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Four advanced implementation plans, which describe expansion and replication possibilities

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Summary

The Energy Villages (EVs) were intended to create and establish sustainable energy communities with adequate energy from renewable resources, with economic impact in as well as to improved living standards, which is in fully alignment with the global goals for sustainable development (SDGs). Some partners chosen model Energy Village for implementation and replicability for example ? Uganda ? Bidi-Bidi refuge settlement and Ethiopia ? AASTU campus Energy Village. Some main objectives are ? 1) the identification of current and future source of energy; 2) engage and educate communities; 3) plan development and advancement implementation; 4) implement the required solutions; 5) integrate renewable energy (e.g. ? for EV sties); 6) success factors identification; and 7) advocate for supportive policy and regulations. The main implementation requirements are ? feasibility studies; financial acquisitions; co-design with communities; capacity building; installations; monitoring; evaluation & identification success factors; policy advocacy and support; and stainable EVs. Success criteria would be evaluated how EVs advanced the livelihood of the locals; cost savings; protecting the environment and local?s health; and job creation opportunities. Single and separate technical solutions suggested are ? for Bidi-Bidi refuge settlement in Uganda an off-grid system with a possibility for future grid synchronization; for Botswana Hybrid Renewable Energy Conversion Approach (HyRECA) the most promising sustainable solution; for AASTU Campus in Ethiopia microgrid stand-alone systems; and for Cheboiwo village renewable sources such as biogas and solar PV technologies in Kenya. Roadmaps can start by assessment of the community's energy needs and resources; followed by engagement with residents and stakeholders to gather input and build support; technology selection, planning and implementation for example such technologies ? wind; solar technologies; bioenergy technologies and advanced system reliance technologies. In addition, EV concept can be replicated at the universities and scaled up to large firms based on the availability of renewable energy resources at the sites. Expansion possibilities can be the installed and scaling up the size; advancing the renewable energy technologies ? such as improved efficiency and cost-effectiveness; offer opportunities for upgrading existing infrastructure and integrating new innovations. Expansion possibilities for RE ...

Approval

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LEAP-RE

Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

Research & Innovation Action

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Four advanced implementation plans, which describe expansion and replication possibilities

as a deliverable for WP14

Version Final

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Abbreviations and Acronyms

Acronym	Description
AASTU	Addis Ababa Science and Technology University
AMI	Advanced metering infrastructure
BIUST	Botswana International University of Science and Technology
DMS	Distribution management systems
EV	Energy Village
LED	Light-Emitting Diode
MaK	Makerere University
MU	Moi University
PV	Photovoltaic/Solar Technology
SCADA	Supervisory Control and Data Acquisition
UVA	University of Vaasa
WECS	Wind Energy Conversion System
WP	Work Package

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Summary

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Single and separate technical solutions suggested are – for Bidi-Bidi refuge settlement in Uganda an off-grid system with a possibility for future grid synchronization; for Botswana Hybrid Renewable Energy Conversion Approach (HyRECA) the most promising sustainable solution; for AASTU Campus in Ethiopia microgrid stand-alone systems; and for Cheboiwo village renewable sources such as biogas and solar PV technologies in Kenya. Roadmaps can start by assessment of the community's energy needs and resources; followed by engagement with residents and stakeholders to gather input and build support; technology selection, planning and implementation for example such technologies – wind; solar technologies; bioenergy technologies and advanced system reliance technologies. In addition, EV concept can be replicated at the universities and scaled up to large firms based on the availability of renewable energy resources at the sites. Expansion possibilities can be the installed and scaling up the size; advancing the renewable energy technologies – such as improved efficiency and cost-effectiveness; offer opportunities for upgrading existing infrastructure and integrating new innovations. Expansion possibilities for RE technologies will require sufficient community education and sensitization about the Energy Village concept; access to reliable meteorological and energy use data for planning purposes; access to adequate funding for capital and operating costs and appropriate business modes; as well as close monitoring and evaluation.

Keywords: Renewable energy; Energy Village; Single-separate solutions; Replicability; Expansion possibilities; Sustainability

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1. Introduction

Energy Village (EV) concept has been seen as a facilitator for change in the strive to attain energy self-sufficiency of villages including the rural settings. Several models of these villages have been developed across different countries in African including Uganda, Kenya, Botswana and Ethiopia as listed in the Table 1.The common criteria followed in the design of these villages was collection of reliable data to ascertain energy profiles for the villages and matching them with actual and projected supplies.

Table 1. List of Energy Villages chosen in Africa.

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

Success of these selected EVs is dependent on several factors including adoption of the right implementation plan. From the documented approach, the implementation stages across all the villages remain closely related because the target result for the village was the same only with some variations in energy potential in different villages. The advanced implementation plans mentioned included system design and feasibility studies of the EVs, adoption of the right technology and installed system performance evaluation criteria. The villages' possibility of expansion involve analysis of the ease of technology transfer in case of increase in demand. Similarly, replication possibilities for the villages were discussed.

2. Implementation plans across demo villages

2.1. Uganda

The implementation plan for Uganda EV focussed on the following areas:

- Goals and objectives of the EV
- Tasks, due dates and time lines for the implementation of activities

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- Tools and technology requirements
- Success criteria

Uganda has five demo EVs namely Nakasengere, Wanale, Refugee camp, Maziba Murole and Kayanzi Energy Village. The model village chosen for this implementation plan is the Refugee camp EV with replication possibilities.

1. The main goal of this project is energy self-sufficiency of the rural areas across Africa, in this context, specifically Refugee settlement. The first stage is the critical analysis and derivation of procedures on how this goal and objective will be achieved. Under this, the team leader and community engagement focal people for the different tasks leading to attainment/achievement of the goals will be laid down. This will range from the resource mobilization team to the implementation team for the project.

2. Tasks and milestones for the implementation activities. Table 2 shows the breakdown of milestones for the Refugee Camp EV.

Table 2. Milestone and implementation precedence.

S/N	Task/Milestone	Implementation precedence (Period)						
		First	Second	Third	Fourth	Fifth	sixth	Seventh
1	System design							
2	Financing and funding							
3	Training and capacity development							
4	Community sensitization							
5	Equipment acquisition							
6	Supply, installations and operation							
7	Evaluation and success criteria							

3. Tools and technology requirement

Tools and technology requirement for the implementation of the project will involve the following:

- Selection and sizing of the energy system technologies for the Refugee Camp EV. This will focus on capacity of the systems that will be installed in the settlement.

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- Cost estimates for the technology. After the choice of the systems, cost associated with the acquisition and installation shall be laid down. This will form the budgeting aspect of the plan.

- Acquisition and installation. After the cost estimates, the plans for the acquisition and installation will be laid and will guide the next installation proceedings.

- Evaluation of performance – the system performance will be evaluated after installation and energy supply to the camp. This will help determine feasibility of the process.

4. Success criteria – the success criteria of the system will be evaluated based on how the system has improved the livelihood of people in the zone. This will be done after a given period of time to evaluate success.

2.2. Botswana

2.2.1. Goals and objectives

In Botswana, we have selected four Energy Village namely Regent Hill School EV, Jamataka EV, Majwannaadipitse EV, and Matsaudi EV. The EVs were chosen in view of replication potential to other villages in Botswana. The overall goal is to establish sustainable energy communities based on renewable energy sources, solutions, and productive applications leading to both an economic impact in as well as to improved living standards in Botswana, which is in fully alignment with the global goals for sustainable development (SDGs). In the course of this, a subsequent goal is to promote the green energy transition in Africa based on the EV concept.

The main objectives in Botswana are the analysis of current energy sources together with the evaluation of potential renewable energy sources and how to integrate renewable energy solutions. The formation of a distributed energy service company (DESCO) in Energy Villages is one aspect for a successful integration of renewable energy solutions. This includes also capacity building in energy communities and the development of financial instruments, the refinement of existing renewable energy policies and regulations. Energy Villages should also help relevant players (investors, donors, and policy makers) to improve strategic decision making.

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2.2.2. Implementation activities for EVs

The implementation plan for Energy Villages in Botswana is based on the main activities summarized in Table 3:

Table 3. Phases, activities and measures for the implementation of Energy Villages.

Phase	Activities	Measures/Tasks
1	Community Engagement and Feasibility studies	Needs Analysis, Community and Stakeholder meetings, Workshops to raise awareness of successful renewable energy projects/solutions/systems
2	Training and capacity building	Workshops, Seminars, BQA accredited short courses
3	Design of sustainable renewable energy solutions (RES)	Develop and deploy smart renewable energy systems based on innovative concepts (hybrid RES, smart control, storage implementation)
4	Foundation of distributed energy service company (DESCO)	Establish an owning entity of installed renewable energy equipment, operation of renewable energy infrastructure, Maintenance of renewable energy infrastructure
5	Financing plan	Funding through Loan and Insurance products or investors for RES
6	Installation and Maintenance of renewable energy infrastructure	Local DESCO is trained RES operation and maintenance (O&M)
7	Monitoring and evaluation	Evaluation of progress and success

2.3. Ethiopia

2.3.1. Goals and objectives

In Ethiopia, four prospect Energy Villages have been selected namely AASTU EV, Tulefa EV, Wonji EV and Langano EV based on variety of renewable resources. AASTU Energy Village can more or less be a representative Energy Village for the others. The goal of establishing and implementing an Energy Village is to create a sustainable community that meets its energy needs through renewable sources, fosters local energy independence, reduces environmental impact, and promotes economic development.

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Moreover, objectives include integrating renewable energy infrastructure, enhancing energy efficiency, engaging and educating the community, promoting local energy production, implementing energy storage solutions, integrating smart grid technologies, stimulating economic growth, fostering environmental sustainability, enhancing energy resilience and security, and advocating for supportive policies and regulations. Through these efforts, an Energy Village can contribute to building a more sustainable, resilient, and self-sufficient community while serving as a model for broader renewable energy adoption. The Table 4 presents activities, milestone and implementation of Energy Village in Ethiopia.

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2.3.2. Tasks and milestones for the implementation activities

Table 4. Activities, milestones and implementation of Energy Village.

S/N	Activities	Tasks	Milestone	Precedence				
				1st	2nd	3rd	4th	5th
1	Feasibility Study and Planning	Conduct a feasibility study to assess the viability of establishing an Energy Village in the community	Completion of renewable energy infrastructure installation, with energy production commencing					
2	Community Engagement and Education	Organize community meetings and workshops to raise awareness and gather input on the Energy Village project						
3	Renewable Energy Infrastructure Installation	Procure and install renewable energy generation systems such as solar panels, wind turbines generators and biogas generator						
4	Energy Efficiency Measures	Implement energy efficiency measures in buildings, transportation, and appliances						
5	Smart Grid Development	Develop and deploy a smart grid infrastructure for efficient energy distribution and management	Operation of energy storage systems, ensuring reliable energy supply during peak demand periods					
6	Community-Owned Energy Projects	Facilitate the establishment of community-owned renewable energy projects to promote local energy production						
7	Energy Storage Implementation	Deploy energy storage solutions such as batteries or pumped hydro storage to store excess energy						
8	Policy Advocacy and Support	Advocate for supportive policies and regulations at the local, regional, and national levels to incentivize renewable energy adoption	Sustainable and clean energy supply					
9	Monitoring and Evaluation	Establish monitoring systems to track energy production, consumption, and environmental impact						
10	Sustainability	Sustain the Energy Village to remain an energy efficient and sufficient village						

2.3.3. Tools and technology requirement

Implementing an Energy Village requires a combination of tools and technologies to effectively harness renewable energy sources, optimize energy distribution, and promote energy efficiency. Here's a list of possible tools and technologies needed:

1) **Renewable Energy Generation Systems**
   - Solar panels for solar energy generation
   - Wind turbines for wind energy generation
   - Hydroelectric generators for hydro energy generation
   - Biomass systems for biomass energy generation
2) **Energy Storage Solutions**
   - Battery storage systems (e.g., lithium-ion batteries) for storing excess energy
   - Pumped hydro storage for large-scale energy storage
   - Thermal energy storage systems for storing heat energy
3) **Smart Grid Technologies**
   - Advanced metering infrastructure (AMI) for real-time monitoring of energy consumption
   - Distribution management systems (DMS) for optimizing energy distribution
   - Demand response systems for managing peak demand periods
   - Grid automation technologies for improving grid reliability and efficiency
4) **Energy Efficiency Technologies**
   - LED lighting systems for energy-efficient lighting
   - Energy-efficient appliances and equipment
   - Building insulation and sealing materials for improving thermal efficiency
   - Smart thermostats for optimizing heating and cooling systems
5) **Community Engagement Platforms**
   - Online platforms and mobile apps for community engagement and education on energy conservation and renewable energy technologies

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6) Monitoring and Control Systems

- SCADA (Supervisory Control and Data Acquisition) systems for monitoring and controlling energy infrastructure
- Remote monitoring systems for renewable energy assets

7) Financial and Economic Analysis Tools

- Financial modelling software for assessing the financial viability of energy projects
- Economic impact assessment tools for evaluating the economic benefits of renewable energy investments

2.3.4. Success criteria

The success of establishing an Energy Village can be evaluated through various criteria including achieving energy independence by reducing reliance on external sources through renewable energy adoption, increasing the penetration of renewable energy within the village's energy mix, decreasing carbon emissions, realizing cost savings for residents and businesses, fostering high levels of community engagement and participation, generating job opportunities and economic development, delivering environmental benefits, ensuring resilience and reliability of energy infrastructure, securing policy and regulatory support, and demonstrating replicability and scalability of the Energy Village model. By assessing these criteria, stakeholders can gauge the overall effectiveness and impact of the Energy Village in promoting sustainability, resilience, and local empowerment.

2.4. Kenya

The implementation plan for Kenya's Energy Villages focussed on the following aspects:

2.4.1. Goals and objectives of the EV

Kenya had the following Energy Villages – Cheboiwo, Langas, Kerio Valley, Nandi Hills, and Lelan. The EVs were intended to create sustainable communities with adequate energy from renewable sources, with minimal environmental impact, and high economic impact. The objectives include identification of current sources of energy; determination of potential renewable energy sources within a community; development of implementation plans for the adoption of renewable energy sources; and advocating for supportive policies and regulations.

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2.4.2. Implementation matrix and required infrastructure

Typical EV projects will be implemented as shown in Table 5.

Table 5. EV project implementation matrix.

Phase	Task	Requirements
1	Feasibility studies	Needs assessment questionnaires
2	Co-design with communities	Meetings with communities and other stakeholders
3	Training and capacity development	Workshops, seminars
4	Installation and operation of renewable energy infrastructure	Solar panels, wind turbines Biogas reactors
5	Monitoring and evaluation	Evaluation of progress and success

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3. Single separate technical solution relevant to each village

3.1. Uganda

The model envisioned for Uganda is channelled towards the Refugee Camp Energy Village. This village was modelled to operate on an off-grid system with a possibility for future grid synchronization. This is because, often times the asylum seekers are settled in remote areas and with growth and development, they eventually get grid connection.

The village was modelled to be supplied by power from three primary renewable sources of solar, bioenergy and wind power. In this case, the main player in the energy mix is solar with battery backup system. The biogas generator comes in as a backup source especially during off peak solar periods. This source is brought in to play to meet the excess demand after the battery is drain.

Therefore, the technical solution in this case to meet the energy demand for the village involved use of solar photovoltaic system optimized to meet the energy demand for the village. The capacity and rating of the chosen monocrystalline solar system depended on the rating of the individuals' modules and the number of panels installed.

The bioenergy source involved incorporation of biogas generator to the total energy mix. Biomethane generated using anaerobic digestion was purified and eventually used to run a stand by biogas generator of a given rated capacity and gas consumption. This provided for reliability and autonomy of the designed system and assured operation at all times.

Due to low wind potential for the village, the configured Wind Energy Conversion System (WECS) was literally modelled to meet part of the village's water energy demand. The wind speed was feasible for water pumping.

3.2. Botswana

In Jamataka EV, a Hybrid Renewable Energy Conversion Approach (HyRECA) is the most promising sustainable solution for rural energy supply and employment creation. It innovates small-scale hybrid renewable energy systems (Hy-RE-SyS) as rural village solutions are based

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on agriculture-integrated photovoltaics (PV-minigrid) combined with gasifying biomass technologies processing residues, such as invasive encroacher bush and waste, for a reliable energy supply in rural Energy Village. By combining solar PV systems and biomass, a reliable and secure energy supply can be guaranteed in every hour of the year. The collection and energetic use of ecosystem-threatening biomass creates local value chains with a strong participation of female villagers and contributes to climate adaption and ecosystem preservation. The HyRECA social innovation is completed by developing an already founded distributed energy services company (DESCO) into a cooperative utility organisation. The project provides also a digital insights hub delivering up-to-date information on biomass availability as well as regional energy system infrastructure and demands.

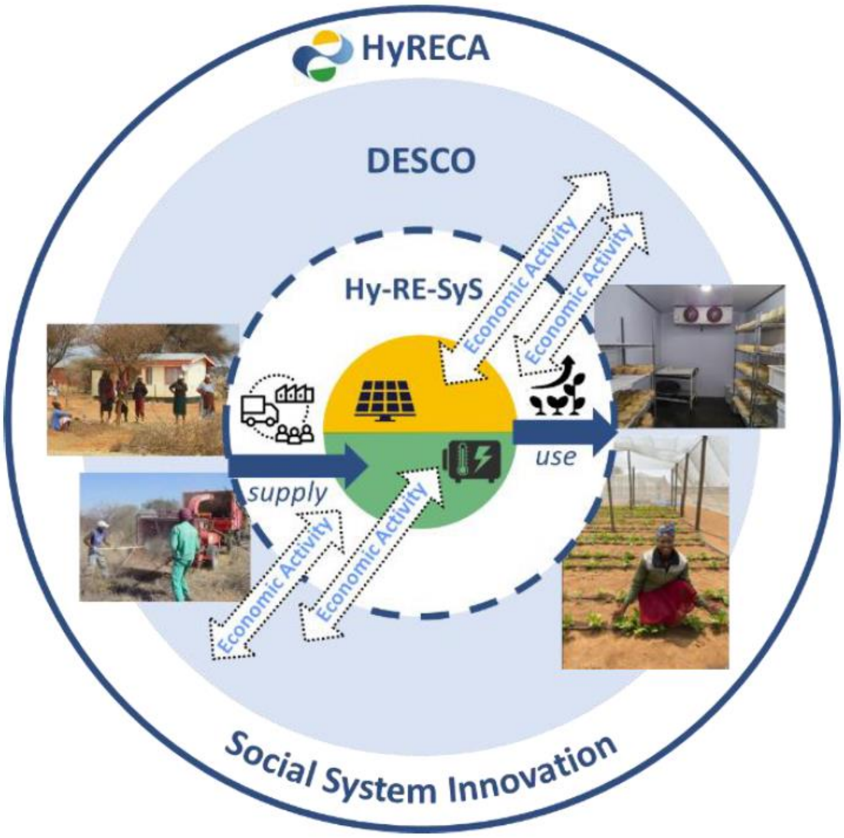

Figure 1. HyRECA social system innovation concept.

In Figure 1, Hy-RE-SyS are deeply integrated in communal water-energy-food systems and serve as social innovation hubs for involving citizens in income-generating activities – creating a social system innovation. They require adjacent upstream value chains for biomass supply including harvesting, logistics, and preparation activities and enable downstream agricultural,

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artisanal, or industrial value chain activities that utilise the energy services offered. The emerging income perspective strengthens the community's purchasing power, making energy access affordable and enhancing living standards. Hy-RE-SyS operations and maintenance (O&M), energy services as well as the adjacent up – and downstream value chains are shaped, owned and organised by community led cooperatives taking the legal form of distributed energy services companies.

In conclusion, the implementation of HyRECA in Jamataka Energy Village contributes to a reliable and secure energy supply, generates a circular bio-economy, opens new economic perspectives, provides safe and healthy jobs, restores, and preserves native ecosystems, and aids climate adaptation and mitigation in the transboundary region.

3.3. Ethiopia

For AASTU Energy Village, it seems that microgrid stand-alone systems can be a solution. A microgrid is essentially a localized electricity grid that can operate autonomously or in conjunction with the main utility grid. In the context of an Energy Village, it serves as a flexible and resilient energy management solution that integrates various renewable energy sources and energy storage technologies. For instance, solar panels installed on rooftops, wind turbines in open spaces, and small-scale hydroelectric generators can all contribute to the generation of electricity within the village. These renewable energy sources are complemented by energy storage systems, such as batteries or pumped hydro storage, which store excess energy generated during periods of high production for use during times of low production or high demand.

One of the key advantages of a microgrid system for an Energy Village is its ability to operate independently from the central grid or "islanded mode" during emergencies or grid disruptions. This ensures continuous electricity supply to critical facilities like hospitals, emergency services, and community centres, enhancing the village's resilience to power outages caused by extreme weather events or other disruptions. Furthermore, by optimizing energy distribution and managing demand locally, a microgrid can help reduce transmission losses and alleviate strain on the broader utility grid, leading to increased energy efficiency and reliability.

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Moreover, microgrid systems offer opportunities for peer-to-peer energy trading and community engagement within the Energy Village. Residents and businesses can participate in energy-sharing programs, where surplus energy from one household or building with renewable energy generation capacity can be sold or exchanged with others in the community. This not only promotes energy self-sufficiency and cost savings but also fosters a sense of collective ownership and collaboration among community members.

In summary, the implementation of a microgrid system in an Energy Village provides a holistic solution for integrating renewable energy sources, managing energy storage, enhancing resilience, and promoting community engagement. It empowers the village to become more self-reliant, sustainable, and resilient in its energy supply while fostering a sense of community and collaboration among residents.

3.4. Kenya

In Cheboiwo village, 100% of the respondents showed strong interests in renewable sources such as biogas and solar PV technologies. The community is ready and willing to embrace the use of these renewable energy sources. The village is in an agricultural region with abundant biomass for biogas generation. Also, the region receives adequate solar radiation, coupled with available space for installation of solar panels. The adoption and success of the Energy Village concept at Cheboiwo village is expected to inspire similar ventures in other areas in Uasin Gishu county and across the country.

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4. Roadmap towards a more comprehensive system solution, consisting of separate technologies

4.1. Uganda

To come up with a very comprehensive roadmap for an Energy Village solution, several factors have to be put into consideration. These include among others sustainability and resilience of the system, possibility of technology transfer and consideration of the key milestones in the roadmap.

For the Refugee Camp Energy Village, system resilience and sustainability involved analysing the possibility and ease of adoption of the solution in the village. For optimal system operation, right operation and maintenance factors were put into consideration to ensure resilience in supply of energy for the zone.

Attainment of the right technical solution for supply of required energy to meet the demand in the village will take an approach of sizing the right solution for the energy conversion systems. This will be done while taking into factors such as the cost of the solution, the overall generation efficiency, required labour for operationalization among others. Acquisition roadmap then follows through.

Derivation of the key milestones – the milestones in the roadmap for system solution for the Refugee Camp Energy Village include:

- System sizing and modelling based on real time data
- Community sensitization
- System installation and commissioning
- Evaluation of system performance
- Moreover, replication of the solution to other villages

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The technologies involved in the roadmap are the wind energy conversion technologies, solar system technologies, bioenergy power generation technologies and advanced system reliance technologies.

4.2. Botswana

Developing a roadmap towards a more comprehensive system solution for an Energy Village to be self-sustainable is quite challenging. First of all, it requires the integrating of various separate technologies, such as single photovoltaic installations, hybrid renewable energy solutions etc., in rural areas into a cohesive framework that could lead to 100 percent self-sustainability. A kay factor is the building of transmission lines between energy production hubs, single renewable energy solutions and the households and production areas in a rural Energy Village. This roadmap should also incorporate the implementation of smart control technologies to optimize energy distribution and manage demand. Furthermore, community engagement and education initiatives are absolutely necessary to introduce energy saving and resource-saving 24/7 energy consumption strategies for villagers. Otherwise, a resilient and self-sufficient energy system remains an unattainable goal in an Energy Village approach.

4.3. Ethiopia

Developing a roadmap towards a more comprehensive system solution for an Energy Village involves integrating various separate technologies into a cohesive framework that maximizes energy efficiency, resilience, and sustainability. This roadmap begins with a thorough assessment of the energy needs and resources of the community, identifying suitable renewable energy sources such as solar, wind, and hydro, along with potential sites for installation. Additionally, the roadmap incorporates the implementation of smart grid technologies to optimize energy distribution, manage demand, and enable grid integration. Furthermore, energy efficiency measures such as building insulation, LED lighting, and energy-efficient appliances are integrated to minimize energy wastage and reduce overall consumption. Community engagement and education initiatives are also vital components, fostering awareness, participation, and collaboration among residents. As the roadmap progresses, ongoing monitoring, evaluation, and adjustment ensure that the Energy Village evolves to meet the changing needs and technological advancements, ultimately achieving a

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sustainable, resilient, and self-sufficient energy system tailored to the specific characteristics of the community.

Realizing the roadmap towards a more comprehensive system solution for an Energy Village involves several key steps. It begins with a thorough assessment of the community's energy needs and resources, followed by engagement with residents and stakeholders to gather input and build support. Technology selection and planning entail evaluating renewable energy sources, energy storage options, and smart grid technologies, culminating in the development of a detailed implementation plan. Infrastructure deployment includes installing renewable energy generation systems, deploying energy storage solutions, and implementing smart grid technologies for efficient energy distribution. Energy efficiency measures are integrated, along with community engagement and education initiatives to raise awareness and encourage participation. Monitoring and evaluation systems are established to track performance and gather feedback for adaptation and optimization, ensuring continual improvement and alignment with community goals and needs. Through these steps, the Energy Village can successfully achieve its objectives of sustainability, resilience, and energy independence, benefiting both the community and the environment

4.4. Kenya

The establishment of Cheboiwo Energy Village can be a model for different regions across the country. In quite similar fashion, all, if not, most rural areas in Kenya use firewood for cooking. The renewable energy resources in most rural areas in the country are like those in Cheboiywo village. As a result, the proposed application of biogas and solar based technologies can be adopted in various areas. The Energy Village concept, consequently, can be replicated at the universities and scaled up to large firms based on the availability of renewable energy resources at the sites. The Energy Village concept and the proposed solution can be customized to fit the energy demand of a given village. This can similarly be replicated in schools, hospitals, refugee camps, and other social settings.

To achieve this, there is need for wider stakeholder engagement including local and national leadership, provision of adequate funding for the rolling out the RE technologies and training of communities.

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5. Expansion possibilities for the technologies

5.1. Uganda

Expansion possibilities for technologies used for energy supply in several Energy Villages is immense. In the context of the Refugee Camp EV, the proposed technologies which include solar systems, WECS and bioenergy sources have great expansion possibilities. These can be looked at from the following dimensions.

5.1.1 Solar system

Solar system comprises of the solar panels, charge controllers, inverter among others. These components are used hand in hand to ensure smooth supply of solar power to meet a given demand. This system is much responsive to any change in demand. Expansion can be achieved by increasing the capacities of the components through acquiring and adding new components to the existing ones. This is very important in refuge setup where village size explosion is always unpredictable.

5.1.2 Bioenergy system

Bioenergy source in this case focused on anaerobic generation of biogas from biodegradable organic matter. The generated biogas is used as fuel for electricity generation using biogas generators. Therefore, the expansion possibility of this technology involves:

- Scaling up the size of the biogas digester. This is depended upon the available biodegradable compounds. In case where there is size explosion in the village, the increase in waste is guaranteed and hence possibility of scaling up the size of the digester.

- Scaling up the generation capacity of the generator. More biogas generator can be produced in the energy mix depending on the prevailing condition.

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5.2. Botswana

Expansion possibilities for renewable energy technologies in Botswana have high economic and social potential. Innovative and modern technologies, such as green hydrogen-based solutions, are of great importance for Botswana and the neighbour countries. However, this requires first of all the engagement of Botswana's stakeholders, the refining of policies and energy regulations and funding opportunities to establish scalable Technology readiness level 7 Hy-RE-Sys prototype demonstration including green hydrogen. In addition, Botswana and the whole Sub-Sharan region need to create a Hydrogen atlas that capture the data on the potential and existence of hydrogen and Power-to-X in Botswana and how to the ramp-up of the hydrogen economy publicly available.

5.3. Ethiopia

Expansion possibilities for the technologies of the Energy Village concept are vast and hold significant potential for further enhancing sustainability, resilience, and energy independence. One avenue for expansion involves scaling up renewable energy generation capacity within the village. This could entail adding more solar panels, wind turbines, or hydroelectric generators to harness additional energy resources and meet growing demand. Moreover, advancements in renewable energy technologies, such as improved efficiency and cost-effectiveness, offer opportunities for upgrading existing infrastructure and integrating new innovations.

Additionally, expanding energy storage capabilities enables the village to store surplus energy for longer durations and enhance resilience against fluctuating energy supply. Integrating emerging technologies like advanced battery storage systems or innovative energy storage solutions further strengthens the village's ability to manage energy resources efficiently. Furthermore, expanding the smart grid infrastructure facilitates greater integration of renewable energy sources, enhances grid stability, and enables more sophisticated demand-side management strategies. Moreover, leveraging digitalization and data analytics can optimize energy distribution, predict energy demand patterns, and improve overall system efficiency. Furthermore, exploring collaborative initiatives with neighbouring communities or forming energy cooperatives can facilitate shared resources, economies of scale, and collective action towards a more sustainable energy future. Overall, the expansion possibilities

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for Energy Village technologies are diverse and promising, offering avenues for continuous innovation and advancement towards a more resilient and sustainable energy system.

The Energy Village concept can be replicated and implemented in other sites or villages with similar characteristics and needs. Replicating the concept involves adapting the successful model and methodologies developed in one village to other locations, while considering local context and resources. Key steps for replicating the Energy Village concept include conducting assessments to identify suitable candidate sites, engaging with local communities and stakeholders to build support and gather input, customizing the concept to fit the unique characteristics of each site, deploying infrastructure and implementing renewable energy solutions, monitoring and evaluating project performance, and advocating for supportive policies and regulations to facilitate replication and scaling up. By replicating the Energy Village concept in multiple sites, the benefits of renewable energy adoption, energy independence, and community empowerment can be extended to a broader range of communities, contributing to sustainable development on a larger scale.

5.4. Kenya

Expansion possibilities for RE technologies in Kenya are numerous and will require sufficient community education and sensitization about the Energy Village concept; access to reliable meteorological and energy use data for planning purposes; access to adequate funding for capital and operating costs and appropriate business modes; as well as close monitoring and evaluation systems. With these in place, the EV concept can be replicated in different parts of the country.

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6. Way forward

The identified and suggested single and separate technical solutions can be used only after identifying the local challenges and needs, the suggested systems if needed can be replicated and trimmed to locals need then implementation would happen with the support of future projects, financial resources and investors. These will be required a capacity building; training; education support from EU and other nations with the support of locals in order to make sure the sustainability of current and future projects. One important issue is that the main concept of Energy Village meaning making forward 100% RE in locals can be only specific to every Energy Village. The available resources and consumptions are different in each local villages and regions. The overall goal is to achieve and help the sustainability of the planet, which is truly possible. Now on what is left is to replicate this concept across the world.

7. Conclusions

The Energy Villages (EVs) were intended to create and establish sustainable energy communities with adequate energy from renewable resources, with an adequate economic impact in as well as to improved living standards, which is in fully alignment with the global goals for sustainable development (SDGs). This is possible and achievable through the Energy Village concept. Key steps for replicating the Energy Village concept include conducting assessments to identify suitable candidate sites, engaging with local communities and stakeholders to build support and gather input, customizing the concept to fit the unique characteristics of each site, deploying infrastructure and implementing renewable energy solutions, monitoring and evaluating project performance, and advocating for supportive policies and regulations to facilitate replication and scaling up.

Single and separate technical solutions suggested are – for Bidi-Bidi refugee settlement in Uganda is an off-grid system with a possibility for future grid synchronization; for Botswana Hybrid Renewable Energy Conversion Approach (HyRECA) is the most promising sustainable solution; for AASTU Campus in Ethiopia is that microgrid stand-alone systems; and for Cheboiwo village is renewable sources such as biogas and solar PV technologies in Kenya. Roadmaps can be used for the assessment of the community's energy needs and resources; followed by an engagement with residents and stakeholders to gather input and build support;

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technology selection, planning and implementation for example such technologies – wind; solar technologies; bio-energy technologies and advanced system reliance technologies. In addition, EV concept can be replicated at the universities and scaled up to large firms based on the availability of renewable energy resources at the sites. Expansion possibilities can be the installed and scaling up the size; advancing the renewable energy technologies – such as improved efficiency and cost-effectiveness; offer opportunities for upgrading existing infrastructure and integrating new innovations. Expansion possibilities for RE technologies will require sufficient community education and sensitization about the Energy Village concept; access to reliable meteorological and energy use data for planning purposes; access to adequate funding for capital and operating costs and appropriate business modes; as well as close monitoring and evaluation.

The overall conclusion can be having a possibility to replicate in other Energy Villages across the whole world, to Africa and other nations. The suggested solutions have to be trimmed to specific local needs to improve the local situation. One can know only through locals' knowledge and experience of living about the local needs, culture, life, environment and available natural resources and solutions of the whole type of need.

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