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Energy village concept implementation: A comparison between Africa and Finland

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ABSTRACT

This study aimed to assess the implementation energy village (EV) projects with a comparison between Europe and Africa. This was effectively addressed to improve the understanding of available resources and solutions. This was accomplished by comparing energy availability for the populations of Finland and Africa. The significance of this work lies in its highlighting of the potential of such collaborative projects to foster the creation of better living environments in both regions. Through sharing experiences and cultural insights, these initiatives can help address local challenges more effectively. Additional benefits of EV-related collaborations can include motivating communities, creating employment opportunities and supporting rural sustainability in Africa economically, socially and environmentally. Key research objectives achieved in this study include the identification and comparison of renewable energy resources in the European Union (EU) and the African Union (AU); the mapping of relevant policies in both regions; the provision of guidance to African nations in recognizing and utilizing available renewable energy sources; and the mutual benefit of informing new policies and management techniques for the AU and EU (including Finland). A qualitative methodology was employed in this work, combining case studies analyses with descriptive evaluation techniques. The energy village concept is a way to create a new village become using renewable energy only by using local renewable energy resources this is the novelty of this paper. The research gap is giving real cases across four countries in Africa and one country in Finland. Combining all real cases one can notice the difference, the challenges and possible policy recommendations areas. Our findings suggest that despite the potential for significant collaboration important economic, cultural, and religious differences exist between the EU and AU. However, these highlighted challenges can be overcome through mutual commitment and knowledge sharing, facilitating the successful implementation of EVs in the AU.

1. Introduction

The paper aims to assess the Europe and Africa collaboration on energy village (EV) projects. A previous project, the long-term joint European Union–African Union research and innovation partnership on renewable energy (LEAP-RE), served as a valuable source of experience and insight for this study. During the LEAP-RE project, conducted from 2020 to 2024, institutions from the African nations of Ethiopia, Botswana, Uganda, and Kenya collaborated with the University of Vaasa, which is located in the city of Vaasa, Finland. The experience was beneficial, enabling African nation institutions to experience and apply the EV concept, which is originally developed by the University of Vaasa. Based on [1] their explanation of the EV concept: "The EV concept was started at the University of Vaasa and it maps out a selection of villages with various levels of intervention, and categorizes them according to their readiness levels. This EV is a replicable concept for creating RE self-sufficient small regions, with a particular initial focus on rural/remote areas or at the scale of a suburb. The EV concept starts with

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the following ideas: Firstly, the continent is endowed with strong renewable energy source (RES) potential including biowaste, solar, wind, geothermal and hydro-energy that exceeds demand, especially in rural regions. Secondly, there are already positive drives for new strategies and practical solutions to boost the transition from fossil fuels to sustainable energy sources. The growing shift in general public opinion toward RES and increased energy security can also support huge economic opportunities at a regional level. Theoretical support for the EV concept can be drawn from sociology, technology, natural science, industrial management, economics, juridical, and evolutionary psychology through philosophy toward conceptual integrations. Conceptual integration, [2] explains, aims toward large intellectual entities from the various branches of science by explaining and merging the background presuppositions."

As noted by the Ministry of Energy and Petroleum [3], there is vast potential for renewable energy (RE) in Kenya (as in the majority of African nations). However, several factors hinder the efficient exploitation of renewable energy (RE) potential. These include: a) the lack of publicly available RE potential assessments to support investment promotion, decision-making, and energy planning; b) the limited diversity of policies promoting renewable energy technologies (RETs); c) insufficient private sector support for RETs; and d) inadequate grid connections to RE-endowed areas (Ministry of Energy and Petroleum, 2015). Social innovations are required in African nations to address the above factors, for example to use solar PV technology to alleviate the shortage of electricity in some African nations. Additionally, the use of firewood has compromised population health and contributed to CO_2 emissions. An innovative approach can be reducing the adverse effects of firewood use or carbon emissions by converting biomass materials into briquettes. Wihersaari [4] further notes that stored firewood can emit gases that need to be evaluated and managed to minimize risk. In addition, the integration of RE with fossil fuels innovation can generate environmental benefits as well as social innovation as a result of associated improvements in the well-being of individuals and local communities. The following subsections further outline examples of social innovations in the field of bioenergy.

Converting firewood to a briquette is an effective means of reducing carbon emissions, ensuring a sustainable supply of heat energy and income source for local communities. Social innovation in briquette production includes the use of novel, locally manufacturable machines. The machines are for example ram-piston presses, motorized screw presses, shredders, wooden presses, and mold-box piston presses, rather than relying solely on manual production methods [5]. Bio-coal has increasingly received attention in the media. However, there is a lack of published scientific research on its feasibility as a full-scale product, and its usefulness for Africa and other nations [6]. According to Agar and Wihersaari [6], bio-coal research has explored three key properties of biomass: the mass and energy balance, product friability, and the equilibrium moisture content. Ketlogetswe [7] has identified biomass-to-biodiesel conversion as a form of social innovation in bioenergy, with potential applicability in African contexts. While the Addis Ababa Science and Technology University (AASTU) has suggested producing biogas from cafeteria waste, food waste, and human waste. Other innovative approaches may involve optimizing biogas plant design through variations in size and configuration.

According to the EV Concept, there usually is enough renewable energy potential in a village to cover its own needs and often also some excessive potential to be used for the needs of a larger area [8]. The villages featured in this article showcase innovative approaches to harnessing renewable energy sources for local communities, promoting sustainability, and reducing reliance on non-renewable energy sources. The renewable energy resources, the energy consumption and the hybrid system solution for four inspiring energy villages in Africa are included in this report. The five county cases presented in this article are in: Ethiopia [AASTU Campus, Addis Ababa and Tulefa village in Debere-birhan]; Kenya [Cheboiwo in Uasin Gishu and Nandi Hills in Nandi]; Uganda [Bidibidi Refuge settlement and Kayanzi]; Botswana [School-Regent Hill International School in Gaborone and Majwanaadipitse] and Finland [Jopua area energy village and Perho area energy village].

The research objectives of this work were to explore the following: 1) the harnessing of renewable energy resources available in Africa while comparing European and African energy villages by generalizing the diverse energy villages from both continents; 2) mapping of previous energy policies in Ethiopia, Kenya, Uganda, Botswana, and Finland to enable recommendations for future policy directions for Africa; and 3) assisting African nations in identifying available renewable energy resources in local areas and supporting the implementation of related technologies to help local communities. The novelty of the work lies in its 1) potential to assist nations in identifying and harnessing available renewable energy resources; and 2) fostering of mutual support between African and Finnish stakeholders in developing new policies and management techniques. The contributions and significance of this study are as follows: 1) enhancing understanding of resource availability, solutions, and comparing the energy availability for humans in Finland and Africa; 2) promoting improved living environments in both regions through shared experiences and cultural exchange; 3) It will motivate developing nations to use energy village concept to help their locals and their nation; 4) motivating African nations to adopt the energy village concept to support the local economy in the villages; and 5) supporting the long-term sustainability of rural African regions in economic, social, and environmental terms. This research is guided by two central research questions (RQ1) What are the social impacts of bioenergy adoption and its availability when comparing Africa and Finland, based on previous energy villages? and (RQ2) What insights can be drawn from policy mapping in the AU and EU, and what policy and management recommendations from Finland are applicable for African nations?

2. Methodology

Qualitative methods: The methodology employed was guided by key principles outlined by [9], who has noted that the choice between using fixed and/or emergent designs should be viewed not as a strict dichotomy, but as endpoints along a continuum [9].

a) Methodology selection: Creswell and Clark [9] describe mixed methods studies as follows: 'Mixed methods studies where the use of quantitative and qualitative methods is predetermined and planned at the start of the research process, and the procedures are implemented as planned' [9]. However, a purely qualitative research methodology was employed in this study.
b) Design selection: A typology-based approach was adopted. As noted by [9], 'A typology-based approach is the selection and adaptation of a particular design to study purpose and questions.' When matching the study design to the research problem, the goal and targeted questions must be considered. Moreover, the reasons for the qualitative methods utilized must be explicitly stated.

2.1. Case study

This section describes the qualitative analysis approach to addressing RQ1. the case study methodology was selected because it provided a path toward a rigorous analysis based on the reviewed literature, the objectives of the study, and the research questions.

Objectives and research questions: were presented at the end of the introduction section. These research questions were developed through literature review deep investigations.

The case study method: the general procedure followed in this study was based on the framework outlined by [10]. As shown in Fig. 1, which comprises six stages: plan, design, prepare, collect, analyze, and share. The relationships between these stages are also illustrated in the next

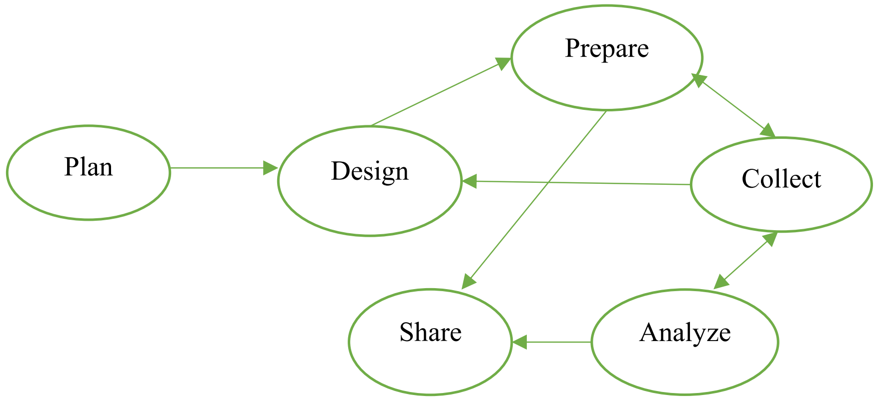

Fig. 1. General steps used in this case study (adapted from [10]).

Fig. 1. The process began with planning, followed by design, preparation, data collection, analysis, and dissemination. During the analysis phase, each case study was examined independently, and the results were subsequently compared to identify similarities and differences. The publication of this article achieves the sharing stage.

- v The following introduces the case study countries and energy villages that were the subject of the qualitative analysis, identifying and describing their potential, as well as the challenges faced.

Design – the units of analysis: Drawing on the experience of the LEAP-RE: WP-14 (energy village concept in Africa) project and other sources, the African partner nations (Ethiopia, Kenya, Uganda, and Botswana) and their respective EVs were identified as case study locations. From the EU, Finnish EVs were used as case study locations, since they had been identified and investigated in previous projects.

Bounding the 'cases': 'Bounding the case in these ways will help to determine the scope of your data collection and, in particular, how you will distinguish data about the subject of your case study (the 'phenomenon') from data external to the case (the 'context')' [10]. The next step involved identifying the challenges and comparing the bio-energy solutions. In terms of their availability and potential contribution to social improvement. These boundaries, which helped define the scope of the study, were established based on the experience gained from WP-14 (work package 14 of the 'Energy Village Concept in Africa' project) and other EV projects in Finland.

Proposition: Propositions guide the identification of relevant information to be collected from each case study. In this case study, the three established propositions were to list, identify, and describe the types of social innovations and solutions, as well as their availability, within the LEAP-RE: WP-14 project. The case study African nations were Ethiopia, Kenya, Uganda, and Botswana and from Finland, and the literature. This was achieved by conducting a systematic literature review, collecting real-world data, and conducting a case study analysis. All procedures in this case study were based on recommendations from [10].

Linking the data to the proposition: The data from the two cases were connected through cross-case synthesis and followed by the development of a cross-case conclusion. Given the choice of a multiple case study research design, the logical procedure was to conduct a cross-case analysis after analyzing the individual cases. This is consistent with recommendations from [10].

Criteria for interpreting the findings: 'While doing case studies, a major and important alternative strategy is to identify and address rival explanations. Addressing such rivals becomes a criterion for interpreting your findings: the more rivals that have been addressed and rejected, the stronger will be your findings' [10].

Identifying the case study design: The study adopted a multiple case study approach and more than four case locations were selected. Multiple case studies are generally considered more robust and reliable than single case designs. It also enables the comparison of locations across different continents, each with varying resources and levels of development, with the expectation of identifying diverse patterns. Cross-case investigations and reporting were conducted after the analysis and reporting of each individual case.

Validity: Case study research is an internationally recognized method that draws on multiple resources (various literature and documents) to enhance the validity of the analysis. In this case study, several methods were utilized. First, multiple sources of data were utilized, including data from several Energy Villages (EVs). Second, a "chain of evidence" was established to link findings to propositions, enabling clear traceability from the formulation of the research question through to the conclusions. This approach ensures that the analytical process can be followed step-by-step, demonstrating how evidence informed the investigation. Third, data and information on the case nations and their respective EVs were verified by key stakeholders, including residents and partner organizations in each country. This verification process included, for example, having key partners review the case study can be one way to do it.

Prepare – hone skills; train for specific case study: Protection of human subjects was not applicable in this case study, as no human participants were involved. Therefore, procedures related to human subject protection were not required.

Develop case study protocol: The only protocol type relevant to this research was the data collection procedure protocol. the literature review, the process began with the selection of initial keywords, followed by the creation of mind maps to generate additional relevant terms. Searches were then conducted using Google Scholar and targeted journal databases. The article screening process involved three stages: first, selecting articles of interest based on their titles; second, reviewing abstracts to determine relevance; and third, conducting a full-text review of selected articles. These sources informed the selection of 'bounding cases' used in the development of the analysis. In addition, real-world data were captured from the LEAP-RE: WP-14 project and previous energy village projects in Finland.

Collect – consider six sources of evidence: According to Yin [10], case study evidence can be obtained from six sources: documents, archival records, interviews, direct observation, participant observations, and physical artefacts. This study applied four principles outlined by [10]: 1) Using multiple, not single, sources of evidence (data source databases); 2) Creating a case study database; 3) Maintaining a chain of evidence; and 4. Exercising care in using data from electronic sources of evidence, such as social media communications. These four principles were followed whenever possible as recommended by [10], strengthening the validity and reliability of this work. For this study, data were drawn from two main sources: documents and direct observation. The documentary evidence was gathered from electronic sources (specific journal databases and Google Scholar), as well as project documentation from energy village initiatives in Finland, the EU, and the AU. The direct observation data were obtained from the LEAP-RE WP-14 project (providing data for the African cases) and previous Energy Village projects in Finland (providing data for the EU cases). For future research, [11] could be used to conduct statistical analyses focused on Africa.

Analyze – array and display data in different ways: The analysis in this study involved scientifically assessing the available information, documents, lived experiences, and synthesizing these to develop an understanding of local conditions with the aim of improving living conditions. Analyzing case study evidence is especially difficult because these techniques still have not been well-defined [10]. According to Yin [10], it is important during analysis to identify promising patterns, insights, and concepts, as well as develop a general analytic strategy. In this work, the most significant patterns were those with the potential to improve living conditions and experiences.

Share – through publication: Findings can be disseminated to a wider audience through publication in an appropriate scientific journal.

2.2. Mapping of policies and recommendations

The section addresses RQ2 through qualitative description. This entailed identifying and listing possible guidelines, roadmaps, and policy recommendations relevant to nations. The village areas and subsequently synthesizing these findings using a mapping literature review procedure.

a) Decision on synthesis procedures:

The synthesis process, following the approach outlined by [12], emphasized the use of techniques, such as analogy, comparison, and contrast, either study-by-study when dealing with a limited number of sources, or across a larger body of findings to identify similarities and differences. Qualitative policy documents were synthesized in tabular format to reveal patterns and commonalities, using a shared set of criteria as an “anchor” (for example, the year of the RE policy publications across countries) to assess trends and expectations. The synthesis results were then integrated to generate future recommendations, explanations, and theoretical insights. The type of synthesis applied in this study was configurative synthesis. According to Booth et al. [12], “configurative syntheses principally involve trying to capture the whole rounded-out picture of a particular phenomenon”. This approach addresses key questions such as: How do the individual themes identified across studies relate to one another? Are all perspectives incorporated within potential explanations of the phenomenon? What are the main areas of agreement or dissonance (lack of agreement) across studies, and how might these differences be explained?

ü The synthesis approach is summarized as follows: 1. Mapping policies through tabular presentation; 2. Developing a roadmap (for the AU based on Finland’s previous roadmap) by building a conceptual model; 3. Formulating policy recommendations by summarizing the results of the mapped policies and the proposed future EV roadmaps.

b) Qualitative data extraction:

- Data gathering: involved searching and collecting possible relevant policies and data on relevant initiatives. Both governmental policy documents and peer-reviewed journal articles were collected from two different databases, google.com and Scopus, using keywords of ‘countries (Ethiopia, Kenya, Uganda, Botswana and Finland) + Energy + Policies’. At this stage, the collected documents were chosen solely by evaluating their relevance based on their titles.
- Build database: an Excel database was created to catalog relevant policy documents and supporting materials for energy road map development; all available electronic copies of these data were downloaded for future reference.
- Data extraction and evidence synthesis: the following procedures were applied to varying degrees to both sections: 1) the mapping literature review and policy analysis; and 2) conceptual mapping of EV roadmap development.
  1. Selection of sources for the synthesis process: selecting or excluding documents based on a sequential review of their title, abstract, and full text. At this stage, decisions were made on which policy documents and EV roadmap development materials from the database would be included in the analysis.
  2. Initial assessment of study reports: this requires a preliminary reading and re-reading of the studies for inclusion based on Booth et al. [12].
  3. Analysis and synthesis: according to Booth et al. [12], this will involve further reading and re-reading of the study reports. However, at this stage you will move from considering the studies as individual reports towards examining these as a body of evidence. As [12] further note and the three components of a synthesis are – 1) pursuing a line of argument; 2) examining consistencies; and 3) identifying the disconfirming case.
  4. Preliminary analysis and interpretation: based one Booth et al. [12] - this move the task away from the detail of the individual reports to more of meat-level of analysis. At this stage, the findings from the studies are categorized and interpreted using tools such as mind maps, logical models, and tabulations.
  5. Full analysis and interpretation: based on Booth et al. [12], this stage takes the task beyond the elementary synthesis techniques used in the preliminary stage to more formal methods of synthesis such as thematic synthesis, framework synthesis or meta-ethnography.
  6. Generation of policy recommendations based on analysis: drawing on lessons learned from Finland for application in African contexts, this stage involves comparing policy frameworks, regulations, and governance structures in both the AU and EU, and formulating corresponding policy recommendations.

3. Results

3.1. Case study of energy villages and social innovations

This section discusses the qualitative analysis relevant to RQ1. The long-term joint European Union–African Union research and innovation partnership on renewable energy (LEAP-RE) project provided the primary data and cases examined in this work. Four case nations (and their energy villages) are highlighted based on their involvement in work package 14 (WP-14): ‘The Energy Village (EV) Concept in Africa’ of the LEAP-RE project: Ethiopia, Kenya, Uganda, and Botswana, which were represented by the national universities in each nation. The project organizing and managing partner for WP-14 was the University of Vaasa in Finland. From the EU, Finnish Energy Villages, identified and investigated in previous projects, were used as comparison cases.

1) Ethiopia: is a nation located in the horn of Africa or the upper east section of Africa. It is a landlocked country on the horn of Africa (Britannica 2024/Ethiopia). The current population of Ethiopia (as of 23/02/2024) is estimated to be approximately 128.6 million [13]. Ethiopia is the second most populous nation in Africa after Nigeria, and the fastest-growing economy in the region [14]. As noted by the [14], ‘while the country is considered by some as a growth miracle and has increasingly caught the attention of international investors, challenges remain in terms of achieving stability’. In addition, substantial work is still needed to ensure equitable energy security and reliable energy supply for all citizens. For example, there are local areas where there is insufficient electricity access (as also noted during the LEAP-RE: WP-14 project). At present, the economic

burden of limited energy access affects a significant portion of the population. The government of Ethiopia is responding to these energy and environment challenges through major new initiatives, such as the Growth and Transformation Plan and the Climate Resilient Green Economy Strategy (CRGE) [14].

Potential demonstration energy villages: the four selected EVs in Ethiopia were: 1) the AASTU (Addis Ababa Science and Technology University campus in Addis Ababa; 2) Wonji Sugar Factory Village, Wonji; 3) Langano, Ziway; and 4) Tulefa village in Debre-birhan. In additional the information is supplied below for the following Ethiopian demonstration energy villages – AASTU Campus, Addis Ababa and Tulefa village in Debre-birhan. To make the paper compressive only two out of four EVs presented for each nation.

a) AASTU Campus, Addis Ababa: Addis Ababa Science and Technology University, campus, is located the city of Addis Ababa, Ethiopia. AASTU has been identified as one of the fastest growing institutions in Ethiopia. In the LEAP-RE (WP:14) project, the on-grid energy village on the AASTU campus was one of the EVs studied. This campus Energy Village has a significant RE potential, including solar, wind, and biomass. Solar irradiation and wind speed at 30 m are 5.5 kWh/m^2/day and 7 m/sec, respectively, based on annual average calculations. The primary biomass resources are food waste, human waste, firewood and charcoal. However, the campus village consumes a considerable amount of firewood and charcoal for the two on-site cafes, electricity from the national grid, and fuel for vehicles and diesel fuel for generators. The analysis and estimation of the energy balance indicated that the renewable energy potential exceeds current consumption levels. The renewable energy generation potential is 14,032.23 kWh/day, while consumption from firewood, charcoal, electricity, and fuel is 12,572.03 kWh/day. This suggests the possibility of meeting 100 % of the current energy demand of the AASTU EV through renewable energy sources, with surplus production remaining. The next Fig. 2 shows a view of AASTU Energy Village.
b) Tulefa village in Debere-birhan: Tulefa energy village (EV) (off-grid EV), is located around 65 km from Addis Ababa, the capital of Ethiopia. There is a possibility to use the renewable energy resources of solar, wind and biomass (e.g., cow manure) in this EV. An average annual solar intensity of 5.98 kW/m2/day and the most common wind speed was 7.2 m/sec at 50 m height. This village energy consumption is coming from wood, charcoal and kerosene for cooking and lighting. After the energy balance estimation, the total RE potential in the village is approximately 69,400 kWh/day and a consumption of around 18,082 kWh/day. Again, this EV estimation can show a possibility of replacing the current consumption of the Tulefa EV with 100 % RES, with surplus energy production.

2. Kenya: Kenya is located the cost of East Africa, shares borders with Ethiopia, Somalia, Sudan, Uganda, and Tanzania [15]. The current population of Kenya (as of 23/02/2024) is estimated to be approximately 55.8 million [13], and the population in 2010 was 40.9 million [15]. Kenya is famed for its scenic landscapes, highlands with tea plantations, and vast wildlife preserves [16]. According to Britannica [16], Kenya's nature western provinces, marked by lakes and rivers, are forested, while a small portion of the north is desert and semi desert. In addition, Encyclopedia of Britannica also notes that the Kenya's wildlife and panoramic geography draw large numbers of European and North American visitors. Tourism is an important contributor to Kenya's economy.'

Potential demonstration energy villages: the five selected EVs in Kenya were: 1) Cheboiwo in Uasin Gishu; 2) Langas, Eldoret in Uasin Gishu; 3) Lelan in Elgeyo, Marakwet County; 4) Nandi Hills in Nandi; and 5) Kerio Valley in Kerio. In additional, detail is provided below for two of the four demonstration energy villages in Kenya – Cheboiwo in Uasin Gishu and Nandi Hills in Nandi.

a) Cheboiwo in Uasin Gishu: Cheboiwo village is located in Tulwet ward, Kesses sub-county. The population density of Tulwet ward is approximately 241 persons/sq.km [17], and the majority of households in Cheboiwo depend on firewood, and a smaller proportion use charcoal for cooking. The Cheboiwo village has a significant amount of renewable energy resource potential, such as solar, wind, and biomass (for example, for biogas production). Most rural residents in Uasin Gishu County have not adopted the use of renewable sources of energy. A survey conducted in Cheboiwo revealed that most residents expressed strong interest in adopting solar photovoltaic (PV) technologies. The area receives an average solar radiation of 5.6 kWh/m^2/day and approximately 12 hours of sunlight per day. Cheboiwo village is endowed with considerable biomass resources, such as agricultural waste (e.g., maize stalks), cow dung, market waste, and kitchen waste. These substrates are quantified to be approximately 180 tons per annuum, which would be sufficient for supplying a biogas plant. Cheboiwo village is in an area with an average wind speed of 5.29 m/s, and the mean wind power density is 182 W/m^2.
b) Nandi Hills in Nandi: Nandi Hills ward is one of the county assembly wards in Nandi Hills constituency, with a population density of 450 persons/sq.km. As most tea factories in Nandi Hills rely on wood fuel to operate boilers and other machinery, driving a need for alternative

Fig. 2. View of AASTU energy village.

fuel sources. Overreliance on firewood for household cooking energy further contributes to deforestation. In 2020, two tea estates at Nandi Hills introduced and promoted simple but effective energy-saving solutions. Moreover, demonstrating that small changes can have a significant cumulative impact [18]. According to Tofaris [18], one kilogram of tea production in Kenya consumes 3–6 kWh of thermal energy from wood and 0.2–0.5 kWh electricity for the grid, renewable energy, and diesel generators. In addition, in 2020, Eastern Produce Kenya (EPK), Kenya's largest tea producer and exporter, invited the Institute for Manufacturing (IfM) to implement the 'Cambridge Sustainable Improvement Method' (CSIM). Analysis revealed that energy consumption was lower in wet weather, even after adjusting for weather effects on both high- and low-productivity days. The three main factors contributing to improved performance were identified as variables within the factories' control [16]. After 12 months, teams in Nandi Hills reported reductions of 15–30 % in both thermal and electric energy consumption and a significant increase in tea produced per unit of fuel wood (kWh/m^3) on both tea estates.

3. Uganda: is an equatorial nation in East Africa, bordered by Kenya to the east. Uganda is bordered by South Sudan to the north, Kenya to the east of Tanzania, Rwanda to the south, and the Democratic Republic of the Congo to the west [16]. Uganda is a landlocked country in east-central Africa, often referred to as "the Pearl of Africa" [16]. As described by Encyclopedia Britannica, 'Uganda embraces many ecosystems, from the tall volcanic mountains of the eastern and western frontiers to the densely forested swamps of the Albert Nile River and the rainforests of the country's central plateau. The land is richly fertile, and Ugandan coffee has become both a mainstay of the agricultural economy and a favorite of connoisseurs around the world.' [16]. This rich natural diversity offers insight into why the country has earned its celebrated title. The current population of Uganda (as of 23/02/2024) is estimated to be approximately 49.4 million [13].

Potential demonstration energy villages: the five selected EVs in Uganda were: 1) Bidibidi Refuge settlement; 2) Kayanzi; 3) Wanale; 4) Maziba Murole; and 5) Nakasengere. The Ugandan demonstration Energy Villages, Bidibidi Refuge settlement and Kayanzi, are described in greater detail in the following.

a) Bidibidi Refuge settlement: is located in northwestern Uganda, within Yumbe district. The total annual energy demand for the over 8000 households in the zone is estimated at 24,218 MWh per annum. The survey findings indicated that more than 92 % of the settlement community depends on the firewood to meet their cooking needs, with most of this energy used in inefficient systems, such as open fire (three-stone stoves), clay stoves, and metallic fabricated stoves. There is significant potential for biogas generation from various sources, including human waste, chicken droppings, cow dung, and goat manure. Full exploitation of such resources has the potential to generate over 24,000 MWh of electricity per annum. The solar energy potential is also substantial, with an average hourly irradiation of 5.94 kWh/m^2 for an average of sunshine hours per day; if harnessed, this could add a considerable amount of energy to the local energy mix. However, wind potential is relatively low, with an hourly average wind speed of 2.1 m/s. The next Fig. 3 show that the aerial view of some parts of Bidibidi Refugee Settlement.
b) Kayanzi: Kayanzi fishing village is located in the sub-county of Kichwamba in the Kasese district of western Uganda. This fishing village is located near the shores of Lake Edward and is only 10 km off the Kasese-Bushenyi highway in the Queen Elizabeth National Park. The village has one primary school, Kayanzi Primary School, a small resort hotel, and local video halls. Its population of approximately 1341 people is divided across a total of 320 households. The village has a rich, year-round solar energy supply. Year-round wind speeds are intermittent, with the highest wind speeds recorded in May and the lowest in June. The village has a rich biomass resource comprising bushes, gullies, and trees; additionally, most local villagers are cattle keepers, providing further biomass sources for potential energy generation.
c) Botswana: is a nation located in the southern part of Africa, bordered by South Africa to the south and southeast. Botswana is a landlocked country in the center of southern Africa [16]. According to the report from our partners, Botswana also belongs to Sub-Saharan Africa and has a very small population, which is spread over 581,730 km^2. The current population of Botswana (as of 23/02/2024) is estimated to be approximately 2.7 million [13]. Thus, the population density in Botswana is approximately four individuals per square kilometer. Botswana receives abundant solar irradiation, with approximately 300 clear sky days. The country's average total solar radiation of 21 MJ/m^2/day, which is approximately 2100 kWh/m^2/yr, ranks it among the highest worldwide. The average direct normal irradiation (DNI) ranges from 2118 to 2848 kWh/m^2, and the average global horizontal irradiation (GHI) ranges from 2045 to 2337 kWh/m^2 per annum. An additional renewable energy resources include biomass from extensive bushland, slow-growing wood, and cattle dung can be used for heat energy. However, wind speeds and directions are generally moderate.

Potential demonstration energy villages: the four selected EVs in Botswana were – 1) School-Regent Hill International School in Gaborone; 2) Jamataka; 3) Majwanaadipitse; and 4) Matsaudi Learning Centre. Further details for the School-Regent Hill International School in Gaborone and Majwanaadipitse demonstration energy villages are

Fig. 3. Aerial view of some parts of Bidibidi refugee settlement.

presented below.

a) School-Regent Hill International School in Gaborone: The village has a population of approximately 2560 people. Although solar energy is the main RE source in Botswana, there is also potential for combination with wind energy and biomass sources in the future. The following Fig. 4 presents the Regent Hill School Energy Village.
b) Majwanaadipitse: Majwanaadipitse village is located near Serowe, Central district, approximately 70 km north of Palapye. The village is sparsely populated and has a population of approximately 400–500 people. Solar energy is the preferred renewable energy source for the region and is available over the entire year. The measured annual solar data for Majwanaadipitse village is 2267.4 kWh/m^2 (direct normal irradiation), 2092.5 kWh/m^2 (global horizontal irradiation), and 626 kWh/m^2 (diffuse horizontal irradiation). The optimum tilt for a PV module is 25°, and the global irradiation at the optimum tilt is 2279.1 kWh/m^2. Wind energy may be a secondary renewable energy source; the annual average wind speed is 6.55 m/s at 100 m elevation. Additionally, the thick bush in the surrounding area of the village is a potential biomass source.

4. Finland: is a nation located in northern Europe between Sweden and Russia. The country of Finland is one of the world's most northern and geographically remote countries. It is subject to sever climate. Finland is blanketed by thick woodlands, making it the most densely frosted country in Europe' [16]. Locally, Finland is often called "the land of a thousand lakes", and is known for its clean environment and high standard of living. As of 30 May 2025, the Finland country's population is approximately 5.6 million (as of 30/05/2024) [16]. The Energy Village concept was introduced approximately 24 years ago. The place was the University of Vaasa that enable rural areas to meet 100 % of their energy needs from renewable energy sources. Since then, numerous projects based on this concept have been implemented in Finland. Moreover, other nations in Europe, demonstrating its potential, which also translates to AU. The University of Vaasa projects were selected for this case study analysis Finnish energy villages highlighted in prior.

Potential demonstration energy villages: Current Finnish EV projects in the Vaasa region include Hoisko, llvesjoki, Jopua, Karijoki, Komossa, Leskelä, Närvijoki, Pensala, Perho, Ruona, Sauvonmäki, Ullava, Ylihärmä, and Ysikylät.

a). Jopua area energy village: Jopua is now part of the municipality of Nykarleby and was a separate municipality between 1906 and 1975 [19]. Moreover, its southern border runs through Keppo to the regional border of South Ostrobothnia. Jopua village has a notable commitment to and interest in renewable energy and sustainability development, and is characterized by innovation, entrepreneurship, and progressiveness [19]. The Jopua biogas production plant is one example of past successes as a result of the application of the energy village concept in Finland. The current energy consumption in Jopua is distributed as follows: 10,973 MWh for heating; 2022 MWh for household electricity; 24,514 MWh for industry, business, and agriculture; 875 MWh for municipal real estate; and 32,883 MWh for vehicle fuel consumption. This yields a total consumption of 71,249 MWh. In contrast, the renewable energy produced and consumed in the energy village is estimated as 18,136 MWh from biogas, and 5661 MWh from forest resources. Assessment of the renewable energy potential for the area suggests the following estimates – 7239 MWh from forest resources; 5583 MWh from straw; 28,388 MWh from wind; 15,552 MWh from water; and 1244 MWh from reuse, yielding a total potential of 58,005 MWh. In addition, revised energy calculations in 2014 added 65,600 MWh of energy from pulpwood to the total renewable energy potential, which is a comparatively large energy resource. The next Fig. 5 shows Jepppo biogas plant visit with some of LEAP-RE: WP 14 members and biogas plant leaders.

Perho area energy village: The Perho EV was part of the Erergibi project [19]. It has approximately 426 heated buildings within its boundaries, 35 of which are industrial halls or public buildings [19].

Fig. 5. Jepppo biogas plant visit with some of LEAP-RE: WP 14 members and biogas plant leaders.

Fig. 4. Regent Hill School energy village.

According to the final report on the Perho project [19], the principal methods used for heating are wood (from wood chips and pike), electricity, district heat (from a new district heating plant), fuel oil, and heat pumps in a few dozen properties. The current energy consumption of the Perho energy village is divided as follows: 10,515 MWh for heating, 2195 MWh for power consumption, 5889 MWh for industry + entrepreneurship + agriculture; 10,617 MWh for real estate properties; and 24,495 MWh for vehicle fuel consumption. Microproduction yields energy savings of −2415 MWh, resulting in a total consumption of 51,295 MWh. The renewable energy available production potential for Perho includes 9502 MWh from biogas; 2972 MWh from forest resources; 3308 MWh from straw; 57,312 MWh from wind; and 1489 MWh from waste to energy by incineration, yielding a total potential of 74,582 MWh. Currently utilized renewable energy consists of 10,278 MWh from forest resources (e.g., wood chips) and 1489 MWh from waste-to-energy incineration. Transportation fuel can account for the largest energy expenditure in Perho. This is a trend consistent with most energy villages in Finland. In contrast, in the AU energy villages assessed in this study, the majority of energy produced is allocated to heating. The next Table 1 shows Comparative framework to present similarities, differences and lesson learned.

Comparing the African Energy Villages and with the Finnish one the social acceptance; energy potential; technology maturity; government framework; and financial models the Energy Villages in Finland have better potential than the African ones. Comparing these evaluation criteria between African nations most seems to have the same potential patterns. The best in both continents for Energy Village concept is social acceptance and the worst is financial constraints. The rest evaluation criteria's depends in local level based on the technology readiness and local community development scale.

Analysis and description of the challenges identified through the LEAP-RE project: Identification of EV challenges.

The common challenges from the literature and the LEAP-RE WP-14 project include societal acceptance of RE, such as resistance and fear of change, the high cost of RE technology (including bank loans, investment, and insurance), lack of knowledge and existing knowledge gaps, and data availability. The existing literature has also indicated barriers as a result of a lack of RE infrastructure, such as connections to the grid. During the LEAP-RE: WP-14 project, challenges such as difficulty in establishing contact with locals and security issues in some locations were noted as the primary disrupters of RE technology research. Table 2 below lists the challenges identified from the literature and insights from the LEAP-RE: WP-14 project.

Table 2
Challenges identified from the literature and the LEAP-RE WP-14 project experiences. (Italicized items indicate challenges found in both the literature and the LEAP-RE WP-14 project.).

Challenges based on the literature review	Challenges based on the LEAP-RE: EV project
1) The acceptance of RE by society	*1) Resistance and fear of changing the energy resource locals use*
2) The cost of RE technologies and lack of financial means, including insurance	*2) Lack of bank loans, investment, and insurance*
3) Lack of knowledge regarding RE production and management	*3) Lack of knowledge, knowledge gaps in RE, and management*
4) Data availability	*4) Lack of long-term energy and weather data*
5) Lack of RE infrastructure (e.g., connections to the grid)	5) Difficulty in establishing contact with locals
	6) Lack of willingness to engage and provide data. This may be due to a lack of knowledge regarding relevant data on energy consumption
	7) Security concerns

3.2. Mapping of policies and recommendations

This section discusses the qualitative results for RQ2. As outlined by [20], the strategic priorities are – 1) power generation (to diversify the energy mix and improve energy efficiency); 2) energy access (to improve efficiency of biomass use and accelerate non-grid energy access); 3) irrigated and industrial agriculture (to accelerate irrigation plans, support the resilience of rain-fed agriculture and balance water demands; 4) access to WASH (to accelerate universal access to WASH and enhance the climate resilience of self-supply); and 5) cross-cutting responses (to develop data systems for decision support and accelerate the delivery of existing plans). In Ethiopia, energy policy initiatives promoting green energy and energy efficiency were first proposed as early as 1994 [21]. In 2023, Ethiopia's long-term low emission and climate resilient development strategy (2020–2050) was released with the goal of providing both a vision and a pathway to facilitate a transition to decarbonization under the Paris agreement [22]. 'Ethiopia aims to achieve middle-income status by 2025 while developing a green economy' [23]. The climate-resilient green economy strategy [23] seeks to identify green economy opportunities to enable Ethiopia to achieve its ambitious growth targets while minimizing greenhouse gas emissions. Moreover, through the Ethiopia Rural Energy Development and Promotion Initiative Center [24], Ethiopia has been moving toward a national biogas program. Four regions were chosen for this biogas program based on population size, livestock quantity, the loss of vegetative cover, status, woody biomass consumption, and the availability of relatively well-documented information [24].

The government of Kenya has been promoting generation of electricity from green sources, e.g., geothermal and other renewable energy resources, and Kenya anticipates a transition to clean cooking by 2028 as part of their national green incentives [25]. Policy actions outlined by the Kenya's 2022 National Green Incentives Program is focused on the following: 1) Electricity – to promote green electricity and increase consumer connectivity (e.g., through a phase-out of fossil fuel-based thermal electricity; accelerate geothermal development; promote off-grid renewable energy options; and provide incentives for electricity connection); 2) Clean cooking – through a range of incentives to unlock and accelerate the transition to modern and clean cooking. For example, incentives target clean cooking, fuels, and technologies, enabling markets for clean cooking services as well as investment in research and

Table 1
Comparative framework to present similarities, differences and lesson learned.

	Energy villages	Social acceptance	Energy potential	Technology maturity	Government framework	Financial models
Ethiopia	AASTU	Great	Great	Medium	Medium	Medium
	Tulefa	Medium	Medium	Low	Low	Low
Kenya	Cheboiwo	Medium	Low	Low	Low	Low
	Nandi Hills	Medium	Medium	Medium	Medium	Medium
Uganda	Bidibidi	Great	Low	Low	Low	Low
	Kayanzi	Great	Low	Low	Low	Low
Botswana	School -regent	Great	Medium	Medium	Medium	Low
	Majwanaadipi	Medium	Low	Low	Low	Low
Finland	Jopua	Great	Great	Great	Great	Great
	Perho	Great	Great	Great	Great	Great

development of renewable energy); 3) Manufacturing – particularly, greening of industries and investment in the manufacturing and production of green products to reduce emissions and provide guidance to manufacturers for undertaking product-related life cycle assessment (LCA) impact reports (e.g., promote efficient management of production systems; and develop eco-labelling schemes); 4) Transport – specifically, the Kenyan government aims to use fiscal policy to promote sustainable transportation, both public and private (e.g., promotion of mass rapid transit, incentives for electric vehicles, expansion of the e-mobility infrastructure, implementation of congestion charging, and development of alternative transport fuels).

The aims of the Kenyan government's Sustainable Energy for all by 2030 policy [3]. There are to 1) Mobilize all stakeholders to ensure universal access to modern energy services; 2) Double the global rate of improvement in energy efficiency; and 3) Double the share of renewable energy in the global energy mix [3]. This policy is being implemented in phases from 2015 to 2030 and involves multiple stages and knowledge-sharing sessions [3]. One of its strategic initiatives is through the Geothermal Development Company (GDC), which deploys early-developed portable modular power plants. These plants can be commissioned within six months and relocated to another drilled site after ten years, supporting Kenya's long-term renewable energy development plans [3].

A renewable energy policy has been in place in Uganda since 2007 [26], with the goal of increasing the use of modern renewable energy from 4 % to 61 % of the total energy consumption by the year 2017. This goal the above policy is probably achieved. In addition, one of the main aims of 'Electricity Licensing Policy' is to ensure that a proposed project is aligned with the energy needs of the country [27]. In Botswana, the Rooftop-solar program serves as a notable example to other nations of a targeted renewable energy initiative. The primary aim of Rooftop-solar [28], is to provide an affordable, reliable, and adequate supply of energy for sustainable development. As well as to improve access to and efficient use of energy sources. The BERA (Botswana Energy Regulatory Authority) is a national agency that develops laws and other approaches to enable locals to progress toward a transition to green energy [29]. Such initiatives are demonstrated governmental support for the expansion of renewable energy access and improvement of energy sustainability. The 2021 annual report of BERA further outlined strategies to assist locals through energy laws, contracts, and regulations, including the Rooftop-solar program [29]. The next Table 3 shows mapping of energy policies in Ethiopia, Kenya, Uganda, Botswana, and Finland, indicating the policy aims, the latest revisions, and the primary policy components for each country.

The gap between Finland and the four African nations in policy can be generalized due to the technology, economy, system and local and governmental knowledge advancement in Finland ever policy of systems works well. However, in African context most systems such as data collections systems, not following law or policies and other related issues make the written policy malfunction. To bridge these gaps between two contents African nation shall develop well in technology, knowledge, economy, system, education and other areas if African are willing to be helped while EU comes with less income looking mind just to help to develop nations.

Table 3
Mapping of energy policies in Ethiopia, Kenya, Uganda, Botswana, and Finland, indicating the policy aims, the latest revisions, and the primary policy components for each country.

Mapping Nations Policies Example			
Ethiopia	Kenya	Uganda	Botswana
Develop a commercially viable biogas sector in Ethiopia [24]	1. Mobilize all stakeholders toward ensuring universal access to modern energy services; 2. Double the global rate of improvement in energy efficiency and; 3. Double the share of renewable energy in the global energy mix [3]	Increase the use of modern renewable energy, from the current 4 % to 61 % of the total energy consumption by the year 2017 [26]	Provide an affordable, reliable, and adequate supply of energy for sustainable development, as well as improve access to the efficient use of energy sources [28]
A strategy to identify green economy opportunities to enable Ethiopia to achieve its ambitious growth targets while minimizing greenhouse gas emissions [23]	The overall objective is to provide affordable quality energy for all Kenyans to ensure sustainable, adequate, affordable, competitive, Secure, and reliable energy costs while protecting the environment [30]	Best to expand the hydropower plants, which are currently the most dominant source of electricity in Uganda. Their rate of development remains low [31]	Assisting locals through energy laws, contracts, and regulations, including in Rooftop-solar program [29]
The Climate Resilience Green Economy vision for Ethiopia is geared toward enabling the country to become a middle-income country by 2025 and has 11 strategic plans [20]; and Provide both a vision and a pathway to a transition to decarbonization under the Paris agreement [23]	Generating electricity from green sources has been encouraged, e.g., geothermal and other renewable energy resources, and Kenya anticipates transition to clean cooking by 2028 [25]	One of the main aims of 'Electricity Licensing Policy' is to ensure that a proposed project is aligned with the energy needs of the country [27]	The need for efficient solid waste management practices has become increasingly urgent, particularly in developing nations experiencing a population boom [32]

3.3. *Recommendations of policy based on analysis: learning experience from Finland to Africa*

Among the 9 – 60 policy documents reviewed in this article and in work by Girgibo et al. [33] (respectively) – the outlined for policy recommendations advocating for a focus on supporting and educating local communities about RE.

1. **Long – term policy recommendation**: Ethiopian climate policies, such as the Green Economy Strategy, should include educational workshops, demonstrations, open discussions on the environmental, economic benefits of RE and site visits. These measures will also promote peaceful coexistence between the communities.
2. **Medium – term policy recommendation**: The availability of data, including meteorological data, should be significantly improved to support the development of RE in African nations, as well as other developing nations.
3. **Short – term policy recommendation**: Innovative energy technology solutions are necessary. For instance, the use of briquettes was made from biomass residue in Kenya. It is a prime example of ensuring the sustainable supply of biomass energy.
4. **Long – term policy recommendations**: Finance remains a considerable barrier to the implementation of RE projects. International organizations, governments, and refugee agencies shall advocate for the use of funding for flexible and sustainable RE systems.

4. Conclusions

This study aimed to assess the collaboration between Europe and Africa on energy village (EV) projects. The energy village concept is a way to create a new village become using renewable energy only by using local renewable energy resources this is the novelty of this paper. The research gap is giving real cases across four countries in Africa and one country in Finland. Combining all real cases one can notice the difference, the challenges and possible policy recommendations areas. This was effectively addressed by improving the understanding of available resources and solutions, and by comparing energy availability for the populations of Finland and Africa. The significance of this work lies in its highlighting of the potential of such collaborative projects to foster the creation of better living environments in both regions. Through sharing experiences and cultural insights, these initiatives can help address local challenges more effectively. Additional benefits of EV-related collaborations include motivating communities, creating employment opportunities, and supporting rural sustainability in Africa, economically, socially, and environmentally. Key research objectives achieved in this study include the identification and comparison of renewable energy resources in the European Union (EU) and African Union (AU); the mapping of relevant policies in both regions; the provision of guidance to African nations in recognizing and utilizing available renewable energy sources; and the mutual benefit of informing new policies and management techniques for the AU and EU (including Finland). A qualitative methodology was employed in this work, combining case study analysis with descriptive evaluation techniques.

A comparison of the selected AU energy villages with those in Finland reveals several challenges or drawbacks. Nevertheless, the EV concept are demonstrating a significant potential for supporting local communities in improving. Their economic circumstances were through the effective utilization of available RE resources. The AU has a vast reserve of REs. However, there is a lack of technological advancement. In contrast, renewable energy resources and supporting technology are widely available in Finland. Collaboration between the EU and AU on energy village initiatives should combine local human capacity with advanced research and technology to strengthen the economies of African communities. Achieving this requires both parties to share a common vision, establish agreements, and ensure mutual interests are clearly defined in advance. However, significant challenges remain, including cultural misunderstandings, differing societal interests, variations in religious practices, and procedural differences in local contexts. Varying research approaches and behaviors have also posed obstacles. Nonetheless, these challenges are expected to diminish over time through sustained engagement and mutual learning.

In Ethiopia, the selected case study villages were AASTU Campus in Addis Ababa and Tulefa Village in Dibere Birhane. In Kenya, the examples were Cheboiwo in Uasin Gishu and Nandi Hills in Nandi. In Uganda, Bidibidi Refugee Settlement and Kayanzi were examined, while in Botswana, the selected cases were School–Regent Hill International School in Gaborone and Majwanaadipitse. From Finland, Jopua (known for its biogas production) and Perho were selected. These case studies highlight substantial differences between the EU and AU contexts, particularly in cultural and religious aspects. Cultural and religious practices could potentially be enriched through exchange and mutual learning; for example, by sharing governance experiences from Ethiopia's Orthodox Church, where appropriate. A key limitation of this stems from the primarily research-oriented status of the LEAP-RE WP-14 project. Its implementation in the AU context will depend on future funding and project opportunities, which may require proceeding without Finland's involvement, since the forthcoming LEAP-SE program will not be financed through Finland. As a result, AU communities have not yet had direct access to the technologies needed to fully utilize renewable energy resources.

Comparing the African Energy Villages and with the Finnish one the social acceptance; energy potential; technology maturity; government framework; and financial models the Energy Villages in Finland have better potential than the African ones. Comparing these evaluation criteria between African nations most seems to have the same potential patterns. The best in both continents for Energy Village concept is social acceptance and the worst is financial constraints. The rest evaluation criteria's depends in local level based on the technology readiness and local community development scale. Implications for future EV implementations and collaborations are different challenges appear in different nations even though the concept can be applied all over the world it has to be adjusted and researched for each individual village. Clear research agenda for further studies are implementing new energy projects that can install renewable energy solutions in each 16 energy villages in Ethiopia, Kenya, Uganda and Botswana. As well, future research should in depth analyses and research other energy villages in Ethiopia or other nations in developing nations to get more project start developing rural areas. The limitations of the methodology can be only it is somehow descriptive research not quantitative analyse were not to be able to conduct using this case study method that might implicate shortage in the methodology.

Abbreviations

AASTU - Addis Ababa Science and Technology University, Ethiopia
AU- African Union
BEMP - Botswana Energy Minister's Plan
BERA- Botswana Energy Regulatory Authority
BIUST - Botswana International University of Science and Technology, Botswana
BPC - Botswana Power Company
COVID-19 - Coronavirus disease
CRGE - Climate resilient green economy
CSIM - Cambridge Sustainable Improvement Method
DEA - Department of Environmental Affairs
DoE- Department of Energy
DNI - Direct normal irradiation
ECS - Electrotechnical Certificate Scheme
EEU - Ethiopian Electric Utility
EEP - Ethiopian Electric Power
EIA - Environmental impact assessment
EIC - Ethiopian Investment Commission
EPA - Environmental Protection Agency
EPK - Eastern Product Kenya
EPRA - Energy and Petroleum Regulatory Authority
ERA - Ethiopia Road Administration
ERCA - Ethiopian Revenue and Customs Authority
EREDPC - Ethiopia Rural Energy Development and Promotion Center
EU - European Union
EV - Energy Village
EVC - Energy village concept
GDC - Geothermal Development Company
GHG - Greenhouse gases
GHI - Global horizontal irradiation
GoE - Government of Ethiopia
IfM - Institute for Manufacturing
ISO - International Standard Organization
KEBS - Kenya Bureau of Standards
LEAP-RE - Long-term Joint European Union – African Union Research and Innovation Partnership on Renewable Energy
MaK - Makerere University, Uganda
M&E - Monitoring and evaluation
MMGE - Minister of Mineral Resources Green Technology and Energy Security
MoA - Minister of Agriculture
Moi - Moi University, Kenya
MoME - Ministry of Mines and Energy
MoWIE - Ministry of Water, Irrigation and Energy

NDP - National Development Policy
NEMA - National Environmental Management Authority of Kenya
NEP - National Energy Policy
NGO - Non-Governmental Organization
RE - Renewable energy
REA - Research Executive Agency
REDD - Reducing emissions from deforestation and forest degradation
RERS - Renewable energy resources
RES - Renewable energy sources
RETs - Renewable energy technologies
ROI - Return on Investment
OPM - Office of the Prime Minister
WASH - Water, sanitation and hygiene
WP - Work package
UNBS - Uganda National Bureau of Standards
UNHCR - United Nations High Commissioner for Refugees
VDC - Village Development Committee

Statements of declarations

1. The authors declare that they have no known competing financial interests or personal relationships that could appear to influence the work reported in this paper.
2. There is no conflict of interest.

Ethics approval and consent to participate

Not applicable

Consent for publication

All the authors agreed and gave their consent for publication.

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Availability of data and materials

The data is not available for public use because the research is ongoing, and our research teams would like to continue with it, so we are not currently sharing our data.

CRediT authorship contribution statement

Nebiyu Girgibo: Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Pekka Peura:** Writing – review & editing, Writing – original draft, Funding acquisition. **Getachew Adam:** Writing – review & editing, Writing – original draft. **Mario Einax:** Writing – review & editing, Writing – original draft, Conceptualization. **Achisa Cleophas:** Writing – review & editing, Writing – original draft. **Hillary Kasedde:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

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

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