SDG7: Tackling Energy Poverty through Renewable Energy Solutions

*The **Global Forum on Sustainable Energy (GFSE)** is a neutral multi-stakeholder platform that facilitates international dialogue on energy for sustainable development by taking into account the special interests and challenges of Low- and Middle-Income Countries (LMICs). GFSE aims to establish a sustainable world energy system from a social, economic, and environmental perspective.*

GFSE contributes to both international discourse and information dissemination on sustainable energy. The multi-stakeholder platform is crucial in facilitating sustainable energy projects by bringing together donors, investors, and project developers. Their interaction creates new opportunities and enhances existing initiatives in sustainable energy.

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Abstract

This Policy Brief outlines global actions to reduce energy poverty. Despite some progress, 675 million people remain without electricity, mostly in sub-Saharan Africa, which accounts for over 83% of the global energy deficit.

In Africa, Productive Uses of Renewable Energy (PURE), such as solar irrigation systems and solar-powered refrigeration, improve agricultural productivity and support local businesses. These renewable solutions create jobs, stimulate economic growth, and reduce reliance on inefficient energy sources, helping to alleviate energy poverty. However, expanding renewable energy infrastructure requires thoughtful land and water management to avoid encroaching on habitats, disrupting migration corridors, or straining local water resources. To be truly regenerative, energy solutions should be integrated into local ecosystems - enhancing biodiversity, restoring soils, and conserving water.

Table of Contents

Introduction

Sustainable Development Goal 7 (SDG7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all. It also calls for a significant growth in the share of renewable energy in the global energy mix and a doubling of the global rate of increase in energy efficiency. International cooperation should be strengthened to facilitate access to renewable energy, energy efficiency, and clean technology research and technology and to promote investment in clean energy. The expansion and modernization of infrastructure are also essential to provide modern and sustainable energy services for all in Low- and Middle-Income Countries (LMICs).

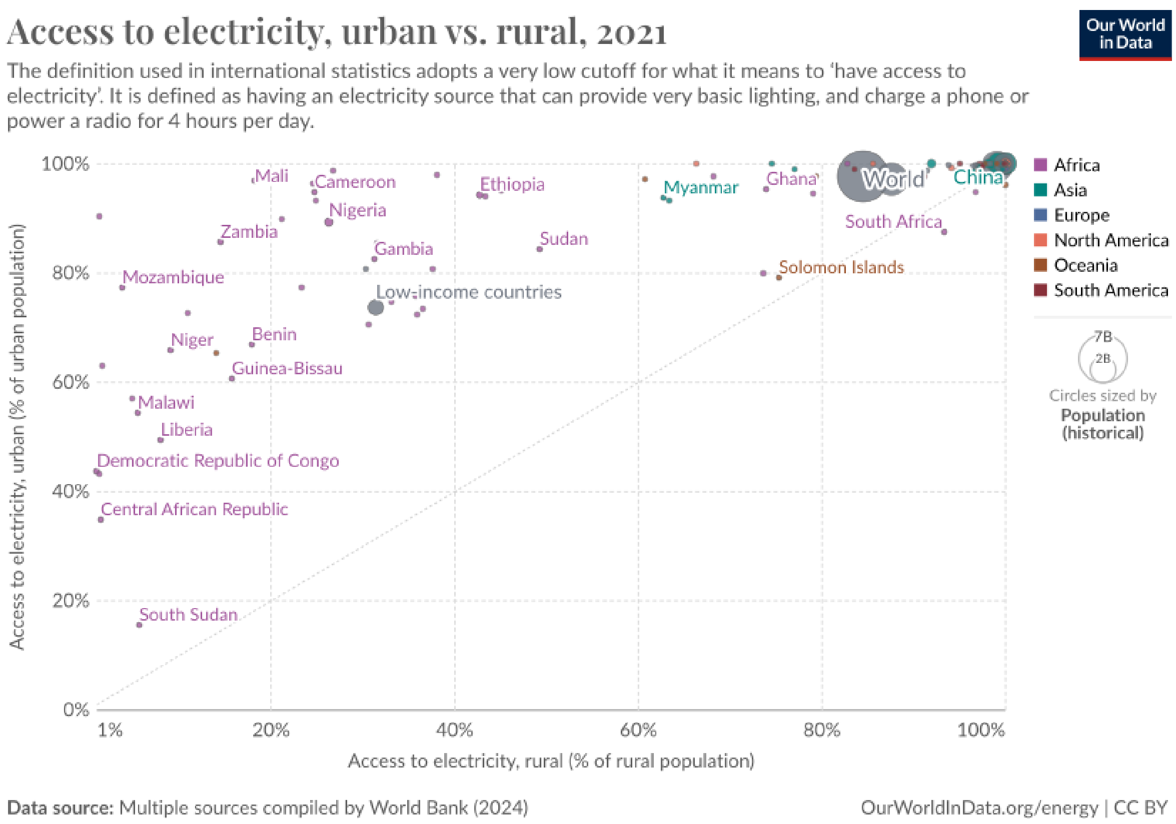
As the present Policy Brief assesses progress through widely used standard indicators, such as electrification rates and financial flows, we want to briefly acknowledge the need to expand toward more holistic and integral ways of achieving sustainability. Beyond the urgency of expanding energy access, it is equally important to rethink the broader assumptions behind energy transitions. High energy consumption is often presented as a universal pathway to development, but it must be designed not only to improve human welfare, but also to regenerate local ecosystems - forests, soils, rivers, and the myriad non-human species that share these habitats - thereby increasing both socio-economic resilience and ecological integrity. Regenerating local ecosystems also enhances human well-being, providing abundance and reducing energy demand. A regenerative approach recognizes humans as an integral part of nature rather than separate from it. Rather than simply minimizing harm, regeneration seeks to actively restore and evolve the vitality of both human and ecological systems. Based on living systems perspective, it views nature as a dynamic, self-organizing web of relationships, where decisions are guided by a biocentric focus on the life itself. Through regenerative development—an intentional process of aligning human activities with the ongoing evolution of living systems—energy transitions can be shaped by place-based wisdom and emergent, co-creative strategies. This shift from a mechanistic to a living systems worldview encourages policies that not only deliver clean energy but also honor local landscapes and cultural identities, ultimately ensuring that progress in energy access supports the broader flourishing of life on Earth.

Energy poverty and energy access

Worldwide 675 million people still do not have access to electricity. Some indicators show progress, but the current pace is not sufficient to meet the 2030 targets, and progress varies widely across regions. In 2022, the number of people living without energy access increased for the first time in over a decade. Although the percentage of people with access remained constant at 91%, the number of people without access grew faster, leaving 685.2 million people without access, compared to 675.1 million in 2021, which is around 10 million more. The drop can be partly attributed to the global COVID-19 situation and the disruption of energy markets caused by the war in Ukraine, but also to regional circumstances such as increasing droughts and floods in sub-Saharan Africa due to climate change. The lack of access is highly concentrated in the Low-Income Countries, particularly in sub-Saharan Africa. While progress has been made in some areas, the current pace of progress is insufficient to stay on track to meet the 2030 goals. Progress has been very uneven across regions.

Between 2010 and 2020, the average annual percentage increase was 0.77, and this significant progress fell to 0.43 percentage points between 2020 and 2022. To achieve the SDG target of 7.1 by 2030, an average annual percentage increase of 1.08 will be required. Since 2010, 48 additional countries have achieved universal access to electricity, with the greatest growth in Latin America and the Caribbean - 18 out of 48 countries - compared to sub-Saharan Africa, where only 2 countries have achieved universal energy access. There are still 93 countries without universal access, most of them in sub-Saharan Africa. The achieved progress is uneven, and the wide regional disparities continue to grow. While Central and South Asia accounted for 36.8 percent (414 million people) of the access gap in 2010, the significant progress in electrification reduced the share of the non-connected people in this region to 4.8 percent (33 million) in 2022. Over the same period, Sub-Saharan Africa's share of the global access deficit increased from 49.6 percent in 2010 (566.1 million in 2010) to 83.3% in 2022 (571.1 million people).

The proportion of the urban population with access to electricity increased from 96% in 2010 to 98% in 2022. In rural areas, access grew rapidly from 73% to 84% over the same period. This accelerated progress between 2020 and 2022 was driven by Central and South Asia, where 23.7 million people in rural areas gained access annually, while the rural population grew by only 3.5 million. In sub-Saharan Africa, an average of 11.2 million rural people gained access to energy annually. In East and South-East Asia, the rural population decreased significantly, while rural access to electricity increased.



This graph illustrates the comparison of urban and rural electricity access across countries in 2021, represented by the percentage of the urban population on the y-axis and the rural population on the x-axis. The graph shows significant disparities, particularly in low-income countries, where rural access often lags far behind urban access. Most high-income countries have almost universal access for both urban and rural areas. In contrast, many low-income countries, particularly in Africa, show a significant gap between urban and rural access.

The main economic factors hindering the implementation of SDG7 include the uncertain macroeconomic outlook, high inflation, currency fluctuations, debt challenges in a growing number of countries, lack of finance, supply chain bottlenecks, tighter fiscal frameworks, and rising material prices. The impact of the COVID-19 pandemic and the steady rise in energy prices since the summer of 2021 are expected to further hinder progress, especially in the most vulnerable countries. 20 countries in Sub-Saharan Africa and Asia face the largest gaps in access to electricity and clean cooking facilities, representing 80% of all countries worldwide that lack access to electricity.

Despite an increase in the use of renewable energies (target 7.2) since 2010, the proportion of renewable energies in total final energy consumption remains insufficient to achieve the target.

Furthermore, the improvement in the implementation of energy efficiency (target 7.3) is not on track to be doubled by 2030, despite steady progress. The current trend of 1.8 percent falls short of the expected increase of 2.6 percent per year between 2010 and 2030. To compensate for the lack of progress, implementation must be accelerated and reinforced by 2030. Progress towards target 7.a - increasing international public financial flows to support clean energy in LMICs - was already declining before the outbreak of the COVID-19 pandemic, since 2020 funding is more than a third lower than the average of the previous decade (2010-19). As a result of declining financial flows, the focus is increasingly on a small number of countries. Particularly for low-income countries, landlocked middle-income countries and low- and middle-income small island states, the declining trend in international public financial flows could delay the realization of SDG7.

Since 2020, international public financial flows to support clean energy in LMICs have decreased significantly. In 2021, these flows amounted to USD 10.8 billion, an 11% drop compared to 2020 and a 35% decrease compared to the 2010-2019 average. This decrease is significant compared to the peak of USD 26.4 billion in 2017 when public financial support was at its highest. Between 2010 and 2019, the average annual financial flows for clean energy were USD 16.7 billion, but from 2020 the total falls below the average, showing a consistent downward trend. The COVID-19 pandemic and other global economic challenges, such as rising energy prices and inflation, have contributed to this decline. In 2017, international financial commitments reached their highest level, with USD 26.4 billion directed towards renewable energy projects in LMICs. The sharp decline in subsequent years, particularly the drop to USD 10.8 billion in 2021, represents only 40% of the 2017 figure, highlighting a severe contraction in available funding. In 2020-2021, public financial flows also become increasingly concentrated, with fewer countries receiving most of these funds. This financial decline is particularly concerning for Low Income Countries and Small Island Developing States, which rely heavily on public financial support to advance clean energy initiatives. Without a reversal of this trend, the achievement of SDG 7 targets, particularly universal access to clean energy, risks being delayed well beyond the 2030 target. This trend is in strong contrast to the situation before 2020 when public finance flows were more robust and spread across a wider range of countries. In 2017, for example, around US$2.9 billion was allocated to India alone, the majority of which supported solar energy projects, whereas by 2021, such high levels of financial commitment are no longer present across so many LMICs.[1]

While the SDGs provide an essential framework for tracking progress, there is growing recognition that a broader approach may help ensure that energy expansion aligns with planetary boundaries and socio-ecological thresholds. Some complementary strategies propose context-based sustainability approaches to measure not only progress toward targets but also whether energy systems remain within environmental and social carrying capacities. This perspective aligns with frameworks such as Kate Raworth's Doughnut model, which emphasize the need to balance ecological ceilings and social foundations. From a living systems perspective, meeting SDG 7 targets will be most effective when policies actively preserve and regenerate the natural and social conditions upon which energy systems depend. Expanding sustainability reporting beyond year-over-year improvements to include factors such as water availability, biodiversity, and community resilience could further strengthen decision-making. Experts caution that relying exclusively on traditional reporting indicators (e.g., GRI, SASB, or ISSB metrics) may overlook another critical sustainability aspects. By integrating context-based sustainability principles, policymakers and organizations can complement SDG progress tracking with a deeper assessment of long-term

[1] IEA, IRENA, United Nations Statistics Division, et al., 2023: *Executive summary: Tracking SDG7 The energy progress report 2023* https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2023-full_report.pdf

ecological and social impacts, ensuring that energy access remains sustainable for both people and the planet.[2]

Gender and Energy Poverty

Women are disproportionately affected by energy poverty for a variety of reasons related to economic, social, and health factors. The World Bank report 'A Global View of Poverty, Gender, and Household Composition' highlights that women are more vulnerable to poverty worldwide, particularly in female-headed households, which are at higher risk of energy poverty due to income disparities, limited access to resources, and traditional gender roles.

Key reasons why women are more affected by energy poverty:

1. **Income Disparities and Economic Vulnerability**:
   - Women generally earn less than men; they hold lower-paying jobs and are often concentrated in informal or part-time work without stable incomes. In many regions, they earn on average 24% less than men, which affects their ability to afford adequate energy services.
   - Single mothers and female-headed households are especially vulnerable to energy poverty because they rely on a single income. Female-headed households often have lower income levels and less wealth accumulation, leading to difficulties in paying for energy, thus directly affecting their quality of life.

2. **Household Composition and Caregiving Roles**:
   - Women are usually the primary caregivers in households, meaning they are more exposed to the direct impacts of energy poverty. For example, they are responsible for cooking, cleaning, and caring for children or the elderly, which are activities that require access to adequate energy for lighting, heating, or cooking.
   - This caregiving role becomes especially crucial in contexts where energy access is limited or reliant on traditional fuels like wood or charcoal. Collecting and using these fuels is time-consuming and labor-intensive, and disproportionately affects women's time, health, and safety.

3. **Health and Environmental Impacts**:
   - Women's health is significantly affected by energy poverty. In low-income households without access to clean energy, women often rely on solid fuels (e.g., wood, coal, dung) for cooking and heating, leading to indoor air pollution. This exposure is associated with severe health issues, including respiratory diseases, eye problems, and other chronic illnesses.
   - As women are often responsible for household cooking, they are at higher risk for these health complications, and this increases the gender gap in both energy access and health outcomes.

4. **Limited Decision-Making Power**:

[2] Rugi, T., 2024: Interview with Bill Baue*: 2023 catastrophic year for sustainability standards.* https://economiacircolare.com/; McElroy, M., 2008: *Mark McElroy on What's Wrong with Sustainability Reporting.* https://sustainablebrands.com/

- In many parts of the world, women have less control over household finances and energy choices. This limited decision-making power means they may not be able to prioritize or access clean energy solutions, even if they recognize the need for them.
- Women's restricted participation in decision-making processes extends to broader policy-making on energy access and use, limiting the development and implementation of gender-sensitive energy policies.

5. **Geographical and Societal Barriers**:
   - In many rural or underdeveloped regions, the lack of infrastructure makes it more challenging for women to access modern energy sources. Women in these areas often have to travel long distances to collect firewood or water for energy-related needs, exposing them to safety risks and consuming large portions of their time.
   - Additionally, societal norms in some regions can restrict women's movement or access to resources, further compounding their ability to secure adequate energy for their households.

6. **Energy Poverty Among Older Women**:
   - Older women are particularly at risk of energy poverty. In many cases, elderly women live alone or have fewer financial resources compared to men, due to lifetime earnings disparities. This makes it difficult for them to afford sufficient energy for heating, especially in colder climates, increasing their vulnerability to "fuel poverty."

In summary, gender inequalities in income, health risks, household roles, and decision-making significantly contribute to women's heightened vulnerability to energy poverty. To effectively address energy poverty, policies and interventions need to consider these gender-specific factors to ensure that women have equitable access to clean, affordable energy. Access to clean energy solutions would improve health outcomes, reduce time poverty, and enhance women's economic and social empowerment.[3]

Energy poverty in Europe

Energy poverty has become an increasingly urgent issue in Europe, affecting millions of households struggling to meet their basic energy needs. Defined as the inability to afford sufficient energy for heating, electricity, and other essential services, energy poverty is closely linked to rising energy costs, inefficient housing stock and wide socio-economic inequalities/ Energy poverty stems from a mix of low-income, high-energy expenses, and inefficient housing. In recent years, the European Union has taken steps to address this growing concern through policy frameworks such as the Clean Energy Package for All Europeans and the establishment of the EU Energy Poverty Observatory, which aims to track and mitigate energy poverty across Member States. Despite these efforts, responses at the national level remain uneven, with significant differences in how countries are addressing the issue.[4]

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[3] World Bank, 2021: *A Global View of Poverty, Gender, and Household Composition*. Washington, DC: World Bank Group. https://documents1.worldbank.org/curated/en/776061614181162133/pdf/A-Global-View-of-Poverty-Gender-and-Household-Composition.pdf.

[4] Cornelis, M., & Sovacool, B. K., 2021: *Confronting Energy Poverty in Europe: A Research and Policy Agenda*. Energies. https://www.mdpi.com/1996-1073/14/4/858

The *European Parliamentary Research Service (EPRS)* briefing highlights the growing issue of energy poverty in the EU, which affected over 41 million people in 2022.[5] Countries such as Bulgaria, Lithuania, and Greece are particularly affected, with more than 30% of households in these countries unable to keep their homes adequately warm during the winter months. By contrast, in wealthier countries such as Sweden and Finland, the figure is less than 5%. In addition, the proportion of European households spending more than 10% of their income on energy bills - a common threshold for defining energy poverty - has been steadily rising, particularly in the wake of the COVID-19 pandemic and the war in Ukraine, which have significantly increased energy prices across Europe.

While current policy efforts focus on measurable indicators such as income-to-energy cost ratios and the percentage of households in cold homes, broader perspectives on sustainability suggest that such metrics alone may not fully address the root causes of energy poverty. A living systems approach highlights how energy access is deeply intertwined with structural issues such as income inequality, housing quality, and uneven policy implementation. One of the key challenges in tackling energy poverty is measurement. While existing indicators, such as household energy costs as a share of income, provide insights into affordability, they do not always reflect the broader ecosystem impact of energy production and consumption. A living systems perspective emphasizes not just short-term affordability, but also whether solutions align with long-term ecological and social well-being. For instance, lowering energy costs through fossil fuel subsidies may provide temporary relief, but without ensuring ecological regeneration or reducing carbon dependency, such strategies may contradict Europe's broader climate commitments. Instead, holistic approaches—including high-efficiency housing retrofits, renewable energy microgrids, and sustainability thresholds such as local carbon budgets and ecosystem carrying capacity—could provide long-term solutions.[6]

The effects of energy poverty go beyond mere inconvenience and have a significant impact on health and well-being. Households in energy poverty are more likely to experience cold or damp living conditions, which in turn worsens health conditions, especially among vulnerable groups such as the elderly or single-parent families. It is estimated that cold homes contribute to 100,000 premature deaths per year in Europe (SpringerLink). The health implications of living in energy-poor environments have become a focus for researchers and policymakers alike, highlighting the need for targeted interventions to address both the immediate and long-term consequences of energy poverty.

Mitigating energy poverty requires a multifaceted approach that combines social protection measures with improvements in energy efficiency. In many European countries, policies aimed at retrofitting old and poorly insulated housing have proven effective in reducing energy poverty. For example, retrofitting schemes in the UK have been shown to reduce energy bills for some households by up to 50%, dramatically reducing the burden of energy costs. Social protection systems also play a critical role, as countries that invest heavily in social assistance programs tend to have lower levels of energy poverty. However, achieving lasting solutions requires more than policy adjustments; it requires a sustained commitment to addressing the root causes of energy poverty, such as rising energy costs and income inequality. [7]

Achieving long-term solutions requires more than policy adjustments or market-based mechanisms; it necessitates a fundamental shift in the way energy poverty is framed and addressed. Ultimately,

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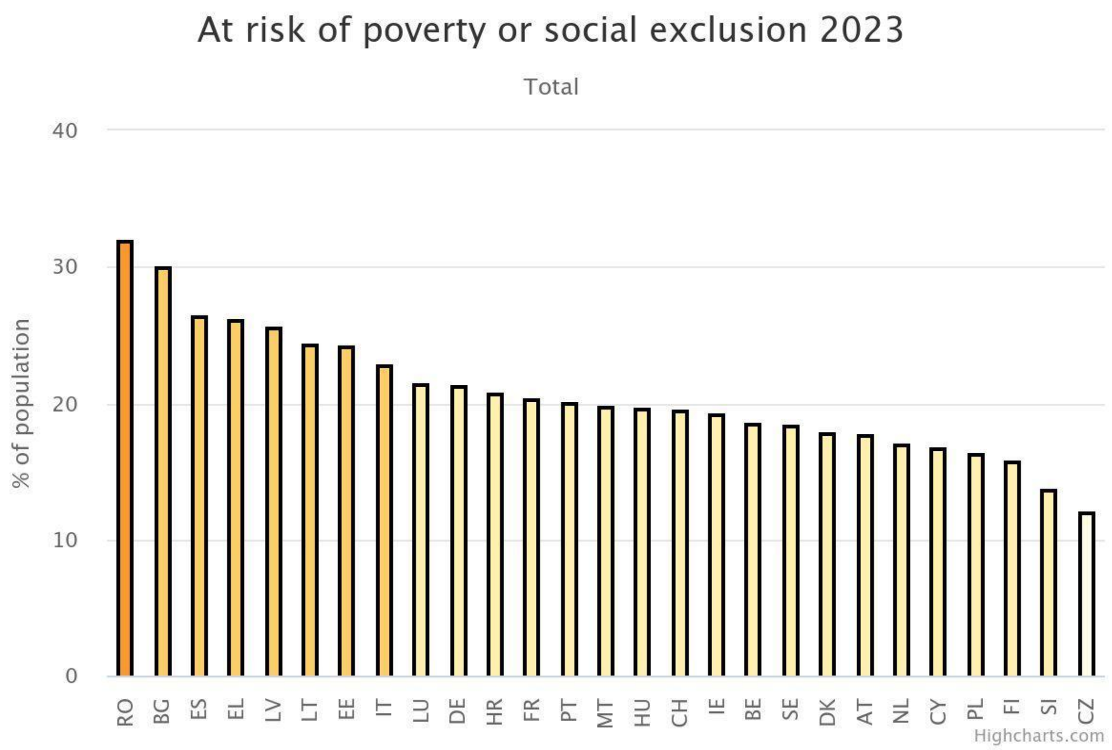
[5] European Parliamentary Research Service, 2022: *Energy poverty in the EU: A critical overview of the evidence.* https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733583/EPRS_BRI(2022)733583_EN.pdf

[6] Pfeiffer, M., & Marwah, T., 2022: *Energy poverty in Europe: Using evidence to address an urgent challenge*. The Abdul Latif Jameel Poverty Action Lab. https://www.povertyactionlab.org/blog/9-12-22/energy-poverty-europe-using-evidence-address-urgent-challenge

[7] Fizaine, F., & Kahouli, S., 2023: *A comprehensive review on energy poverty: definition, measurement, socioeconomic impact and its alleviation for carbon neutrality.* Environment, Development and Sustainability.

tackling energy poverty in Europe should be part of a holistic transformation—one that not only provides immediate relief but also ensures that energy access remains equitable, resilient, and ecologically responsible. By integrating contextual, threshold-based indicators, policymakers can redefine success beyond short-term energy affordability and create pathways that uphold both human dignity and planetary health in tandem.



Energy Poverty Advisory Hub

Social Energy Consulting by klimaaktiv

In response to the growing challenge of rising energy costs for households, klimaaktiv has developed a training program aimed at combining social work with energy consulting. This initiative provides practical knowledge about energy management, focusing on empowering vulnerable households to better manage their energy consumption without requiring financial investments. The social energy consulting model emphasizes behavioral changes that lead to more efficient energy use, rather than relying on costly renovations or technology upgrades. Through collaboration with households, specific energy challenges are identified, and tailored, actionable steps are created to reduce energy costs and improve the quality of life. One of the most important aspects of this program is the training it offers. The free, additional qualification is available to professionals in social work and social consulting, equipping them with the skills to provide energy-saving advice to low-income households. The goal is to bridge the gap between technical knowledge and social expertise, enabling consultants to effectively support households in lowering heating and electricity costs. By encouraging community collaboration and offering targeted guidance, this initiative fosters a collective approach to addressing energy poverty, helping vulnerable households reduce their costs and improve their living conditions. This integrated model of social and energy consulting strengthens both social responsibility and sustainable energy management within communities.[8]

Zelena Energetska Zadruga, Croatia

Križevci, a town in central Croatia near the capital Zagreb, is actively tackling energy poverty while promoting renewable energy sources. The municipality launched an innovative pilot project in 2016 to combat energy poverty. They trained 13 long-term unemployed residents as energy advisors who visited households struggling with high energy costs. These advisors provided energy-efficient equipment and offered practical advice on easy-to-implement measures to reduce energy consumption and lower energy bills. Furthermore, the Croatian cooperative Zelena Energetska Zadruga (ZEZ) initiated the "Križevci Solar Roofs" project. This initiative used crowdfunding campaigns to finance and install solar power plants on public buildings such as the Development Center, Technology Park, and Town Library. By promoting local energy independence and reducing greenhouse gas emissions, the project addresses energy poverty on a broader scale. ZEZ also empowers communities by fostering citizen engagement in renewable energy projects and providing education on energy efficiency. Their efforts include supporting households facing energy poverty by supplying energy-saving equipment and offering consultations to help them manage and reduce their energy expenses.[9]

Energy communities and energy poverty reduction

Energy communities are positioned within the framework of energy democracy and energy justice, empowering citizens to play an active role in energy production, consumption, and decision-making. These communities aim to democratize the energy system by ensuring that citizens are not just consumers, but active participants and stakeholders in shaping energy policy. By promoting greater citizen participation and control, energy communities are seen as central to achieving a just energy transition that prioritizes social equity and inclusion. Energy poverty - the inability of households to afford essential energy services - is an important form of distributional injustice, where disparities in income, energy prices, and energy efficiency create barriers to energy access. Vulnerable groups often face procedural injustice, when they are excluded from energy decision-making processes, and recognitional injustice when their specific energy needs are ignored by the system.

Energy communities can address these injustices by empowering citizens to participate in decision-making and ensuring that vulnerable populations have access to affordable, sustainable energy. They have the potential to address distributional justice by helping the energy poor afford energy and invest in energy efficiency. They also promote recognition justice by recognizing and addressing the unique energy needs of disadvantaged groups, and procedural justice by involving these groups in key decision-making processes.

[8] klimaaktiv. *Soziale Energieberatung.* https://www.klimaaktiv.at/bildung/weiterbildungen/management_beratung/soziale-energieberatung.html

[9] Zelena Energetska Zadruga (ZEZ). *Official Website.* https://www.zez.coop/

As social innovations, energy communities can bring broader socio-economic benefits, such as job creation, increased social participation, and the democratization of energy systems. They help create local employment opportunities, build community resilience, increase acceptance of renewable energy, and promote gender equality. By reshaping the relationship between citizens and their energy systems, energy communities help build new civic traditions and address systemic inequalities within the energy sector.[12]

SOM Energía, Spain

Som Energia, a renewable energy cooperative established in 2010 in Girona, Spain, promotes the use of 100% renewable energy sources such as solar, wind and biomass. It operates on a democratic model that allows its more than 69,000 members to actively participate in decision-making and support community-owned renewable energy projects. A key aspect of Som Energia is its commitment to alleviating energy poverty by ensuring that green energy is accessible to low-income households. The cooperative offers several innovative approaches to making renewable energy affordable and available to vulnerable populations:

- *Affordable Energy Access:* Som Energia allows members to share their membership benefits with others, enabling low-income households to access green energy without having to pay a joining fee. This inclusivity ensures that vulnerable groups have access to sustainable energy solutions.
- *Generation kWh Project:* Through this initiative, members collectively invest in solar fields that generate energy that directly supports more than 1,300 households. This model helps reduce energy costs for members, especially those struggling with high energy prices.
- *Rural and low-income focus:* Som Energia works with rural villages and communities, waiving membership fees for smaller communities. This ensures that the most vulnerable populations in less populated areas benefit from clean energy solutions.

By promoting community ownership of renewable energy projects and lowering the financial barriers to access, Som Energia is making a significant contribution to reducing energy poverty and supporting a just energy transition in Spain.[10]

Énergie Solidaire, France

Énergie Solidaire, launched by Enercoop, is a key initiative in addressing energy poverty in France by leveraging the surplus energy produced by renewable sources and engaging consumers in micro-donations from their energy bills. These micro-donations are used to fund local programs that help low-income households improve their energy efficiency through renovations and other measures. A key goal of the initiative is to empower vulnerable communities by lowering energy costs, reducing energy consumption, and increasing access to renewable energy. A significant social aspect of the program is its focus on community-driven solidarity. By allowing individuals and producers to contribute their surplus energy or financial resources, Énergie Solidaire encourages the creation of a collective response to energy poverty, helping communities tackle fuel poverty together. This effort not only improves the living conditions of those affected but also fosters a sense of social responsibility and solidarity in the energy transition.[11]

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[10] Pellicer-Sifres, V., Belda-Miquel, S., Cuesta-Fernández, I., & Boni, A., 2018*: Learning, transformative action, and grassroots innovation:* Insights from the Spanish energy cooperative Som Energia. *Energy Research & Social Science*. https://www.sciencedirect.com/science/article/abs/pii/S2214629618302184?via%3Dihub

[11] Énergie Solidaire. *REScoop.eu.* https://www.rescoop.eu/news-and-events/news/energie-solidaire

[12] Koukoufikis, G., Schockaert, H., et. Al, 2023: *Energy Communities and Energy Poverty*. JRC Science for Policy Report. Publications Office of the European Union, Luxembourg. https://publications.jrc.ec.europa.eu/repository/handle/JRC134832

Community-based energy projects play a key role in advancing Sustainable Development Goal 7 (SDG7), which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. These initiatives leverage renewable energy sources, enhance energy efficiency, ensure reliable power supply, reduce costs, and create local jobs. By fostering more inclusive, equitable, and resilient energy systems, local energy communities highlight the transformative potential of citizen-driven solutions. Recognized globally as effective models for energy transitions, these projects demonstrate their capacity to drive both socio-economic development and environmental sustainability.

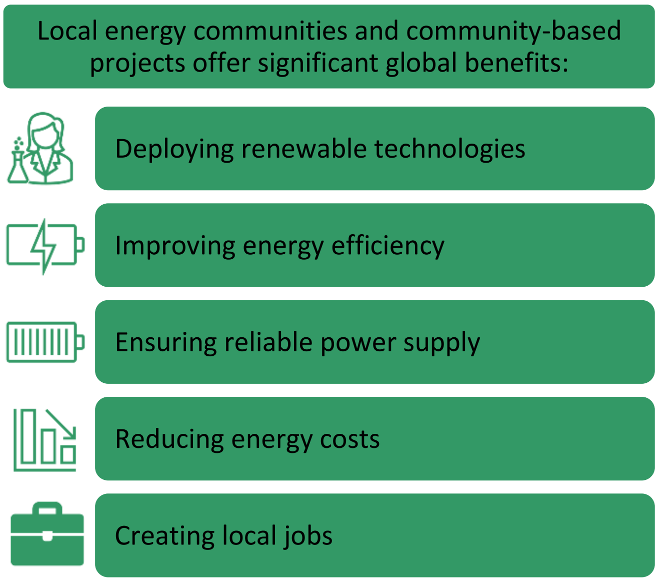

Figure 1 Benefits of local energy communities, Author's Own Illustration

RevoluSolar, Brazil

The RevoluSolar project in the Babilônia and Chapéu Mangueira favelas of Rio de Janeiro, Brazil, is an example of this impact. It provides renewable energy to more than 50, using profits from the project to reinvest in local charities and job training programs. The initiative not only protects residents from rising energy costs but also builds community resilience and economic independence. Projects like RevoluSolar highlight how local energy initiatives can address energy poverty while fostering broader social and economic development.[13]

At the policy level, the European Union has established an advisory hub and disseminates best practice examples to guide the creation and implementation of local energy communities. These efforts aim to engage citizens in the energy transition process, ensuring that renewable energy initiatives are accessible and impactful. Similarly, the International Energy Agency (IEA) has launched initiatives to promote community participation through its People-Centred Clean Energy Transitions Programme and the Digital Demand-Driven Electricity Networks Initiative (3DEN), both of which focus on empowering local stakeholders and improving energy access. [14]

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[13] RevoluSolar, 2023: *Babilônia e Chapéu Mangueira.* https://revolusolar.org.br/babilonia-e-chapeu-mangueira/

[14] International Energy Agency, 2023: *Empowering people: The role of local energy communities in clean energy transitions*. https://www.iea.org/commentaries/empowering-people-the-role-of-local-energy-communities-in-clean-energy-transitions

Microgrids in Africa

In Africa, microgrids have emerged as a vital solution for providing clean and reliable energy to rural and underserved areas. These decentralized energy systems are particularly valuable in regions with limited grid capacity or where extending the traditional grid is economically unfeasible. Microgrids use renewable energy sources such as solar photovoltaic (PV) systems, wind, and fuel cells to provide consistent power while reducing dependence on fossil fuels. Eskom, South Africa's main electricity supplier, has been a leader in advancing microgrid technology on the continent.

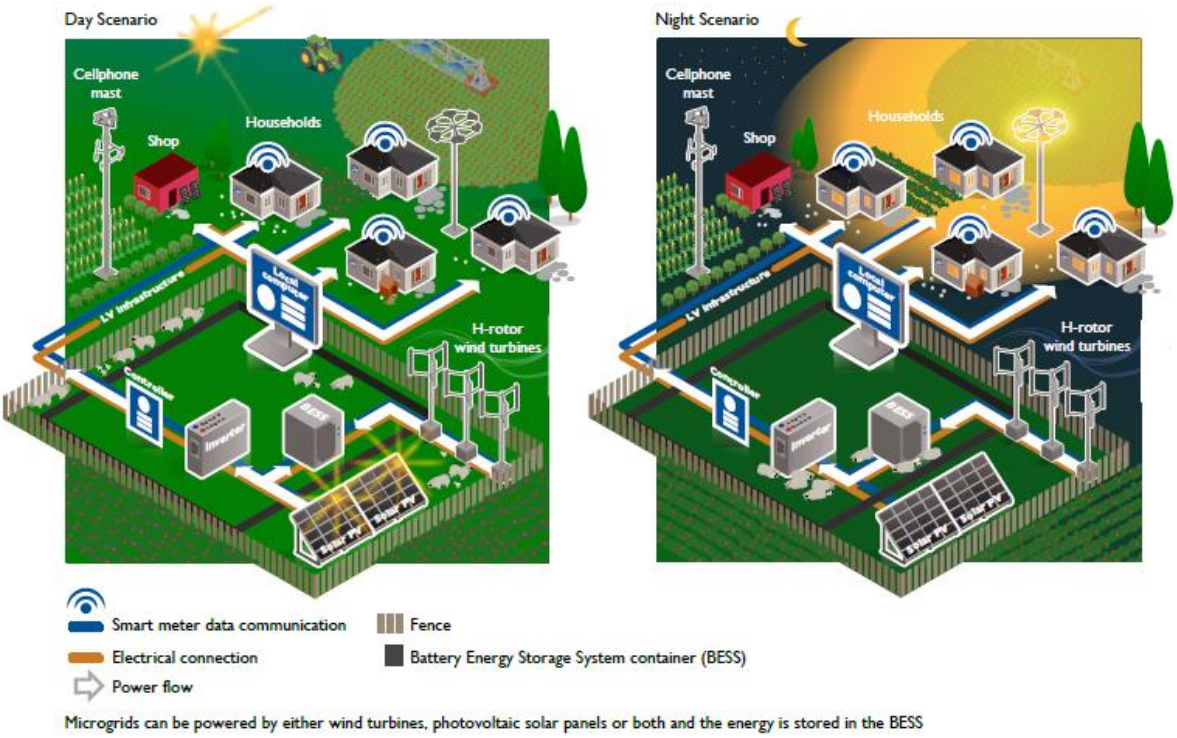
Eskom, South Africa

Eskom Holdings Ltd is a State-Owned Company (SOC) fully owned by the South African government. As the largest electricity producer in South Africa and across Africa, Eskom generates around 95% of the electricity consumed in South Africa and approximately 45% of the electricity used on the continent.

Eskom, South Africa's main electricity supplier, has been a leader in advancing microgrid technology on the continent. The company has established microgrid pilot sites in Ficksburg and Lynedoch to research and develop scalable models for remote communities. The Ficksburg pilot has demonstrated the potential of microgrids to provide a cleaner and more sustainable alternative to traditional grid electricity. The system integrates renewable energy sources and is managed by a centralised control centre equipped with artificial intelligence and machine learning capabilities. These technologies enable the system to predict weather conditions, solar irradiation and other factors that affect energy production, optimising operational efficiency. Beyond energy access, the Eskom´s microgrid project also facilitates community development. The system includes a communication network that provides internet access to users, enhancing education and business opportunities in the area. By combining reliable green energy with digital connectivity, microgrids offer a holistic approach to rural development, aligning with SDG7's vision of sustainable and inclusive energy systems. [15]

Through projects like RevoluSolar in Brazil and Eskom's microgrid initiatives in Africa, the transformative power of community-driven and decentralized energy systems is becoming increasingly evident. These models not only address energy poverty but also strengthen local economies, reduce environmental impact, and enhance social equity, providing a blueprint for advancing SDG7 globally.

[15] Eskom Holdings SOC Ltd. (n.d.). *Microgrid technology*. https://www.eskom.co.za/distribution/microgrid/



Visualization of Installation, taken directly from Eskom Holdings SOC Ltd. (n.d.). Microgrid technology. https://www.eskom.co.za/distribution/microgrid/

Energy poverty in Africa

Energy poverty in Africa is a critical issue that affects more than 600 million people, particularly in sub-Saharan Africa. Many communities lack access to modern energy services and rely on traditional biomass sources such as wood and charcoal for cooking and heating. This reliance on inefficient energy sources contributes to environmental degradation, deforestation, and health problems, particularly respiratory diseases caused by indoor air pollution.

The causes of energy poverty in Africa are many and complex. They include underdeveloped infrastructure, high energy prices, political instability, and a lack of investment in both conventional and renewable energy sources. Although Africa has enormous potential for renewable energy - especially solar, wind, and hydropower - scaling up these resources remains difficult due to poor regulatory frameworks, financial constraints, and technical capacity limitations. Countries face challenges in implementing large-scale energy projects that would improve access to clean and sustainable energy for their populations.

Numerous initiatives have been launched to address energy poverty, such as government-led programs and international partnerships focused on electrification through decentralized renewable energy solutions. Technologies such as solar home systems, mini-grids, and other off-grid energy models hold great promise, especially for rural areas that are difficult to connect to national grids. These decentralized systems can provide reliable and affordable electricity to underserved populations, improving livelihoods and reducing dependence on polluting energy sources.

Addressing energy poverty is critical not only to improving quality of life but also to achieving the broader Sustainable Development Goals (SDGs). In particular, SDG7 calls for ensuring access to affordable, reliable, sustainable, and modern energy for all. Energy access is closely linked to progress in education, healthcare, economic growth, and gender equality. Without energy, schools cannot provide adequate education, health facilities cannot function efficiently, and local economies struggle to grow.

Efforts to reduce energy poverty require coordinated action by governments, the private sector, and international organizations. Investment in clean energy infrastructure is critical to expanding access to sustainable energy. Innovative financing models, such as pay-as-you-go solar systems, have emerged to help overcome financial barriers for low-income households. Stronger policies are also essential to encourage private sector participation and create an enabling environment for renewable energy projects.[16]

Despite progress, much remains to be done to achieve universal energy access by 2030. Africa's energy transition will depend on a combination of grid expansion, off-grid solutions, and targeted investments in renewable energy technologies. Multi-stakeholder collaboration is essential to unlock the continent's renewable energy potential and reduce energy poverty across the region.[17]

Rural off-grid solutions

Off-grid solutions in rural areas, especially in Sub-Saharan Africa, provide crucial energy and water resources where conventional infrastructure is often lacking. These decentralized systems, often powered by renewable energy sources such as solar or wind, are particularly beneficial to the agricultural sector, such as solar-powered water pumps for irrigation, which increase crop productivity while reducing reliance on diesel generators, thereby reducing greenhouse gas emissions.

Communities in sub-Saharan Africa, often isolated from the national grid, benefit from solar mini-grid or off-grid systems that power essential activities such as irrigation, refrigeration, and food processing. These systems provide access to reliable electricity that is critical to maintaining food quality, such as solar milk cooling systems in Kenya that preserve milk and extend its marketability. In addition to energy, off-grid solutions help manage water resources more efficiently. Smart irrigation systems using solar-powered pumps reduce water waste and support sustainable agricultural practices, which are essential in regions with limited water supplies.[18]

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[16] Ajide, F. M., & Dada, J. T., 2024: *Energy poverty and shadow economy:* Evidence from Africa. International Journal of Energy Sector Management. Emerald Publishing. https://www.emerald.com/insight/content/doi/10.1108/IJESM-04-2023-0018/full/html?skipTracking=true

[17] OECD, 2021: *Energy and Poverty in Africa*. OECD Development Centre Policy Insights. OECD iLibrary. https://www.oecd-ilibrary.org/development/energy-and-poverty-in-africa

[18] UNFCCC (United Nations Framework Convention on Climate Change) Secretariat, 2019: *Off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain.* Technical paper Bonn, Germany: UNFCCC. Available at UNFCCC Technical Paper.

The Productive Uses of Renewable Energy (PURE)

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The Productive Uses of Renewable Energy (PURE) approach highlights how renewable energy can drive sustainable economic growth, social development, and environmental resilience, particularly in climate-vulnerable regions. Off-grid and weak-grid technologies offer communities the opportunity to thrive by integrating renewable energy into agriculture, small businesses, and public infrastructure by improving resilience to extreme weather events and by supporting essential services such as communications and emergency planning.

PURE technologies can increase agricultural productivity, improve food security, and reduce waste. For example, solar water pumps provide irrigation during the dry season, while solar refrigeration units help preserve food and medicines. These technologies also improve health services by providing refrigeration for vaccines and medical supplies. However, when deploying solutions such as solar pumps, it is important to consider local water resources to avoid exacerbating water scarcity. Applications must also not only increase yields, but also revitalize soils, protect pollinators, and safeguard forests and wetlands.

Agriculture is the livelihood of more than 2.5 billion people. It accounts for 30% of global energy consumption and one third of greenhouse gas emissions. The transition to renewable energy in agri-food systems is critical to achieving standard progress or development indicators such as increasing yields, improving incomes, reducing losses, and building climate resilience. However, disparities in access to energy and continued reliance on fossil fuels remain major challenges, particularly in low- and middle-income regions. It is important to note that while renewable energy can provide sustainable solutions to modernize food systems and ensure their long-term security and resilience, a living systems or complex systems perspective shows that relying on renewable energy to power intensive, monoculture-based agriculture may inadvertently exacerbate medium- to long-term challenges. For example, pumping water from underground sources to increase yields may temporarily increase productivity indicators, but over time it can deplete aquifers and degrade soils. In contrast, regenerative farming practices - such as diversified cropping systems, soil-building techniques that improve water retention, and holistic land management - can reduce the need for irrigation and external inputs altogether, conserving resources and strengthening ecosystems. These approaches optimize ecosystem services, such as aquifer recharge, biodiversity protection and soil fertility, while enhancing social equity and long-term resilience. This is an example of how measuring success purely in terms of short-term productivity risks overlooking deeper environmental and social dimensions; incorporating indicators of soil health, water balance and community well-being helps to ensure that renewable energy investments genuinely contribute to sustainable development, rather than simply shifting environmental burdens into the future.

Las Gaviotas, Colombia

Las Gaviotas in Colombia is a pioneering model of how renewable energy can support biodiversity and ecological restoration while fostering sustainable development. Founded in the 1970s by Paolo Lugari, Las Gaviotas is located in the Llanos region of Colombia, a previously degraded savanna. The initiative integrates renewable technologies with ecological restoration to create a self-sustaining community. Key innovations include high-efficiency windmills, solar-powered water pumps and solar cooking systems, all adapted to the region's harsh conditions. A major achievement has been the transformation of 8,000 hectares of barren land into a thriving forest. By introducing mycorrhizal fungi, Las Gaviotas cultivated Caribbean pine trees, which produce valuable resin and create microclimates that support native biodiversity. This reforestation effort improved soil fertility, regulated rainfall, and enhanced groundwater filtration. The project also developed sustainable infrastructure, including a solar-powered hospital with passive cooling. Although later converted into a water bottling plant, it continues to generate income while providing clean, naturally filtered drinking water from the restored ecosystem. Las Gaviotas remains a leading example of how renewable energy, ecological restoration and sustainable infrastructure can work together to regenerate degraded landscapes and support resilient communities.[19]

Productive Uses of Renewable Energy (PURE) play a critical role in reducing energy poverty by enabling the mechanization of agriculture, powering enterprises, and electrifying public infrastructure. PURE technologies such as solar water pumps (SWPs) and solar refrigeration units (SRUs) are vital for improving food security, access to clean water, and healthcare services. By providing renewable energy access in projects that are designed based on living systems approach, PURE helps improve resilience to climate change and reduces vulnerability to economic and global shocks.

EnDev, Ghana

EnDev is a multi-donor program aimed at improving energy access for rural communities in Ghana. The project focused on providing solar PV systems to power irrigation pumps, which improved agricultural productivity by giving farmers access to a reliable water supply. In addition, MSMEs (Micro, Small and Medium Enterprises) were able to use solar energy to power small-scale

[19] Lugari, P. Las Gaviotas, 2016*: Sustainability in the Tropics*. ResearchGate. https://www.researchgate.net/publication/294817973_Las_Gaviotas_Sustainability_in_the_tropics

processing and other productive activities, such as refrigeration and food processing, resulting in increased employment opportunities. EnDev's support for solar irrigation particularly helped small-scale farmers by reducing energy costs and increasing crop yields through more reliable irrigation during the dry season.[20]

Ensol, Tanzania

Ensol Tanzania implemented solar-powered water pumps in rural areas, providing access to clean water for communities that previously struggled with poor water availability. These solar water pumps helped irrigate agricultural land, which improved food production, especially in drought-prone areas. In addition to increasing agricultural production, the project created new employment opportunities for local technicians to maintain the solar equipment. By replacing traditional diesel-powered pumps, the project significantly reduced greenhouse gas emissions and contributed to the development of sustainable agricultural practices.[21]

The following paragraphs outline key contributions to reducing energy poverty while also illustrating how a living systems perspective can be applied to each of these contributions. This perspective is not a fixed or static framework, but rather a dynamic set of evolving guidelines shaped by the work of regenerative movements. Their collective research and practice underscore the interconnectedness of social, ecological and economic systems and highlights how a focus on resilience, biodiversity and community well-being can drive truly sustainable development.

1. Mechanization of Agriculture

PURE technologies, like solar-powered water pumps (SWPs), enable smallholder farmers to irrigate their fields more efficiently, leading to a 30% increase in agricultural yields. The availability of water through SWPs allows farmers to cultivate crops even during dry seasons, directly improving food production and security. Additionally, solar-powered refrigeration systems, such as solar cold storage units, help reduce post-harvest losses by 30–40% by preserving perishable goods like milk, fruits, and vegetables. This is particularly important in regions without stable electricity access, where farmers can minimize food waste and increase income by storing and selling fresh produce for longer periods.

Living Systems Approach:

- ***Contextualizing Water Use***: A living systems approach would measure irrigation water withdrawals against local watershed capacity. For instance, a solar pump may be "clean energy" but still lead to over-extraction of groundwater if thresholds are not respected.
- ***Regenerative Agriculture Integration***: Instead of merely scaling up production, farmers could integrate SWPs with soil-building practices (e.g., agroforestry, permaculture). This maintains soil fertility, sequesters carbon, and conserves biodiversity.
- ***Local Seed Varieties & Crop Diversity***: Mechanization often encourages monocultures if tied solely to market-driven crops. Ensuring farmers can maintain crop diversity and preserve local seed varieties strengthens resilience against pests, diseases, and climate shifts.[22]

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[20] European Union Energy Initiative Partnership Dialogue Facility, 2015: The *Productive Use of Renewable Energy in Africa.* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn. https://africa-eu-energy-partnership.org/wp-content/uploads/2020/04/151001_euei_aeep_are-info-paper_en_rz_01_web_2.pdf

[21] UNFCCC Secretariat , 2019: *Off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain.* UNFCCC Technical Paper, Bonn. https://unfccc.int/sites/default/files/resource/TEMs%202019_TP_Designed%20Version.pdf

[22/23] Mang, P., & Haggard, B., 2016*: Regenerative Development and Design: A Framework for Evolving Sustainability.* Wiley.

2. Improving Healthcare Services

In many LMICs, rural healthcare centers lack reliable electricity. PURE technologies address this issue by providing solar-powered refrigerators to store vaccines, medicines, and blood samples in remote areas. Furthermore, solar-powered water pumps deliver clean drinking water, reducing the spread of waterborne diseases. Access to clean water is crucial for public health and improves the quality of life for millions of people in underserved communities.

Living Systems Approach:

- ***Community Health Ecosystem:*** Holistic healthcare isn't just about refrigeration and clean water; it also depends on local nutrition, environmental health, and social cohesion. Renewables can be part of a broader plan (e.g., building climate-resilient health facilities, ensuring local staff training).
- ***Energy-Efficient Infrastructure:*** Solar refrigerators and water pumps should be paired with energy-efficient building designs (insulation, passive cooling) that lower overall energy demand and improve reliability of service delivery.
- **Long-Term Maintenance & Ownership:** In remote or under-resourced communities, consider community-based management and training programs so solar units remain functional over time.[23]

3. Job Creation and Economic Development

PURE technologies support the creation of green jobs. The renewable energy sector already provides more than 370,000 jobs globally in areas such as distribution, customer service, and management. In Sub-Saharan Africa and South Asia, which have the largest electricity deficits, PURE technologies have the potential to significantly expand employment opportunities in rural areas.
In addition, PURE innovations enable new economic opportunities for micro, small, and medium-sized enterprises (MSMEs) by providing the energy necessary to power businesses such as cooling, drying, and processing agricultural products. This helps local businesses grow and allows users of PURE technologies to diversify their income streams, increasing economic independence.

Living Systems Approach:

- ***Quality Over Quantity of Jobs:*** While increasing the number of jobs is beneficial, a living systems lens asks whether these jobs contribute to ecological and social regeneration. For instance, do new solar installation or maintenance jobs include training in environmental stewardship?
- ***Inclusive Ownership Models:*** Instead of purely private or corporate-driven approaches, cooperatives or community-owned enterprises can foster local empowerment and equitable wealth distribution.
- ***Context-Based Indicators:*** Rather than tracking only the number of jobs, measure how these jobs enhance local resilience (e.g., building skills in ecological restoration, setting up local repair networks, enabling women's leadership in energy governance).[24]

4. Enhancing Resilience to Climate Change and Global Shocks

Many communities affected by energy poverty are located in regions highly vulnerable to climate change. PURE technologies enhance adaptability by offering stable and reliable renewable energy

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[24/25/26] Mang, P., & Haggard, B., 2016: *Regenerative Development and Design: A Framework for Evolving Sustainability.* Wiley.

sources, which can withstand the challenges of extreme weather events.
By ensuring access to electricity, PURE technologies help communities better respond to crises such as rising energy prices or natural disasters. For example, PURE facilitates the electrification of emergency communication networks, which are essential for disaster preparedness and response coordination.

Living Systems Approach:

- ***Broader Ecological Resilience:*** Resilience also depends on healthy soils, forests, and water cycles. PURE technologies should go hand in hand with land restoration efforts—for example, reforestation near watersheds, using solar pumps in integrated watershed management.
- ***Community-Led Disaster Planning:*** Rather than top-down technology rollouts, involve local communities in designing how renewable systems function during emergencies, ensuring shared governance and accountability.
- ***Long-Term Adaptation: Use local indicators*** (e.g., rainfall patterns, biodiversity levels) to gauge whether new technologies are truly buffering communities against climate extremes or inadvertently creating dependence on external inputs.[25]

5. Supporting Rural Development and Infrastructure Building

PURE promotes rural infrastructure development by providing technologies that ensure access not only to electricity but also to clean water, improved healthcare services, and communication systems. This revitalizes rural economies and gives people who were previously isolated due to a lack of infrastructure access to new markets and economic opportunities.

Living Systems Approach:

- ***Ecosystem-Based Planning:*** Rural development should be mapped against ecological constraints and opportunities, ensuring minimal disruption of habitats and encouraging regenerative land use.
- ***Participatory Governance:*** Infrastructure projects often fail when community voices aren't central. A living systems approach includes local leadership in planning, so infrastructure solutions reflect on-the-ground realities and knowledge systems.
- ***Sociocultural Dynamics:*** "Improved infrastructure" can sometimes erode cultural ties or local economies if not managed thoughtfully. Balancing modernization with the protection of cultural heritage strengthens overall community resilience.[26]

6. Financial Support and Incentive Mechanisms

Financial support and incentive mechanisms are critical to advancing the productive use of renewable energy (PURE) in Africa. These mechanisms address the high upfront costs of renewable energy technologies and create an enabling environment for their widespread adoption, particularly in rural and underserved areas. Subsidies and tax exemptions are critical tools in this effort, significantly reducing the financial barriers for both providers and end users. Across Africa, countries are leveraging these mechanisms to make renewable technologies more affordable. For example, South Africa has introduced a revised carbon tax framework, incentivizing companies to invest in cleaner energy by offering tax breaks for adopting renewable technologies. Similarly, Kenya and

Tanzania have implemented VAT exemptions on solar products, lowering the costs of solar-powered pumps and off-grid refrigeration units, which are crucial for rural agricultural and health sectors.[27]

Results-based financing (RBF) has also emerged as a key mechanism for scaling up access to renewable energy in sub-Saharan Africa. By linking financial disbursements to the achievement of specific milestones, RBF ensures that funds are used effectively and aligned with measurable outcomes. Programmes such as the World Bank's Distributed Access through Renewable Energy Scale-Up Platform (DARES) show how this approach can mobilize resources to support technologies such as solar irrigation systems and mini-grids.[28] By focusing on tangible impacts, such as the number of households electrified or the amount of food preserved through solar refrigeration, RBF not only reduces risks for investors but also fosters sustainable development in communities facing significant energy poverty.

Reaching remote and underserved regions requires innovative financing models and market strategies. PURE companies often face high costs and logistical challenges when deploying renewable energy solutions in rural areas. Local financial institutions and microfinance initiatives are bridging this gap by offering tailored loans to smallholder farmers and rural entrepreneurs. In East Africa, pay-as-you-go (PAYG) financing models have gained popularity, allowing households and businesses to access solar technologies with minimal upfront costs. This approach makes PURE solutions more affordable and accessible for low-income users, enabling them to benefit from sustainable energy for agricultural production, storage, and local businesses. Additionally, partnerships with development organizations and international donors provide technical assistance and co-financing to de-risk investments, facilitating the entry of PURE technologies into hard-to-reach areas (WRI, 2023).[29]

Public-private partnerships (PPPs) further strengthen these efforts by mobilizing resources for renewable energy projects. By sharing risks and costs, governments and private investors are working together to deploy large-scale PURE initiatives. For instance, collaborative programs in countries such as Nigeria combine public-sector policy support with private-sector investment to scale up solar-powered technologies for rural electrification.[30] These partnerships, along with policy innovations and financing mechanisms, are crucial for advancing the productive use of renewable energy in Africa, addressing energy poverty, and enhancing economic resilience in rural communities.

Living Systems Approach:

- ***Threshold-Based Subsidies:*** Rather than awarding incentives based solely on units sold or households connected, integrate ecological performance metrics (e.g., water table levels, avoided emissions, biodiversity impacts). This prevents subsidies from inadvertently promoting unsustainable resource use.
- ***Community Equity Shares:*** Instead of all gains accruing to private investors or large institutions, create shared ownership structures for local communities (e.g., cooperative models or partial stock ownership).

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[27] Pueyo, A., Bawakyillenuo, S., Osiolo, H., 2016: *Cost and Returns of Renewable Energy in Sub-Saharan Africa: A Comparison of Kenya and Ghana.* IDS Evidence Report 196.

[28] World Bank, 2022: *World Bank Group Announces Major Initiative to Electrify Sub-Saharan Africa with Distributed Renewable Energy.* https://www.worldbank.org/en/news/press-release/2022/11/09/world-bank-group-announces-major-initiative-to-electrify-sub-saharan-africa-with-distributed-renewable-energy

[29] World Resources Institute (WRI), 2023: *How Local Banks Can Unlock Africa's Clean Energy Future.* https://www.wri.org/insights/how-local-banks-can-unlock-clean-energy-in-africa

[30] Bhattacharyya, S.C., Palit, D., 2016: *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Studies from South Asia.* Springer.

- ***Systems Thinking in Financing:*** Align financial mechanisms with the goal of regenerating natural systems. For instance, a community could earn performance-based payments if solar irrigation projects include practices that restore soil health and reduce deforestation.[31]

Off-grid refrigeration technologies

Off-grid refrigeration technologies are an integral part of the Productive Use of Renewable Energy (PURE) framework, addressing critical challenges in food preservation, healthcare, and economic development in energy-poor regions. Solar refrigeration units (SRUs) enable rural farmers to store perishable goods such as milk, fruits, and vegetables, reducing post-harvest losses by up to 40% and increasing income through extended marketability. These units also support local businesses by providing reliable refrigeration for food processing and storage, promoting economic diversification and resilience. In the healthcare sector, solar refrigerators ensure the safe storage of vaccines, blood samples and temperature-sensitive medicines, particularly in remote areas with unreliable grid connections. By using renewable energy, PURE off-grid cooling increases food security, economic independence, and climate resilience, demonstrating the transformative potential of decentralized renewable energy solutions.[32]

SokoFresh in Kenya

A best practice example of off-grid refrigeration within the PURE framework is SokoFresh in Kenya. This initiative provides smallholder farmers with access to mobile, solar-powered cold storage units, each with a capacity of 5 metric tons. These units are strategically deployed during harvest seasons. By reducing post-harvest losses by up to 40%, SokoFresh allows farmers to preserve their produce longer, ensuring they can sell at better market prices and significantly increase their income. SokoFresh operates on a pay-per-use model, making this technology affordable and accessible even to smallholder farmers with limited financial resources. Beyond preserving food, the initiative strengthens agricultural supply chains, reduces waste, and improves food security. The decentralized solar-powered refrigeration units operate independently of unreliable grid connections, providing reliable storage solutions in remote and underserved areas. This model also promotes local economic development by enabling farmers to access higher-value markets and encouraging sustainable agricultural practices. By integrating renewable energy into the agricultural value chain, SokoFresh demonstrates how off-grid refrigeration can drive economic independence, enhance food security, and build resilience to climate and economic shocks.[33]

Conclusion

Energy poverty remains a critical challenge, with 675 million people—mostly in sub-Saharan Africa—still lacking access to electricity. This gap disproportionately impacts rural communities, women, and low-income households, restricting economic opportunities, healthcare, and education. While progress has been made, current efforts are insufficient to meet global energy access goals.

[31] Mang, P., & Haggard, B., 2016: *Regenerative Development and Design: A Framework for Evolving Sustainability.* Wiley.

[32] Byrne, R., Schoots, K., Holloway, R., & van der Plas, R., 2023: *Reinventing Refrigeration for Off-Grid Use in Sub-Saharan Africa*. Clean Energy, 7(3), 635–649. https://academic.oup.com/ce/article/7/3/635/7174941

[33] CAAS Initiative, 2022: *Case Study: SokoFresh – Solar-Powered Cold Storage for Smallholder Farmers in Kenya.* https://www.caas-initiative.org/wp-content/uploads/2022/04/Case-Study-Sokofresh_April6.pdf

Renewable energy, particularly decentralized solutions such as solar irrigation, microgrids, and off-grid refrigeration, offers a viable path forward. The *Productive Use of Renewable Energy (PURE)* approach demonstrates how renewable energy can enhance agriculture, create jobs, and improve resilience to climate change. Initiatives like SokoFresh in Kenya and EnDev in Ghana highlight how solar-powered cold storage and irrigation enhance food security and economic stability. However, for renewable energy to be truly sustainable, projects must be designed to work with, rather than against, local ecosystems. Energy transitions should not simply replace fossil fuels but actively regenerate landscapes, protect water resources, and restore biodiversity.

Scaling renewable energy solutions requires innovative financial models such as pay-as-you-go (PAYG) systems, results-based financing (RBF), and public-private partnerships. These mechanisms help lower the upfront costs of clean energy, making it more accessible to underserved populations. However, a shift in approach is needed—beyond electrification rates, success must also be measured in terms of ecological regeneration, social inclusion, and long-term resilience.

Energy poverty solutions should move beyond technical electrification efforts to embrace a living systems perspective, where energy access is integrated with ecosystem restoration and local community empowerment. By aligning energy transitions with environmental and social well-being, we can ensure that progress toward universal access is not just about providing electricity, but about creating thriving, resilient societies in harmony with nature.

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