A livelihood is sustainable when it can cope with and recover from sudden breaks and shocks and maintain its capabilities and assets both now and in the future without undermining the foundations of its natural resources. Therefore, livelihoods are affected by external effects that increase their resilience and, consequently, decrease their vulnerability according to Duffy et al., Gutiérrez-Montes et al., and Jacobs [10–12].

The sustainable livelihoods approach has been used by the DFID and Food and Agriculture Organization (FAO) to analyze how a population or community is developing its livelihoods, as well as to assess changes in these over time [13]. This model uses five capitals well known as natural, human, social, physical, and financial to quantify the community's assets.

The asset pentagon is adopted to graphically represent the quantification of the five capitals. This was developed to allow information about people's assets to be presented

visually, providing important interrelationships among the various assets [6]. The asset pentagon shows the state of the assets, where loss implies a deformation or narrowing of the resulting figure when each of the five assets is evaluated. Figure 1 shows how community capitals interrelate to contribute to vulnerabilities and the trend of changes in vulnerabilities. This graph has been modified from the original version of FAO model, focusing on the enablers of energy policies [13]; it presents how energy policies, processes (including energy supply planning), and institutions can be decisive in the accumulation or loss of assets.



**Figure 1.** General vision of sustainable livelihoods framework (FAO) modified for energy projects in remote communities.

The incorporation of cultural and political capital, in the community capitals framework model (CCF) allows analyzing the sustainability of livelihood strategies and the impact of development initiatives in a holistic manner, as it facilitates the identification of the effects (positive and negative) of a livelihood on the remaining capitals and, therefore, on the wellbeing of households and communities according to Cherni et al., Pandey et al., and Scoones [14–16].

Additionally, recent works carried out by Jordaan et al. [17], Nogueira et al. [18], and Butler [19], proposed other capitals derived from the previous models as a way of focusing on the objectives pursued.

Table 1 evaluates a series of papers that measured the development of remote communities according to different interests. Table 1 contributes to identify the capitals considered, the relationship with the ESSs, and the method of calculation. The five capitals model of the sustainable livelihoods approach prevails, evaluated through surveys tabulated with descriptive statistical tools.

**Table 1.** Evaluation of methodologies for calculated assets of SLs.

Authors		Capitals							ESS
		Human	Social	Cultural	Political	Physical	Financial	Natural	Relationship
1.	Emery and Flora [8]	✓	✓	✓	✓	✓	✓	✓	No
2.	Henao et al. [20]	✓	✓	–	–	✓	✓	✓	Yes
3.	Cherni et al. [14]	✓	✓	–	–	✓	✓	✓	Yes
4.	Chen et al. [21]	✓	✓	–	–	✓	✓	✓	No
5.	Fang et al. [22]	✓	✓	–	–	✓	✓	✓	No
6.	Horsley et al. [23]	✓	✓	–	–	✓	✓	✓	No
7.	Martinkus et al. [24]	✓	✓	✓	✓	✓	✓	✓	No
8.	Pandey et al. [15]	✓	✓	–	–	✓	✓	✓	No
9.	Aquino et al. [25]	✓	✓	✓	✓	✓	✓	✓	No
10.	Jordaan et al. [17]	✓	✓	✓	✓	✓	✓	–	No
11.	Herr et al. [26]	✓	✓	✓	✓	✓	✓	✓	No
12.	Hobson et al. [27]	✓	✓	–	–	✓	✓	✓	No
13.	Nogueira et al. [18]	✓	✓	✓	✓	–	✓	✓	No
14.	Butler [19]	✓	✓	✓	✓	✓	✓	✓	No
15.	Hendrickson et al. [28]	✓	✓	✓	✓	✓	✓	✓	No
16.	Mukisa et al. [9]	✓	✓	–	–	✓	✓	✓	Yes

Notes: “✓” = has been deemed and “–” means the opposite.

Table 1 shows that the papers presented by Henao et al. [20] Cherni et al. [21], and Mukisa et al. [8], have a direct relationship with the ESS and SLs approach. As can be seen, most of the works consulted were based on the five capitals proposed by the original SL model, while others, to a lesser extent, used the community capitals framework proposed by Emery and Flora [8].

Chen et al. [21] presented five types of livelihood asset capitals and relevant indicators. Therefore, various scaling and indexing methods can be adopted to make them comparable and enable meaningful interpretation. While others developed a methodology combining livelihood capitals and questionnaire methods, the main proxy variables were selected by Fang et al. [22].

The capabilities and assets that make up livelihoods are divided into five types of capital:

- Human capital: characterized by levels of health, food, education, and knowledge, among others.
- Social capital: these are networks and connections between individuals with shared interests, forms of social participation, and relationships of trust and reciprocity.
- Natural capital: natural resources useful in terms of livelihood.
- Physical capital: infrastructure and equipment that meet the basic and productive needs of the population.
- Financial capital: this refers to the financial resources that populations use to achieve their livelihood objectives.

Flora et al. [8] proposed a model called the community capitals framework, where cultural capital and political capital are added to the SLs framework, while physical capital is referred to as built capital.

Sarmidi et al. [29] adopted two new variables from the World Bank database, the total natural capital and subsoil wealth, identifying a strong relationship between natural resource abundance and economic growth in more than 90 countries.

*Proposed Methodology for the Selection of Indicators and Evaluation of the Community's Assets*

Fang et al. [22] suggested a quantitatively model for assigning key variables and their weights for the assessment of sustainable livelihoods in remote communities. The fourth steps for developing the weighted score are as follows: (1) identify key attributes and variables related to livelihoods, (2) select a group of experts, (3) score the options, and (4) calculate the weighted scores. The methodology for identify key attributes and variables of livelihoods are comprises the following three steps:

1. A participatory analysis of the interaction of capitals. To this end, the results of the capital diagnosis are taken as a starting point, which are socialized with key actors through a workshop in which the interactions between capitals are established and analyzed. This involves conducting a strengths, weaknesses, opportunities, and threats (SWOT) analysis by capital, determining the positive and negative relationship between each capital and its performance.
2. Determination of intervention opportunities, in a participatory manner with key stakeholders, based on the results of the capital interaction analysis workshop. The opportunities are based on the priorities of local stakeholders according to the results of previous exercises.
3. The design of a protocol for baseline collection, monitoring, and evaluation of the evolution of the community's capitals and livelihoods, as a starting point for replicating the experience in other communities.

Several authors have proposed indicator systems to evaluate local development projects. The indicators proposed by Almaguer Torres et al. [30] include, among others, indicators of (1) compliance with the mission and vision, (2) compliance with objectives, and (3) compliance with work plans. However, in this proposal, the indicators are limited to evaluate the implementation process of development projects and do not cover the operational side of this.

The UN has established an indicators framework for the 2030 SDGs [31]; those terms are directly related to this investigation. The indicators that contribute to the purpose of this paper are as follows:

- Guarantee access to affordable, reliable, sustainable, and modern energy for all. Indicators are proposed to measure the population's access to electricity, the proportion of renewable energies and clean technologies used, and the level of investment in these and energy efficiency projects (Objective 7).
- Make cities and human settlements inclusive, safe, resilient, and sustainable. This evaluates indicators of how communities have incorporated mitigation, resilience, social inclusion, and adaptation to climate change in different initiatives and projects that allow them to respond to adversities with a higher level of social cohesion and integration (Objective 11).
- Take urgent measures to combat climate change and its effects. This includes the implementation of climate change adaptation and mitigation plans, the implementation of adaptation, mitigation, and technology transfer activities and development measures, as well as capacity building for climate change planning and management, including those focused on women, youth, and local and marginalized communities (Objective 13).

Indicators based on the sustainable planning framework proposed by some authors for isolated microgrid implementation projects were reported by Horsley et al. and Pedrosa [23,32].

Emery and Flora considered the process of data collection and analysis for the definition of indicators and livelihood assessments developed through a diagnosis, by means of

semi-structured interviews applied to key actors and households [33]. To determine the households and actors to be interviewed, the random snowball sampling method can be used [9,17,20]. This method allows obtaining qualitative information from key stakeholders and achieving efficiency in data collection.

Kaya and Kahraman [34] and Akinyele et al. [1] have reported criterias for evaluated the aspects of endogenous development which should be deemed on the energy planning for remote communities projects. Table 2 shows the main criterias that serve as indicators of the technical, economic, environmental, and social aspects of energy-related.

**Table 2.** List of evaluation criteria used in multicriteria decision-making studies conducted on energy issues.

Aspects	Criteria
Technical	Efficiency, exergy efficiency, Energy demand profiling, Future energy demand, Technology Selection
Economic	Investment cost, operation and maintenance cost, Lifecycle cost
Environmental	NO <sub>x</sub> emissions, CO <sub>2</sub> emissions, Environmental impact
Social	Social acceptability, job creation,

Another paper showed another model divided into three stages, in which socio-economic evaluations were carried out in first to identify the points of consumption, their needs, and the characteristics of the population. However, the conclusions of the study suggested that it is necessary to include other endogenous variables such as the environment, in addition to the fact that the model does not have a direct relationship with the capital frameworks of the study community [4].

Bhaskara, Chowdhury, and other authors [35–38] were more specific and included within their model proposals variables associated with community development factors, as in the case of the one based on the STEEP (social, technological, economic, environmental, and political) model. This is significantly useful for a better understanding of the planning and development of rural community microgrid [39].

The presence of electric power in small and isolated communities is responsible for improving the quality of life of human beings. In several cases, the increasing use of energy is more than expected. Therefore, expansion flexibility is a fundamental aspect to consider when designing such systems [40–43].

Table 3 presents a summary of the criteria and factors adopted in models that integrate endogenous variables in the decision-making process taken from the papers consulted that include indicators for the endogenous dimensions and are related to energy projects. The table shows that there is no coincidence of the criteria used in projects based on endogenous dimensions, since these criteria and factors are selected according to the intrinsic characteristics of each project.

The literature analysis allowed to verify that there is a relationship between the development models based on the SLs framework and the planning models of ESSs, which is why it is necessary to create a model that allows projecting the expansion of demand in the systems. Energy planning is based on the use of endogenous resources and development policies. As outlined in Table 3, Ankinyele et al. [39] included the largest number of criteria, while the most common criterion was initial capital and lifecycle costs.



**Table 3.** Criteria and factors of endogenous models for decision-making process.

Capitals	Criteria	Authors								Total
		Akinyele et al. [39]	Cherni et al. [14]	Bhattarai and Thompson [44]	Karthik et al. [45]	de Souza Ribeiro et al. [46]	Ahmadi and Rezaei [47]	Bhattacharyya [48]	Zhang et al. [40]	
Economic	Initial capital and lifecycle costs	1	1	1	1		1		1	6
	Project financing	1	1		1					3
	Returns on investment	1		1	1			1		4
	O&M costs	1		1		1	1		1	5
Technological	Energy demand profiling	1				1	1	1	1	5
	Maturity of available technologies	1	1							2
	Technology selection	1				1				2
	Reliability of supply	1				1	1	1	1	5
	Future energy demand	1								1
	Types of load/appliances	1			1		1		1	4
	Technical design and feasibility evaluation	1				1			1	3
Social	Cooperativism		1							1
	Leadership		1							1
	Common goals	1	1							2
	Project objectives defined	1								1
	Community Involved Level	1								1
	Educating the potential	1								1
	Identifying suitable sites	1								1
	Characterization of the physical resources of the community: housing, aqueducts, roads, etc.							1		1
Environment	Air quality							1		1
	Land							1		1
	Water and water quality							1		1
	Environmental impact and benefits analysis	1						1		2
Political	Presence of political will or government support	1						1		2
	Fiscal incentives							1		1
	Public and political acceptance							1		1
	Regulatory framework for capacity building and job creation	1								1
Total		19	6	3	4	5	5	11	6	59

### 3. Energy Planning Models

When establishing the indicators of energy demand and supply within an isolated microgrid, the main factors for which the microgrid was developed are considered. It is commonly observable that isolated microgrids use renewable sources as a generation source, which, due to their stochastic characteristics, are variable energy sources. This in turn allows establishing that the generation plant within an isolated microgrid, in general, works with the maximum possible efficiency [46,49–52].

To optimize the design and operation of hybrid systems, several papers have been published, as reviewed in this study. Some papers focused on the operation of interconnected microgrids, where they considered demand response programs to achieve cost-effective operation [47]. Others sought to minimize grid operation cost and CO<sub>2</sub> emissions, while guaranteeing a certain level of supply reliability [44,53,54].

Cuesta et al. [55] proposed an optimization model based on the proposed hybrid generation source systems. Other research focused on traditional models for evaluating the availability of available renewable resources and the cost per kWh of each [40,45,56,57].

A basic model structure was proposed by Bhattacharyya [48] for the optimal design of a hybrid wind-solar energy system for off-grid or grid-connected microgrids. The method employs linear programming techniques to minimize the average cost of electricity production while reliably meeting load requirements and considers environmental factors in both the design and the operation phases. It is important to consider, for the creation of efficient management models for isolated microgrids, the introduction of this concept, which has so far mainly been used in grid-connected microgrid systems [58,59].

According to the hybrid system sizing proposal of Chedid and Raiman [60], models were presented for the limited availability of microturbines and PV panel types that meet the requirements of logistics, simple installation, and adaptation to climatic conditions, greatly reducing the optimization space.

Table 4 shows an evaluation of different reference models that have been used for energy planning, whether local, regional, or global. It can be established that the studies dealing with short- and long-term energy models did not take into consideration the assets of the sustainable livelihoods approach. This limits the evaluation of the contribution to the sustainable development of communities when applying such models. It can also be seen that the five capitals model is the most established, but some research went deeper and proposed the inclusion of other capitals for a more specific evaluation according to their objectives. It can also be seen that the papers used in the SLs deal with the impact on people's livelihoods and are generally developed as multicriteria tools that have a temporal resolution of specific conditions and spatial resolution in localities, mainly because they are tools for measuring development in rural and remote communities.

Table 5 shows a revision of the papers analyzed in Table 4, identifying those including social, technological, economic, and environmental aspects. It is appreciated that the social aspects were included in most studies. This may be supported by the fact that these papers dealt with renewable energy projects in rural communities. Technological and economic aspects were treated to a lesser degree, and only three papers included environmental aspects. This review allowed establishing that the main models for short and long-term planning of ESS are disconnected from the sustainable livelihoods approach.



**Table 4.** Energy planning models factors for remote communities.

No.	References	Capitals	Demand of Energy Services	Services	Methodology	Temporal Resolution	Spatial Resolution	Evaluation Method
1	Emery and Flora [8]	NC, BC, FC, PC, SC, CC, HC	-	-	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
2	Cherni et al. [14]	NC, FC, PC, SC, HC	Specific demand	Electricity	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
3	de Souza Ribeiro et al. [46]	-	Specific demand	Electricity	Study of cases	Specific conditions	Local	Study of cases
4	Henao [20]	NC, FC, PC, SC, HC	Specific demand	Electricity	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
5	Chen [21]	NC, FC, PC, SC, HC	-	-	Study of cases	Specific conditions	Local	Quantitative, case studies
6	Fang et al. [22]	NC, FC, PC, SC, HC	-	-	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
7	Horsley et al. [23]	NC, FC, PC, SC, HC	-	-	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
8	Bhattarai and Thompson [44]	-	Specific demand	Electricity	Study of cases, HOMER model	Specific conditions	Local	Study of cases
9	Martinkus [24]	NC, BC, FC, PC, SC, CC, HC	-	Biofuel production	Study of cases	Specific conditions	Local	Quantitative, case studies
10	Pandey et al. [15]	NC, FC, PC, SC, HC	-	-	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
11	Huang et al. [56]	-	Long-term demand	Electricity	Study of cases	Long-term	Regional	Study of cases
12	Aquino [25]	NC, BC, FC, PC, SC, CC, HC	-	-	Exploratory qualitative	Specific conditions	Local	Quantitative, case studies
13	Jordaan et al. [17]	NC, BC, FC, PC, SC, CC, HC	-	-	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
14	Nadimi and Tokimatsu [61]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
15	Yadav et al. [62]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
16	Yadav et al. [63]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
17	Mahmud et al. [64]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
18	Akinyele et al. [39]	-	Specific demand	Electricity	Study of cases	Specific conditions	Local	Study of cases
19	Herr et al. [26]	NC, BC, FC, PC, SC, CC, HC	-	-	Case studies analysis	Specific conditions	Regional	Study of cases
20	Hobson et al. [27]	NC, FC, PC, SC, HC	-	-	Study of cases	Specific conditions	Local	Study of cases

Table 4. Cont.

No.	References	Capitals	Demand of Energy Services	Services	Methodology	Temporal Resolution	Spatial Resolution	Evaluation Method
21	Nogueira et al. [18]	NC, FC, PC, SC, HC, CC, MC, DC	-	-	Study of cases	Specific conditions	Local	Study of cases
22	Chinmoy et al. [65]	-	Long-term demand	Electricity	Data Analysis	Long-term	Global	Quantitative
23	Khanna et al. [66]	CEPI	Specific demand	Electricity	Data Analysis	Long-term	Regional	Quantitative
24	Søraa et al. [67]	-	Long-term demand	Electricity	Data Analysis	Long-term	Global	Quantitative
25	Karthik et al. [45]	-	Specific demand	Electricity	Study of cases, HOMER	Specific conditions	Local	Study of cases
26	Viteri et al. [68]	-	Specific demand	Electricity	Study of cases, HOMER	Specific conditions	Regional	Study of cases
27	Butler [19]	NC, FC, PC, SC, HC, CC, EC, LC	-	-	Study of cases	Specific conditions	Local	Study of cases
28	Mukisa et al. [9]	NC, FC, PC, SC, HC	Specific demand	Electricity	Multicriteria study case	Specific conditions	Local	Quantitative, case studies
29	Musonye et al. [69]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
30	Lozano and Taboada [70]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
31	Campos and Marín-González [71]	-	Long-term demand	Electricity	Data analysis	Long-term	Global	Quantitative
32	Ahmadi & Rezaei [47]	-	Specific demand	Electricity	Study of cases, HOMER model	Specific conditions	Local	Study of cases

Notes: “-” = not applicable; NC = natural capital; BC = built capital; FC = financial capital; PC = political capital; SC = social capital; CC = cultural capital; HC = human capital; MC = manufactured capital; DC = digital capital; EC = enterprise capital; LC = legal capital.

Table 5. Endogenous factors evaluated in energy planning models for remote communities.

No.	References	Social	Technological	Economic	Environmental
1	Emery and Flora [8]	People’s quality of life	-	-	-
2	Cherni et al. [14]	People’s quality of life impact	Evaluation of generation technologies	-	Yes
3	de Souza Ribeiro et al. [46]	People’s quality of life impact	Evaluation of generation technologies	-	-
4	Henao [20]	People’s quality of life impact	Evaluation of generation technologies	-	Yes
5	Fang et al. [22]	Impact of labor force and land	-	-	-

Table 5. Cont.

No.	References	Social	Technological	Economic	Environmental
6	Horsley et al. [23]	Mining impact on regional development	-	-	-
7	Bhattarai & Thompson [44]	-	Evaluation of generation technologies	Yes	-
8	Pandey et al. [15]	Vulnerability and adaptation on climate change	-	-	-
9	Huang et al. [56]	-	-	Renewable energy integration	-
10	Aquino [25]	People's quality of life	-	-	-
11	Jordaan et al. [17]	Drought resilience	-	-	-
12	Nadimi and Tokimatsu [61]	People's quality of life impact	-	-	-
13	Yadav et al. [62]	People's quality of life impact	-	-	-
14	Yadav et al. [63]	People's quality of life impact	-	-	-
15	Mahmud et al. [64]	People's quality of life impact	-	-	-
16	Akinyele et al. [39]	-	Evaluation of generation technologies	-	-
17	Herr et al. [26]	Potential long-term forestry social impacts	-	-	-
18	Hobson et al. [27]	People's quality of life impact	-	-	-
19	Nogueira et al. [18]	Circular economy	-	-	-
20	Chinmoy et al. [65]	-	-	Wind integration	-
21	Khanna et al. [66]	People's quality of life impact	-	-	-
22	Søraa et al. [67]	People's quality of life impact	-	-	-
23	Karthik et al. [45]	-	Evaluation of generation technologies	Yes	-
24	Viteri et al. [68]	People's quality of life impact	Evaluation of generation technologies	Yes	Yes
25	Butler [19]	People's quality of life impact	-	-	-
26	Mukisa et al. [9]	Impact of implementing alternative energy technologies	-	-	-

Table 5. Cont.

No.	References	Social	Technological	Economic	Environmental
27	Musonye et al. [69]	People's quality of life impact	-	-	-
28	Lozano and Taboada [70]	People's quality of life impact	-	-	-
29	Campos and Marín-González [71]	People's quality of life impact	-	-	-
30	Ahmadi & Rezaei [47]	-	Evaluation of generation technologies	Yes	-

#### 4. Discussion

This paper reviewed different models used for energy planning and evaluation of sustainable livelihoods in remote communities. It is observed that they did not include elements involving endogenous development indicators and sustainable livelihoods. The development of new models that contribute to integrate these elements is an interest approach for the scientific community. It is also important to develop weighting factors to accomplish the integration of the variables of the livelihoods approach; thus, it is possible, according to the weighting, to simplify the model after the correct evaluation of its particularities.

The papers that focused on the application of the livelihoods approach in rural energy projects were based on the original five capitals model; however, there is a trend toward the inclusion of capitals in different papers following the proposal of the community capital frameworks.

The conducted works oriented toward energy issues used the sustainable livelihoods approach to evaluate the optimal configuration of energy carriers that maximize the sustainability of the microgrid. No study used the sustainable livelihoods approach for short- and long-term energy planning. Demand planning must correlate with the development expectations of communities based on their capitals or assets.

Models for the development of community energy systems must be very strict in the selection of the key actors to be consulted for the weighting of indicators. Depending on the indicator type, the source may go from being primary to secondary or from being a key stakeholder to a measurement or statistic.

The models in the literature did not refer to the contribution to growth that energy projects make according to short- and long-term demand planning.

The models found that focused on energy projects did not use the community capital framework approach; hence, they were based only on the evaluation of the five traditional capitals, excluding cultural and political ones.

The evaluations of the various models consulted in Table 4 allowed establishing Times (an evolution of MARKAL) and OSEeMOSYS (open-source energy modeling system) as those that allow modeling both the development and the use of renewable energy sources. This model should consider the relationship of livelihood indicators with energy demand and evaluate the possibility of including these indicators as an energy capital of the study community. The average household demand and the capital that can be used in community development projects should be considered as criteria for sizing the energy project in the short and long term under an hourly resolution.

This paper proposes elements that could be part of a future methodology that uses the sustainable livelihoods approach or community capital framework for decision making in the short- and long-term planning of ESSs in remote communities. Therefore, a system of sustainable development indicators for the ESSs should be proposed.

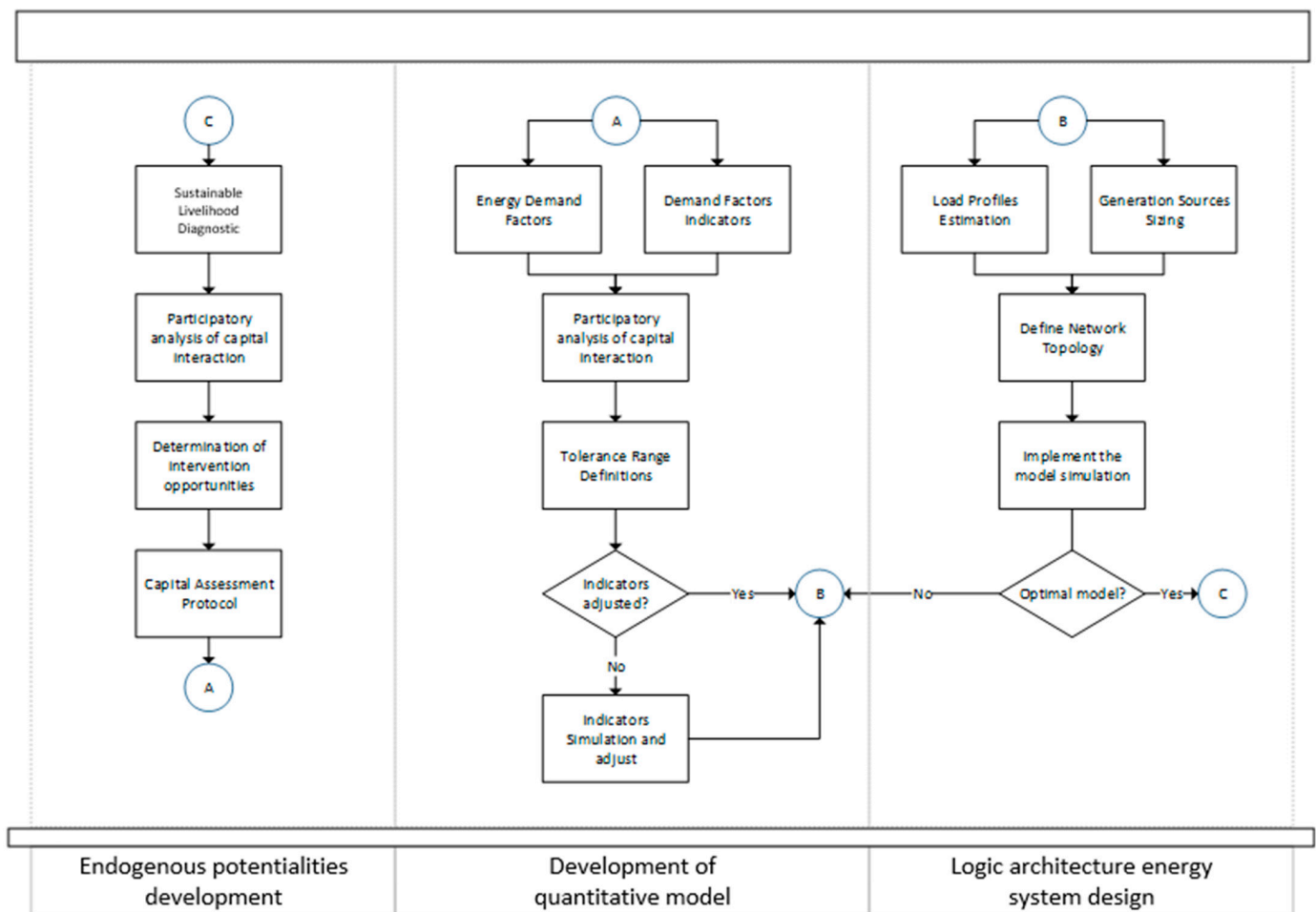
Developing a tool that includes cultural capital and political capital in the methodology for the optimal selection of the microgrid carrier configuration and then proposing an

interpretation scheme of the shape changes in the resulting polygon (a pentagon applies to the five capitals model) of sustainable livelihood could be interesting for development projects in remote communities.

Taking into account the above review of the integration of the livelihoods approach with short- and long-term energy planning for sustainable development, it is proposed to structure a methodology to measure and expand the energy supply system.

The methodology must consider the elements summarized in Figure 2 and have the three main stages described below:

1. The characterization of livelihoods and capitals, which begins with a diagnosis of the livelihoods and capitals of the community where the model will be applied, and then proceeds to develop a participatory analysis of capitals interaction to determine the points of intervention for community planning and create an instrument to evaluate over time the change in these assets of the community using the sustainable livelihoods approach. Flora et. al. [8] proposed a strategy for endogenous potentiality development based on the SLs called the community capitals framework, conducted according to the follow steps: Sustainable livelihood diagnostic: this consists of the evaluation of the current state of the capitals of the community through semi-structured interviews applied to the key stakeholders and to the selected households through the snowball random sampling method, which allows obtaining qualitative information from key actors and achieving efficiency in data collection. Participatory analysis of capital interaction: This entails carrying out a SWOT analysis of the capitals of the community, taking as a starting point the results of the diagnosis of capitals, through socialization with key actors who will analyze the interactions between the capitals and the determination of the positive and negative effects of each capital over others. Determination of intervention opportunities: these opportunities are based on the priorities of the local actors according to the results of the previous exercises. Capital assessment protocol: This protocol allows the baseline survey, monitoring, and evaluation of the evolution of the capitals and livelihoods of the community, as a starting point for replication of the experience in other communities.
2. The development of a quantitative model will simulate the evolution of the ESS in the short and long term, by detecting the factors that affect energy demand and characterizing the indicators for those key factors that affect demand over time [51]. These indicators should be subjected to control ranges within which they should move because of the analysis of the system constraints and then proceed with the simulation run of the model and adjustment of the established indicators to optimize the planning of the ESS. The demand factor indicators establish the factors that will determine long-term demand growth, and the results obtained in the socialization with key actors of the interactions between the capitals must be adjusted, taking as a reference the energy planning developed in the previous steps.
3. Lastly, the design of a network architecture that responds to the energy potential of the community will be carried out and the results will be compared with other supply planning models for remote current communities [72]. For this purpose, the load profiles of the energy services to be supplied will be estimated on the basis of the defined intervention projects, establishing a priority classification. The different sources of energy generation available in the community must be evaluated, after which the network topology configuration must be defined [73]. The simulation of the model must be implemented, and the optimal model must be evaluated through different proposed scenarios. After the implementation of the optimal model, one should return to the first step. With this, the model will have a long-term temporality.



**Figure 2.** Proposed elements for planning energy supply systems in remote communities on the basis of endogenous factors.

After structuring the methodology, it must be validated through case studies, verifying possible corrections that improve the decision-making guide.

## 5. Conclusions

In this review, it was observed through the references consulted that the main studies on methodologies to improve the management and operation of ESSs in remote communities were based on technical and economic factors, as well as on the pure and simple electrification of the community without considering the energy resources as an instrument for future development. It is evident that these models did not make decisive use of the elements that constitute endogenous development or the capital frameworks of the communities to establish a system of indicators to model the impact of the project on the sustainable development of the community in the short and long term.

It was found that the methods of analysis and planning of sustainable local development are disconnected from the models for energy planning. The relationship of the indicators affecting the short- and long-term energy demand of the communities and, therefore, the calculation of their livelihoods is appreciated. The criteria, parameters, and optimization methods necessary for design and expansion were presented.

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