



Research article

Renewable energy villages roadmap development for Ethiopia, Kenya, Uganda, and Botswana nations



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ABSTRACT

This article aims to map out a roadmap 2025–2029 for 4 African nations—Ethiopia, Kenya, Uganda, and Botswana—and associated policy recommendations. The method is to work on the project, long-term Joint Relationship Between European and African in Renewable Energy Research in Energy Village Concept in Africa (LEAP-RE: WP 14) and mapping policies and roadmaps from experience and literature. The significance and contribution is an example to African nations for developing and mapping out a Roadmap for 2025–2029 for Energy Village (EV) projects. The novelty is the African Energy Villages, which were identified to be unique and different from implementations in European nations. The EV concept identifies and analyses potential supplies of renewable energy (RE) and local consumption needs to help local communities become energy self-sufficient. Understanding policies and initiatives for self-sufficient RE villages in Africa under the LEAP-RE program is a crucial prerequisite in implementing EV concepts using clean and secured sources of RE such as biomass, small hydropower, solar, and wind for rural African people. The main conclusion is that such EVs are able to use more than 100% RE from local communities to overcome the energy shortage.

Abbreviations: AASTU, Addis Ababa Science and Technology University, Ethiopia; AU, Africa Union; BEMP, Botswana Energy Master 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; DEA, Department of Environmental Affairs; DoE, Department of Energy; ECS, Electrotechnical Certificate Scheme; EEU, Ethiopian Electric Utility; EEP, Ethiopian Electric Power; EIA, Environmental Impact Assessment; EIC, Ethiopian Investment Commission; EPA, Environmental Protection Agency; EPRA, Energy and Petroleum Regulatory Authority; ERA, Ethiopia Road Administration; ERCA, Ethiopian Revenue and Customs Authority; EREDPC, Ethiopia Rural Energy Development and Promotion; EU, European Union; EV, Energy Village; EVC, Energy Village Concept; GDC, Geothermal Development Company; GHG, Green House Gases; GoE, Government of Ethiopia; 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, Minister of Water, Irrigation and Energy; NDP, National Development Policy; NEMA, National Environmental Management Authority of Kenya; NEP, National Energy Policy; NGO, National Governmental Organization; RE, Renewable energy; REA, Research Executive Agency; REDD, Reducing Emissions from Deforestation and forest Degradation; RES, Renewable energy sources; RERS, Renewable energy resources; 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

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1. Introduction

The WP14 endeavored to establish smart, self-sufficient energy communities capable of generating, managing, and utilizing their own energy resources, with minimal reliance on external power grids. In Kenya, Moi University studied 5 energy villages (EVs) that integrate various technologies to optimize energy use and improve overall efficiency while reducing the environmental impact. The other EVs are in Botswana, where BIUST University studied 5 EVs; in Uganda, where Makerere University studied 5 EVs; and in Ethiopia, where AASTU studied 4 EVs.

In Botswana, there is a self-sufficient energy community of the Botswana Power Company (BPC) coal powered national grid energy supply. The village’s electricity source is clean and renewable, reducing the village’s carbon footprint. In Uganda, key stakeholders include the refugee community, host community, government through the OPM (Office of the Prime Minister), design and engineering consultants, and local authorities. Authorities in Ethiopia include federal, regional, and local governments, as well as regulatory bodies overseeing energy, environment, and rural development. Their involvement ensures that the project aligns with national and regional policies, benefits from regulatory and financial support, and gains legitimacy within the broader framework of sustainable development. In Kenya, roadmap actions include feasibility assessments; stakeholder engagement; obtaining funding and investment; designing the smart energy infrastructure; building or retrofitting energy-efficient buildings; implementing smart grid and energy management systems; promoting community engagement and education; monitoring progress; and ensuring long-term maintenance, sustainability and funding [1–3].

Energy in Africa predominantly involves biomass resources, mainly fuel wood, charcoal, branches, animal manure and agricultural residues. Besides these traditional energy resources, a small amount is supplied by modern energy resources—namely petroleum and electricity—to top up the balance. According to previous reports on EV projects in Finland, transportation accounts for the greatest fraction of fossil energy use, energy cost, and economy. In the African context, however, the most important energy issue is the supply of household fuels, which is associated with massive deforestation and consequent land degradation. Accessing traditional energy resources becomes inevitably more challenging as the population increases, and the effects are already experienced. As is well-known, energy is the backbone of socio-economic development and supplies also political power for states. Governments therefore set out various policies and initiatives to radically transform the current energy landscape in Africa. This is particularly so in Ethiopia, Botswana, Uganda and Kenya where the bigger scope for renewable energy (RE) resources, ambitious electrification targets and numerous legislative incentives have cultivated increasing appeal for private investors. Prioritizing modern and sustainable energy usage is the central basic element of these governments’ policies. To improve energy access by increasing RE production, this report identifies policies that support EV concepts and implementation strategies in Ethiopia, Botswana, Uganda and Kenya.

The EV concept has been seen as a facilitator for change in the striving for energy self-sufficiency in rural villages. EVs have been developed across Uganda, Kenya, Botswana and Ethiopia, as listed in Table 1.

The key concept behind this article is the EV project concept. The EV concept maps out a selection of villages with various levels of intervention, and categorizes them according to their readiness levels. 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 the following ideas as they relate directly related to both the work program and the specific challenge: Firstly, the continent is endowed with strong renewable energy source (RES) potential including biowaste, solar, wind, geothermal and hydroenergy that exceeds demand, especially in rural regions. Secondly, there are

Table 1

List of energy villages in Africa chosen.

S/N	Energy villages	Country
1	Cheboiwo, Langas, Nandi Hills, Kerio Valley, and Lelan	Kenya
2	AASTU, Tulefa, Wonji, and Langano	Ethiopia
3	Regent Hill School, Regent Hill School, Jamataka, Majwannaadipitse, and Matsaudi	Botswana
4	Nakasengere, Wanale, Refugee Camp, Maziba Murole, and Kayanzi	Uganda

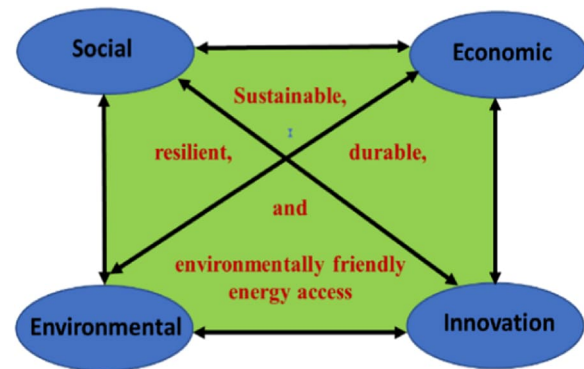


Fig. 1. Four-node network representation scheme visualizing the interplay between social, economic, environmental and innovation aspects for the development of a successful sustainable, resilient, and durable energy supply in rural areas.

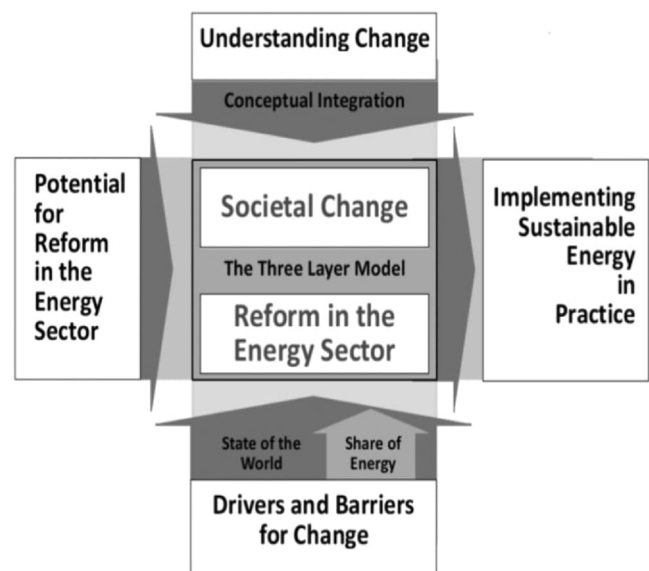


Fig. 2. The conceptual procedure for developing African-context EV roadmaps [29].

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 [29]. Conceptual integration, Peura [29] explains, aims toward large intellectual entities from the various branches of science by explaining and merging the background presuppositions.

Table 2
Roles and required permits from authorities for EV implementation in Botswana.

No	Authority	Summary of the roles	Required permits
1	Villagers/The Chief and the VDC (Village Development Committee)	Permission to interact with villagers and do a needs assessment	No permit required
2	Ministry of Minerals and Energy	Approval if research	Ethics permit
3	The Land Board	Responsible for authorizing and approving land use	Land title deeds
4	The Department of Environmental Affairs (DEA)	Responsible for overseeing the Environmental Impact Assessment process	Certificate of environmental impact assessment
5	Health and Safety Authorities	Responsible systems safety	No permit but general register required
6	Botswana Regulatory Authority (BERA)	Responsible approving power production	Power production permit

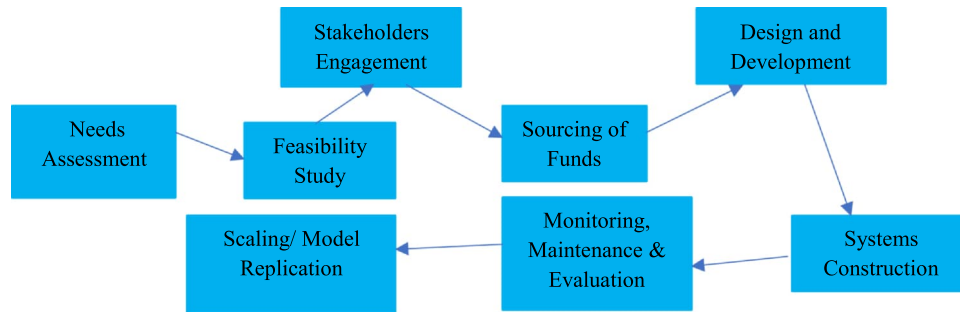


Fig. 3. Roadmap for developing an energy village in Majwanaadipitse, Botswana.

This article proposes and suggests a renewable EV roadmap that might be generalized for African nations, and outlines future energy policy recommendations for them. The novelties, significance and contributions consist in EV roadmaps for 2025–2029 for 4 African nations. The following research questions were raised and addressed in this research—(RQ1) What are the 2025–2029 roadmaps for EVs in Ethiopia, Kenya, Uganda and Botswana? (RQ2) What future policy can be recommended for African nations, combining knowledge from the LEAP-RE project?

The EV concepts mapping joint research and innovation actions for next-step development of RES specific challenges and smart stand-alone systems. As Africa’s population rapidly grows and urbanizes, its need for reliable and sustainable energy supply will become greater than ever. This energy is needed not only to drive the continent’s economic development but also to offer modern energy services to the large population presently living without them. The EV concept recognizes the following as a starting point as it all directly related to the work programmed and the specific challenge. Firstly, RES Potential - The continent is endowed and has the potential of RES, including biowaste, the solar, wind, geo and hydro energy that exceeds the demands, especially in rural regions.

The physical preconditions for RES energy self-sufficiency exist. A potential that EV concept addresses. Secondly, positive drivers – from attitude to the local economy. A large part of the Africa continent is still without clean energy, RES offers an opportunity to leapfrog the fossil-based fuel to clean RES energy in rural energy with smart stand-alone systems. Certainly, there are positive drives that call for new strategies and practical solutions to boost the transition away from fossil fuels to sustainable energy sources. The growing shift in general public opinion toward RES and increased energy security that Long-term RES can provide as well as huge economic opportunities at a regional level.

1.1. Literature review: Obstacles/barriers and problems in energy innovative technology market

Innovation is a way to implement ideas that lead to new or improved products, and services. The overall aim is turning ideas into sustainable tangible values which often happens through the business models reflecting the ability to innovate. We can classify different types of innovations. Two main categories are economic innovations and noneconomic innovations, respectively. Technical innovations belong

to economic innovations, while noneconomic innovations are, for example, social innovations or green innovations.

Our focus in WP 14 is the development of an EV concept that aims to provide, for example, in rural villages with a resilient and durable energy solution including local value creation, rural entrepreneurship, and fair employment. In addition, this also implies a way for the decarbonization of rural regions targeting long-term carbon neutrality, with a strong replication potential. The interplay between social, economic, environmental and innovation aspects for the development of a successful sustainable, resilient and durable energy supply in rural areas can be represented by a 4-node network topology (see Fig. 1). Searching for an affordable RE solution can be linked to that network. “Energy crisis or barriers can intricate interplay between consumer behavior, industry practices, and technological innovations in shaping the energy landscape and; needs and differences between different groups of countries realistic in overcoming barriers” ([12,13]).

Identifying obstacles/barriers to an innovation strategy before setting it out helps to turn ideas into tangible value or to establish sustainable business models. This empowerment of consumers into active players is currently one of the main social innovation challenges for the electrification of rural areas and can be seen as one of the obstacles to innovation. While in most projects technological innovations are the main focus, social innovation and the incorporation of wider societal aspects are regularly overlooked in the design phase of innovation processes. For example, social innovation is to define new roles in an EV community compared to the existing or traditional roles.

- Traditional roles,
- Working on cattle posts,
- Do farming (plowing and growing crops),
- Produce traditional bricks,
- Work as peace jobbers to build traditional houses,
- Collecting and selling firewood.

Rural villages in Sub-Saharan Africa have a high unemployment rate and villagers have a low income. The fear of changing traditional roles is another obstacle to innovation to implement RE solutions, such as moving from traditional cooking with firewood to solar cooking. A third obstacle is the limited eigen-capital due to low income and the associated poverty in rural EVs in Africa. For low-income regions, there is also a lack of innovative investment strategies offered by the banking

Table 3
Roadmap table for actions and its descriptions for 2025 up to 2029.

Action	What	Who	How	When	Interrelations
Village Needs Assessment	The current and future energy needs are assessed	Academic Institution/Project research team	Questionnaires, interviews, and desktop research	Jan–Feb 2025	These data are crucial in solution choice and system sizing.
Feasibility Study	Assess environment and do a cost-benefit analysis	An impact assessment company and Research team	Qualified practitioners are engaged	Mar–July 2025	Guides planners and developers on location, design, size
Funding and Grants	A hunt for grants/loans for project implementation	Research team	Market proposal to funding bodies	Jul–Dec 2025	Funding is tied to project realization
Design and Development	Detailed designs, procurement of equipment	Specialized Renewable Energy Company	Renewable Energy Company Engaged	July 2025–Dec 2026	Designs must suit needs and equipment suit designs
Energy Systems Construction and capacity building	Construction of Energy village	Specialized Renewable Energy Company	Renewable Energy Company Engaged	Jan 2027–Dec 2027	Village needs, impact assessment and funding are required for construction
Training and capacity development	The project implementation team will undergo capacity development inform of training	This will be done by the project managers	Through workshops, seminars and formal filed trainings	Jan 2028 Dec 2028	This will relate to proposed implementation of the project
Monitoring, Maintenance, Evaluation	systems is monitored and evaluated, so is community satisfaction, and financial viability	Research team/Maintenance company	Data collection, processing and analysis	Jan 2029 Dec 2029	The success of the EV hinges on it
Scaling/Model Replication	Setting up similar and larger-scale projects	Research team/All stakeholders	A repeat of the processes resulting in an EV	Dec 2029 and beyond	Replication is a result of success of the first EV

sector. Another obstacle is short-term thinking because a limited eigen-capital and the poverty trap in rural areas lead to long cash back cycles for RE solutions in EVs.

Also, the lack of innovative business models like the establishment of community and companies is an obstacle to innovation. This goes ahead with the lack of leadership to establish sustainable RE solutions. Moreover, geographical constraints and education level are significant obstacles to achieving green innovations. Finally, security reasons in several countries in Sub-Saharan Africa can be seen as an obstacle to innovation. Differently speaking, local and regional conflicts make it often impossible to reach EVs [1–29].

2. Research process/materials and methods

This section presents the general methods used including which systematic review and procedures applied in this article. The conceptual general structure procedure that should apply to the future roadmap is shown in Fig. 2, adapted from Peura [29]. This article tries to build on Peura’s [29] work by building an EV concept roadmap in the African context.

2.1. EV roadmap development

- i. Data was collected from project of LEAP-RE: WP 14 experience and from literature review.
- ii. Conceptual structure identification from EU and/or Finland
The conceptual structure should apply to the future roadmap that was identified and described based on previous publications [29].
- iii. Develop a new conceptual model adapted to the African Union context and general EVs based on literature synthesis and previous knowledges in Finland.
- iv. A sustainable action plan developed.

- 1) Review and analyze roadmaps used in Finland and learn from them: investigate how to apply the steps toward implementing sustainable energy to the African context as a RE roadmap.
- 2) Identify detailed roadmaps, implementation and sustainable action plans used in Finland and from our partners.
- 3) Identify implementation plans for each partner country and commonalities across demo villages and partner countries.
- 4) Search for a single technical solution relevant to every EV at a general level.
- 5) Outline the roadmap toward a more comprehensive system solution, consisting of separate technologies.
- 6) Advance them based on other experiences, for example, in Finland and adapt them to Africa, describing their expansion and their possibilities.
- 7) Identify other possible roadmaps and documents to compare the results roadmap from the EV project.

2.2. Policy recommendations

- 1) *Combine results*: combine mapping of literature reviews and policy results with the new generalized energy roadmap developed.
- 2) *Decide*: what should be the main results, identification and gaps in the current documents to forward as the main policy recommendation for the case nations or Africa in general?
- 3) *Agree on the results with partners*: discuss with every partner in LEAP-RE (WP14: Energy Village Concept) these recommendations about policies. Agree with all partners on what to suggest and document all steps.

3. Results

3.1. EV roadmap development

The detailed implementation and sustainable action plans are described below for Botswana, Ethiopia, Uganda and Kenya.

Table 4
Authorities and required permits.

S/N	Authority	Summary of the roles	Required permits
1	UNHCR (United Nations High Commissioner for Refugees)/ NGO (National Governmental Organization)	Provision of the clearance for access to the village Availing relevant data for the community	Clearance permit for data collection
2	OPM (Office of the Prime Minister)	Responsible for the administrative operation of the village	Camp access permit
3	ERA (Ethiopia Road Administration)	Responsible for managing all the electricity related projects in the country	Project development and implementation permit
4	REA (Research Executive Agency)	Responsible for rural electricity projects	Development permit
5	UNBS (Uganda National Bureau of Standards)	Responsible for quality of products and services the consumers receive	ISO (International Standard Organization) certification of the project

Actions for 2025–2029 Uganda.

3.1.1. Botswana

In Botswana, the suggested roadmap to be achieved from 2025 to 2029 involves the authorities assigning permits and roles for EV implementation. See [Table 2](#) for the permits required.

Actions for 2025–2029 Botswana.

Village Needs Assessment: The village will be assessed to determine who will consume the energy, the current energy needs of the villagers, their activities, culture and practices, living standards, norms and values and to find out what energy uses they aspire to. Also, the geography and climate are preliminarily assessed here in order to determine the possible and available sources.

Feasibility Study: The feasibility study aims at assessing the existing infrastructure, whatever energy technologies that may be available, and compatibility with the local grid (for the possibility of a grid-tied future). Also, the study looks at environmental sustainability and recommends measures to minimize environmental harm. The study will also calculate the required investment, estimate maintenance costs, potential earnings and savings, and economic benefits such as access to cleaner and sustainable energy, jobs and improved agricultural practice, etc.

Stakeholders/Authorities Engagement: The energy policy and regulations department is within the government of Botswana, and needs to be convinced to support the initiative. The local community is involved in planning to ensure that the EV meets their needs and gains their support. Potential investors, collaborators, technology suppliers, and local contractors can be identified at this stage.

Funding and Grants: Potential national, regional, and international grants, loans, or partnering bodies are approached at this juncture to convince them of the viability and benefits of funding the EV. A financial analysis, showing return on investment (ROI) with projections on energy savings, job creation, and the social impact should be prepared to convince funders.

Design and Development: The layout of a solar microgrid and biodigesters are finalized in this phase. Included here should be the local grid that distributes energy to points of use such as homes and boreholes. All necessary permits from the Botswana government for construction, operation, and environmental compliance should be secured at this point. BERA will be consulted in order to align the implementation with national energy regulations. Energy equipment, such as solar panels, battery storage, and digester construction materials such as bricks and cement, will then be procured.

Energy Systems Construction and Capacity Building: The PV microgrid, together with related infrastructure and the biodigesters, is now constructed. Related systems such as energy meters are installed. Capacity building is implemented in the form of training of local community members in the operation and maintenance of RE systems to ensure sustainability. Outreach programs to raise awareness about energy conservation, technology, and sustainability practices are undertaken. Operational tests of the energy systems are carried out to ensure that they are running as planned, along with troubleshooting and adjustment of operations where necessary.

Monitoring, Maintenance, and Evaluation: The energy system's performance is monitored and evaluated along with community satisfaction and financial viability. It is important to regularly evaluate the impact on energy access, economic growth, and environmental sustainability. Maintenance of energy infrastructure is key to preventing breakdowns. Where necessary, adjustments and upgrades should be carried out to mitigate redundancy or increased demand.

Scaling/ Model Replication: Once the EV has been evaluated and certified successful, other villages can be convinced to adopt the same model and possibly larger-scale RE projects that can serve multiple villages or towns may be explored (see below [Fig. 3](#) and [Table 3](#), and [Table 4](#) for a road map 2029–2029 for Botswana).

3.1.2. Uganda

The EV is widely accepted and can be used in Uganda. To start this village particular documents required to be practical. The authorities and required permits are listed in [Table 4](#). In Uganda to start an EV the kinds of documents are required are listed in below [Table 4](#).

Demand mapping for the village: The demand mapping was done by the project team. This involved estimating the community's load profile to eventually determine the community's energy requirements.

Detailed system design, specification, and selection: The detailed design that depended on the available potential, and they will be obtained by the project design team. This will focus on coming up with the specifications of the energy systems, their sizes and the potential suppliers.

Training and capacity development: A team of personnel will be trained in the basic skills needed to work directly in the project.

Equipment acquisition: The project procurement and engineering contractors will consider credible suppliers and implement the acquisitions at the implementation stage of the project.

Supply, installations, and operation: After equipment acquisition, installation training and operation will follow.

Evaluation and success criteria: Periodic evaluation of the project success and impact on the community will be done. This will help to identify prospective improvements required. Please see [Table 5](#) for the actions and their associated interrelations.

3.1.3. Ethiopia

In Ethiopia, the EV concept is already accepted. To implement it requires documentation and permits as listed in [Table 6](#).

Actions for 2025–2029 Ethiopia.

The realization of Tulefa EV as a model smart self-sufficient energy community requires a well-structured action plan, detailing what needs to be done, who will be responsible, how it will be executed, and when each activity should take place. Below is a comprehensive timeline of actions, interdependencies, and key stakeholders involved (see [Table 6](#) and [Fig. 4](#) for EV roadmap in Ethiopia). Implementing a self-sufficient EV in Ethiopia's rural areas requires a comprehensive approach that aligns with national regulations and local community needs.

This initiative aims to harness RE resources such as solar, wind, and biomass to meet community energy demands sustainably. Obtaining the

Table 5
Actions and their associated interrelations

Action	What	Who	How	When	Interrelations
Demand mapping and load profiling	This will focus on estimation of load profile for the village	Project research team	Questionnaires, structured interviews, and desk reviews	Jan–Feb 2025	This will guide in system configuration for optimal load matching and modeling
Detailed system design, specification and selection	This involved development of the supply options by generating the specification of ECS (Electrotechnical Certificate Scheme)	This will be done by project design team	The system simulation software will be used to come up with the detailed and feasible design	Mar–June 2025	This will be based on the available potential and the demand earlier profiled
Sourcing of funds	This will involve sourcing for funds for the project implementation	Project team	Through proposal writing to potential funders for grants	Jul–Dec 2025	The will relate to the budget as per the detailed and implementation plan
Training and capacity development	The project implementation team will undergo capacity development inform of training	This will be done by the project managers	Through workshops, seminars, and formal filed trainings	Jan 2026	This will relate to proposed implementation of the project
Equipment acquisition and procurement processes	The configured equipment will be procured at this stage	The procurement and project team	Sourcing from potential suppliers as per the specifications	Feb–Jun 2026	The required equipped will be shipped
System installation, configurations and operations	The required ECS will be installed at this stage	The subcontracted installation firms and project team will take charge of this exercise	Installing the energy conversion systems at the generation site	Jul–Dec 2029	The delivered ECS shall be installed at the site for operation to kick off
Evaluation and success criteria	To ensure that the project goals are achieved	This will be done by the project (Monitoring and Evaluation) M&E team	Through the project success criteria, the M&E team will evaluate the project key milestones against the proposed objectives	Jan 2028	This will be in relation to all the previous activities

necessary permits and approvals from various government bodies is essential. These include investment licenses, land use agreements, environmental clearances, and energy generation permits, among others. Collaborating with key authorities and ensuring compliance with legal and regulatory frameworks will enable the successful establishment and operation of the EV, fostering economic development and improving the quality of life for rural residents. Below are the main permit documents required to implement the project, along with the governmental bodies that issue them. [Table 7](#) shows one part of the roadmap for Ethiopia.

3.1.4. Kenya

The authorities and required permits for implementing EVs in Kenya are shown in [Table 8](#).

Actions for 2025–2029 in Kenya.

Implementing a smart energy community involves a series of coordinated actions that span planning, design, construction, and ongoing operation. These actions focus on establishing an energy-efficient, sustainable, and self-sufficient energy system, where RESs, smart technologies, and community involvement work together.

1. Feasibility assessment:

Conduct a comprehensive feasibility study to evaluate the potential for RE generation, storage, and smart grid integration within the community.

2. Stakeholders engagement:

Establish a collaborative framework with key stakeholders (local government, residents, utilities, developers, energy providers, etc.).

3. Obtain funding and investment:

Identify and secure funding sources to finance the infrastructure, technologies, and development of the smart energy community.

4. Design the smart energy infrastructure:

Design a comprehensive energy system that incorporates RE, energy storage, and smart grid technologies.

5. Build or retrofit energy-efficient buildings:

Ensure that buildings within the community are energy-efficient, utilizing smart technologies, and equipped with RE systems.

6. Implement smart grid and energy management systems:

Deploy the smart grid infrastructure and energy management systems that enable real-time monitoring, data collection, and optimization of energy consumption.

7. Promote community engagement and education:

Foster active participation from residents by providing education, incentives, and platforms for involvement in the community’s energy system.

8. Monitor progress:

Continuously monitor the community’s energy systems, optimize their performance, and scale the model for wider application.

9. Ensure long-term maintenance and sustainability:

Establish a governance and management structure to ensure the ongoing operation and sustainability of the smart energy community. These actions described above are summarized in [Table 9](#).

The successful implementation of a smart energy community requires careful planning, coordinated action across multiple stakeholders, and an ongoing commitment to innovation and sustainability. By following a structured roadmap, communities can build self-sufficient, resilient, and energy-efficient environments that reduce their carbon footprint and offer long-term benefits to residents, businesses, and the environment. [Fig. 5](#) shows the implementation roadmap for 2025–2029.

4. Discussion: Policies recommendations for AU

Understanding policies and initiatives for self-sufficient RE villages in Africa under the LEAP-RE Programme is a crucial prerequisite to

Table 6
Required documents and permitting organizations in Ethiopia

Required document	Permitting organization
Investment Permit	Ethiopian Investment Commission (EIC)
Land Use Agreement	Ministry of Agriculture (MoA) and Regional Land Administration Offices
Environmental Impact Assessment (EIA) Approval	Environmental Protection Authority (EPA)
Energy Generation License	Ministry of Mines and Energy (MoME)
Construction Permit	Ministry of Urban Development and Construction
Business Registration and Tax Identification	Ethiopian Revenue and Customs Authority (ERCA)
Community Agreement	Regional and Local Authorities (Woreda and Kebele Administrations)
Power Purchase Agreement (if applicable)	Ethiopian Electric Utility (EEU) and Ethiopian Electric Power (EEP)

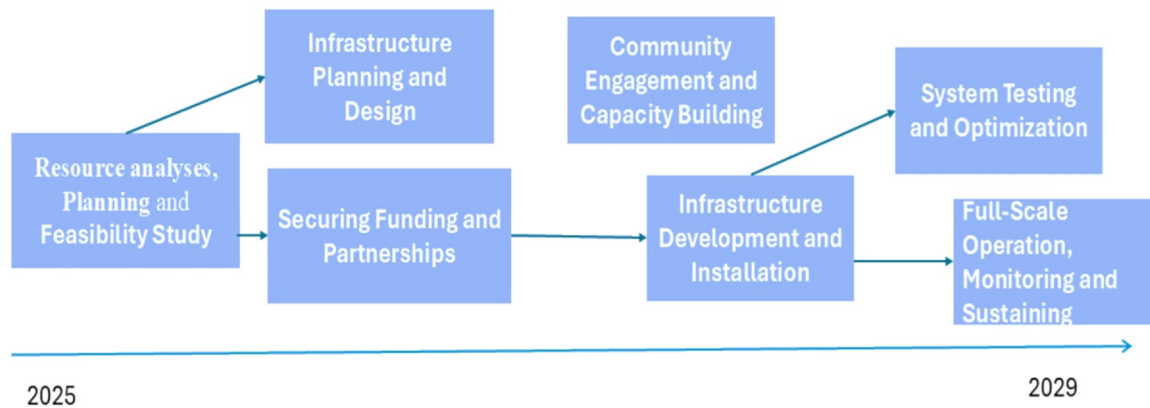


Fig. 4. The roadmap for Actions on developing the EV projects in Ethiopia.

their implementation. Developing an implementation plan and feasible business model with high replication potential requires mapping of policies and initiatives based on each region’s RES potential and total energy consumption report. On top of this, EV strategic plans allow stakeholders to consider the best use of the locally available RE resources and to reduce the impact of climate change on the community.

In line with the objectives of the EV establishment of the LEAP-RE project, the governments of Ethiopia, Botswana, Uganda and Kenya have issued different documents that set out energy policies. In Ethiopia, for instance, energy policies started to take effect in 1994. The energy policy document showed the government of Ethiopia’s (GoE) intentions in each of the subsectors. Thus, it aimed to address household energy problems by promoting agro-forestry, increasing the efficiency of biomass fuels usage, and facilitating the shift to greater use of modern fuels. Furthermore, the policy paper states that the country will rely mainly on hydropower to increase its electricity supply but it also mentions taking advantage of Ethiopia’s geothermal, solar, wind and other RE resources where appropriate. In addition, it aims to further explore and develop oil and gas reserves. It also refers to the need to encourage energy conservation in industry, transport and other major energy-consuming sectors, to ensure that energy development is economically and environmentally sustainable. Providing appropriate incentives to the private sector is the other area that the policy statements emphasize. The energy policy document is further elaborated by further policies and strategies specific to industrial, agricultural, and other sectors. The main energy policies in Ethiopia are:

- Policy on energy resource development
- Policy on energy supply
- Policy on energy conservation and efficiency
- Policy on comprehensive measures

The general objectives of the energy policy are as follows:

- To ensure a reliable supply of energy at the right time and at affordable prices, particularly to support the GoE’s agricultural and industrial development strategies.

- To ensure and encourage a gradual shift from the use of traditional energy sources to modern energy sources.
- To streamline and remove bottlenecks encountered in the development and use of energy resources and to prioritize the development of indigenous energy resources to attain self-sufficiency.
- To set general guidelines and strategies for the development and supply of energy resources;
- To increase energy use efficiency and reduce energy wastage; and,
- To ensure that the development and use of energy are benign to the environment

These kinds of policy initiatives were started and have been developed in most Sub-Sahara African nations and/or the whole of Africa. To promote and realize the country’s Green Development Strategy, ongoing initiatives to generate electricity from hydropower and the development of other RESs like biofuels, solar and wind will remain the strategic direction, as described in the energy policy documents. In addition, new technological innovations will be utilized to ensure that the energy sector does not emit additional carbon dioxide. To promote and sustain rural alternative energy development activities, the policy says efforts will be made to enhance the capacity and knowledge of regions, producers and consumers in this regard. The distribution of fuel wood-saving materials and technologies throughout the country will be continued. The GoE has also initiated the Climate Resilient Green Economy (CRGE) initiative to protect the country against the adverse effects of climate change and to build a green economy that will help realize its ambition of reaching middle-income status. In general, 4 initiatives for fast-track implementation have been selected under the CRGE:

1. Exploiting Ethiopia’s vast hydropower potential;
2. Large-scale promotion of advanced rural cooking technologies;
3. Efficiency improvements to the livestock value chain; and
4. Reducing Emissions from Deforestation and forest Degradation (REDD).

Table 7
 Actions (What, who, how, when? How different actions are interrelated?) required for roadmap, 2025–2029 [30–33].

Action	What	Who	How	When	Interrelations
Resource analyses, Planning and Feasibility Study	Use the detailed assessment already conducted for Tulefa's renewable energy potential and current energy consumption patterns and project future energy demands to design an optimized energy system tailored to the village's specific needs. Conduct technical, economic, and environmental evaluations	Academic institutions, energy consultants, environmental agencies, and local authorities	Using different tools, analyze data to design effective, renewable energy systems	Jan–Jun 2025	Results inform system design, infrastructure planning, and funding proposals
Infrastructure Planning and Design	Develop blueprints for energy systems (solar, wind, and biogas). Identify land and secure permits	Engineering firms, local government, regulatory authorities, and technology providers	Combine resource assessment data with stakeholder consultations. Finalize designs and obtain necessary permissions	Jul 2025–Mar 2026	Provides the foundation for procurement and construction activities
Securing Funding and Partnerships	Mobilize financial resources (grants, subsidies, and investments) and establish partnerships with suppliers and contractors.	Project management team, government agencies, NGOs, and private investors	Submit proposals, negotiate contracts, and secure agreements for equipment supply and technical support	Jan 2025–Dec 2026	Critical to initiating procurement and infrastructure development
Infrastructure Development and Installation	Install renewable energy systems (solar panels, wind turbines, and biogas digesters). Build smart grid and storage systems.	Contractors, equipment suppliers, local labor, and project engineers	Procure equipment, mobilize construction teams, and conduct phased installation with quality and safety checks	Apr 2026–Dec 2028	Dependent on infrastructure planning and funding. Sets the stage for testing and operations
Community Engagement and Capacity Building	Educate residents about renewable energy systems and train local technicians for maintenance and operations	NGOs, academic institutions, local government, and community leaders	Conduct workshops, training sessions, and awareness campaigns. Develop user manuals and establish energy committees.	Mid-2025–2029 (Ongoing)	Ensures community readiness, acceptance, and a trained workforce for long-term sustainability
System Testing and Optimization	Pilot installed systems, address technical issues, and optimize energy generation and distribution systems.	Project engineers, maintenance contractor, and local operators	Conduct trial runs, monitor system performance, collect feedback, and adjust systems as needed	Jan–Dec 2028	Ensures system reliability before full-scale deployment
Full-Scale Operation, Monitoring and Sustaining	Launch energy systems for all users in Tulefa. Establish long-term monitoring and evaluation frameworks	Project operators, local maintenance teams, and government agencies	Use smart grid technology for real-time monitoring. Schedule regular maintenance and collect data for periodic evaluation	Jan 2029 Onward	Culmination of all actions, achieving Tulefa's energy self-sufficiency vision

Table 8
Authorities and required permits for Kenya

	Authority	Roles	Required permits
1	The Energy and Petroleum Regulatory Authority (EPRA)	Technical and economic regulation of electricity, petroleum and renewable energy subsectors in Kenya	Project development and implementation
2	Kenya Bureau of Standards (KEBS)	Responsible for quality of products and services the consumers receive	Standardization of materials and equipment used in the project
3	The National Environment Management Authority of Kenya (NEMA)	Supervising and coordinating environmental activities and serving as the main national body to implement environmental policies in all sectors within the country	Environmental impact

These initiatives will have the best chances of promoting growth immediately capturing large GHG emission abatement potentials, strengthening Ethiopia's leading role in sustainable growth, and attracting climate finance for their implementation. To ensure a comprehensive program, initiatives from all other sectors will also be developed over time into concrete proposals. These policies and initiatives appear to be the fertile ground for the implementation of the LEAP-RE EV concept.

Shaping a country's RE future depends strongly on the governance and mechanism of the respective valid legal situation in terms of energy policies and regulations. In Botswana, energy-related legislation is administered by the Department of Energy (DoE) of the Ministry of Mineral Resources, Green Technology and Energy Security (MMGE) and the Botswana Energy Regulatory Authority (BERA). BERA, as a regulatory authority, handles all energy regulation matters in Botswana. Thus, BERA is responsible for providing an efficient energy regulatory framework for electricity, gas, coal, petroleum products, and all forms of RE including solar. It was established by the Botswana Energy Regulatory Act 2016 and started operation on the 1st of September, 2017.

Since 1985, Botswana's energy sector developments have been guided by the Botswana Energy Master Plan (BEMP), which was last reviewed in 2002. The BEMP was recently replaced by the National Energy Policy (NEP), which was approved by the Parliament of Botswana in 2021 showing Botswana's commitment to transform the energy sector from fossil sources to RESs. The NEP is founded on 3 guiding principles: (i) economic development, (ii) equity and (iii) environmental protection (Government of Botswana, 2020a). The NPD is closely aligned with the goals of the eleventh national development plan (NDP 11). The eleventh National Development Plan (NDP), for the period 2017–2023, flagged climate change as a challenge faced during NDP 10 and explicitly recognized the imperative of addressing climate change (Government of Botswana, (2017). Under the NDP's "Sustainable Use of Natural Resources" core priority area, the NDP highlighted the role that climate change mitigation and adaptation can play in creating employment and economic growth and emphasized the need to mainstream climate change into development planning. The NDP also called for gender-responsive adaptation and mitigation processes and smart agriculture. Moreover, the NPD is also closely aligned with Botswana's Vision 2036 (Vision 2036 Presidential Task Team, 2016). The transformational Vision 2036 gives the frame and defines the national objectives for Botswana's future development and includes a holistic sustainable energy perspective, being defined by the attribute's availability, accessibility, safety, affordability, reliability and environment-friendliness.

In August 2020, the first Integrated Resource Plan (Government of Botswana, 2020b) of Botswana was approved which provides the national framework for energy planning, that identifies priority renewable and thermal energy projects to meet growing energy demand. Moreover, in 2020, the government of Botswana launched the Rooftop Solar Programme [1–5], which allows domestic and commercial/industrial consumers to install solar systems to generate electricity for self-consumption and to feed the produced excess electricity to the grid, i.e., to sell the produced excess electricity to the Botswana Power Corporation (BPC).

As a further initiative, Botswana aims to reduce carbon emissions by 15% by 2030 compared to the base year 2010 (using 8307 Gg CO₂e as a baseline). For this reason, Botswana developed the UNDP National Climate Change Strategy and Action Plan in 2018 (UNDP, 2018). In a quite similar way, the Governments in Uganda and Kenya introduced different energy policies and initiatives to tackle climate change based on international agreements and yet to transform the traditional ways of energy use. The Government of the Republic of Kenya has long noted the significant potential for power generation from RESs in the country. The Government has, therefore, sought the expansion of RE generation in its overall power development plan for the period 2017–2037. The projection is that, by the year 2037, RESs will provide just over 60% of the installed power capacity in the country.

Kenya adopted the Energy Act No. 1 of 2019 (the Energy Act) to, among other objectives, promote the generation of RE in Kenya. The Energy Act mandates the Cabinet Secretary for the Ministry of Energy and Petroleum to develop, publish and review energy plans concerning RE to ensure the delivery of reliable energy services and to, at a minimum, cost and develop a conducive environment for the promotion of investments in energy infrastructure development. To promote energy investments, national and county governments are required to facilitate the acquisition of land for energy infrastructure development [6].

The Energy Act establishes the Energy and Petroleum Regulatory Authority (EPRA) to, among other functions: regulate the production, conversion, distribution, supply, marketing and use of RE; collect and maintain energy data; ensure, in collaboration with the Kenya Bureau of Standards, that only energy-efficient and cost-effective appliances and equipment are imported into the country; and coordinate the development and implementation of a national energy efficiency and conservation action plan. The powers of the Authority include the power to issue and renew licenses and permits for all undertakings and activities in the energy sector; manage electric power tariffs and tariff structures; to investigate tariff charges; formulate, set, enforce and review environmental, health, safety and quality standards for the energy sector; to approve electric power purchase and network service contracts for all persons engaging in electric power undertakings; investigate and determine complaints or disputes between parties over any matter relating to licenses and license conditions under the Energy Act; and to impose such sanctions and fines as may be appropriate for violation.

The Energy Act establishes a Tribunal to hear and determine civil disputes and appeals from the EPRA and any other licensing authority relating to the energy and petroleum sector. The Tribunal has powers to grant equitable reliefs including injunctions, penalties, damages, specific performance and the power to, on its motion or upon application by an aggrieved party, review its judgments and orders. The main purposes of the RERC are to spearhead the development of RE resources in Kenya and to accelerate the pace of rural electrification in the country. The RERC is mandated under the Energy Act to undertake feasibility studies and maintain data to avail the same to developers of RE resources and provide an enabling framework for the efficient and sustainable production, conversion, distribution, marketing and utilization of renewable sources in Kenya [6]. Kenya's renewable electricity

Table 9
Summary of actions taken to establish a smart energy community.

Action	What	Who	How	When	Interrelations
Feasibility assessment	Conduct a comprehensive feasibility study to evaluate the potential for renewable energy generation, storage, and smart grid integration within the community	Project research team	Analyze local energy demand, availability of renewable resources (solar, wind, geothermal), and existing infrastructure	Jan–Feb 2025	Define specific sustainability, energy efficiency, and self-sufficiency goals for the community
Stakeholder engagement	Establish a collaborative framework with key stakeholders	Local government, residents, utilities, developers, and energy providers	Organize stakeholder workshops or meetings to align on common goals and responsibilities	March–April 2025	Form public–private partnerships with renewable energy providers, technology vendors, and financing institutions
Obtain funding and investment	This aims to identify and secure funding sources to finance the infrastructure, technologies, and development of the smart energy community	Community to apply for government grants, green bonds, and subsidies for renewable energy projects	Seek investment from private investors or venture capital interested in sustainable infrastructure	May–July 2025	Explore energy-as-a-service models or other innovative financing options to make the project financially viable
Design the smart energy infrastructure	Design a comprehensive energy system that incorporates renewable energy, energy storage, and smart grid technologies	Project team plan the integration of renewable energy sources (solar, wind, etc.) based on local resources and needs	Design energy storage solutions (e.g., batteries, hydrogen storage) to store excess renewable energy for use during peak demand or cloudy days	August–October 2025	Develop the smart grid architecture, ensuring real-time monitoring, demand response, and efficient energy distribution
Implement smart grid and energy management systems	This is intended to deploy the smart grid infrastructure and energy management systems that enable real-time monitoring, data collection, and optimization of energy consumption	Project team install smart meters and sensors across the community to track energy production and consumption	Implement demand response systems that incentivize residents to adjust their energy usage during peak hours, reducing overall demand	November–December 2025	Integrate local energy trading systems to enable residents to buy and sell excess energy within the community
Promote Community Engagement and Education	This aims to foster active participation from residents by providing education, incentives, and platforms for involvement in the community's energy system	Community to launch educational programs to inform residents about the benefits of energy efficiency, renewable energy, and how they can contribute to the community's goals	Create platforms or apps for residents to monitor their energy usage and track their contributions to the community's overall sustainability goals	January–March 2026	Organize workshops, webinars, or community events to raise awareness and gather feedback from residents
Ensure Long-Term Maintenance and Sustainability	Establish a governance and management structure to ensure the ongoing operation and sustainability of the smart energy community	Community to create an energy cooperative or management body to oversee operations, maintenance, and upgrades	Regularly update and maintain the smart grid and energy systems to incorporate new technologies and improve performance	April–July 2026	Ensure long-term financial sustainability by continually optimizing energy consumption, reducing costs, and securing ongoing investment

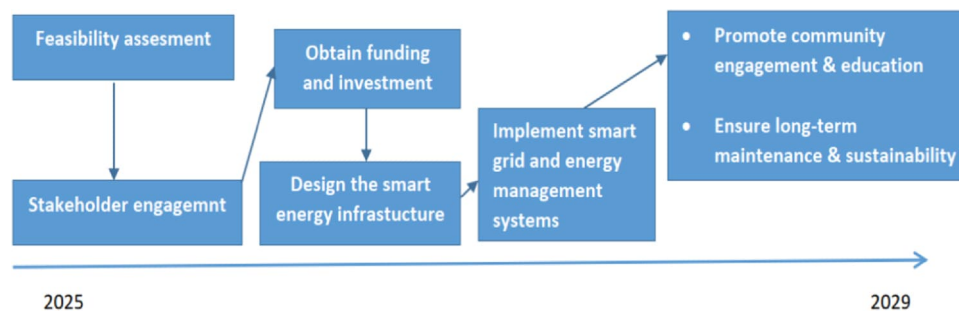


Fig. 5. Implementation roadmap, 2025–2029 for Kenya.

grid is at 90 per cent. According to the African Development Bank, Africa's annual energy financing gap as of May 2022 is \$24.5 billion (Sh2.96 trillion). The Electricity Sector Association of Kenya (ESAK) has unveiled key measures to enable Kenya to achieve 100 per cent RE by 2030. This is even as it reaffirms its commitment to the global climate agenda. Recent Energy statistics report by the Energy and Petroleum Regulatory Authority (EPRA) shows that Kenya has promising potential for power generation from RESs. Following a least-cost approach, the government has prioritized the development of geothermal and wind energy plants as well as solar-fed mini-grids for rural electrification.

5. Conclusions

The aim of this article was to develop an EV Roadmap for 2025–2029 for 4 countries that can be an example for the rest of Africa: Ethiopia, Kenya, Uganda and Botswana. Energy consumption in Africa is predominantly based on biomass energy resources, mainly fuel wood, charcoal, branches, animal manure and agricultural residues. Besides these traditional energy resources, a small amount of energy from modern sources, namely petroleum and electricity, top up the balance. Those have to be replaced by RE resources. To answer these questions: 1) What is the future road map for EVs in Ethiopia, Kenya, Uganda and Botswana Roadmap of 2025–2029 for EV? EV Roadmaps were developed for Uganda, Ethiopia, Kenya and Botswana. 2) What are the future policy recommendations for African nations combining knowledge from LEAP-RE project? Several policy recommendations were identified and presented. Some of them are: Exploiting vast hydropower potentials; Large-scale promotion of advanced rural cooking technologies; Efficiency improvements to the livestock value chain; and Reducing Emissions from Deforestation and forest Degradation (REDD).

The method used in this article is the project experience of LEAP-RE: WP14 and literature review by scientific analysis for mapping policies and giving policy recommendations as well developing Roadmap 2025–2029. The novelty of this research is that the EVs identified in Africa are unique and differ from EU EVs. The significance and contributions are the identification EVs in Africa; contacting them; analyzing and calculating the energy potential and consumption and mapping out the Roadmap 2025–2029 for EU projects as well as giving examples to developing nations and recommending policies. The main conclusion is that EVs can supply more than 100% of their own energy needs using local RE to overcome the energy shortage. Practical implications for society is that giving a long-term Road map for EV projects and identifying and recommending policies for African nations. A limitation of this article is that the given roadmaps are specific to each country and cannot be generalized even in African counties because of the fact that each nations or EV are unique.

CRedit authorship contribution statement

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Mario; Maphane, Phalaneng; Cleophas, Achisa; Kiprop, Ambrose; Kasedde, Hillary; Kirabira, John Baptist.; and Kumakech, Kasim – All contributed in editing; gathering data; writing; compiling and reviewing the paper.

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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