CHAPTER 9

Rural Clean Energy Access
Accelerating Climate Resilience

CLAUDIA RINGLER, ALEBACHEW AZEZEW BELETE, STEVEN MATOME MATHETSA, AND STEFAN UHLENBROOK

Claudia Ringler is deputy director of the Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC. **Alebachew Azezew Belete** is a senior energy researcher, Ministry of Water and Energy, Ethiopia. **Steven Matome Mathetsa** is a senior scientist, Eskom Research, Testing and Development, Johannesburg. **Stefan Uhlenbrook** is strategic program director, Water, Food and Ecosystems, International Water Management Institute, Colombo.

KEY MESSAGES

- Rural livelihoods in low- and middle-income countries are doubly jeopardized by energy poverty and climate change. Lack of access to affordable clean energy reduces agricultural productivity, affects health and nutrition outcomes, and adds to environmental degradation, which in turn, further contributes to climate change.
- Reliable access to clean energy can protect rural households against adverse climatic events and support new off-farm economic opportunities. Accelerating a rural clean energy transition will thus be key not only to reducing climate change but also to improving rural lives and livelihoods.
- Existing rural lending mechanisms are often unsuitable for the purchase of clean energy technologies, such as photovoltaic solar panels.

Several actions can accelerate rural access to clean, sustainable energy for all:

- Identify locations where promising energy and water sources and productive uses are in close proximity; this can jointly support energy, water, and food security without compromising ecosystem health.
- Create an enabling environment for accelerated clean energy development. This requires integrated governance across the water-energy-food-environment sectors, including institutions that can help identify synergies or trade-offs with natural resources and livelihoods and thus grow positive impacts. It also requires equitable access to energy through investments, incentives, and direct support for poor farmers and entrepreneurs.

- Develop appropriate financial incentives to expand dissemination of clean energy technologies to underserved rural populations, for example, credit at lower interest rates linked to climate mitigation and productive uses of clean energy. Implementation of these financial incentives will require capacity building for both credit suppliers and smallholder farmers.
- Strengthen women's agency in rural clean energy systems. Women and men experience energy and water poverty differently, and energy technologies are often aimed at men. Promoting a women-centered clean energy program can trigger multiple social, economic, and environmental benefits in rural communities.

Globally, the energy sector accounts for almost three-quarters of total greenhouse gas (GHG) emissions[1] and is thus responsible for the majority of adverse climate change impacts on rural livelihoods, including growing water, energy, and food insecurity and environmental degradation. According to a recent report from the Intergovernmental Panel on Climate Change, annual investments of US$2.4 trillion (2010 dollars) in energy systems are needed to limit global warming to 1.5°C.[2] Such investments would support decarbonizing the largest polluters and improving energy efficiency. More and cheaper clean energy technologies and greater energy efficiency are equally critical for accelerating access to energy in underserved rural areas in ways that promote ecosystem health and inclusivity.

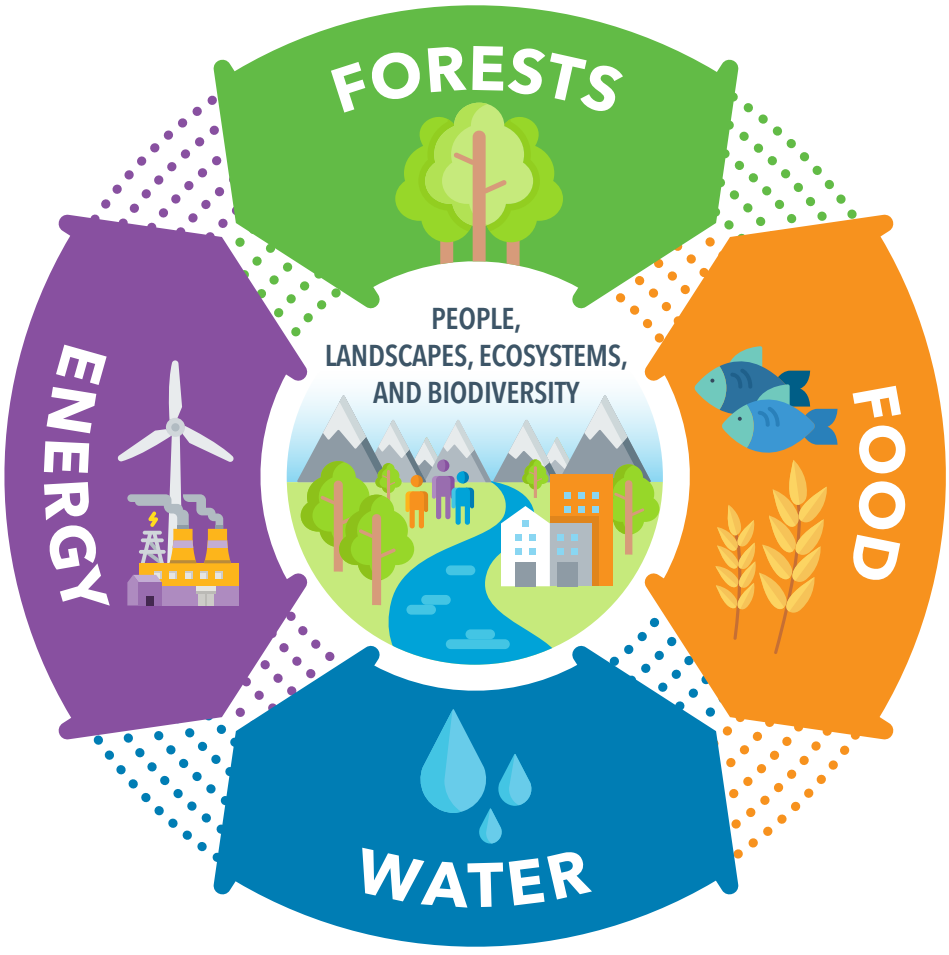
COSTS OF ENERGY POVERTY

Rural livelihoods in low- and middle-income countries are doubly jeopardized by climate change and energy poverty. Climate change diminishes water resources and thus reduces opportunities for food production

and access to water for other uses. At the same time, households that lack access to energy cannot pump or otherwise access sufficient water for crops, animals, and domestic use. Moreover, without cleaner and more efficient energy sources, these households must rely on fuelwood, crop residues, or cow dung for cooking, which degrades remaining forests and agricultural landscapes and has negative health impacts. This can result in a downward spiral of growing ecosystem degradation and vulnerability. Thus, water, energy, food security, and environmental sustainability are closely interlinked, and their interactions are experienced most acutely in rural areas (Figure 1).

Energy poverty is widespread in rural areas. As of 2020, close to 600 million people in rural sub-Saharan Africa and 170 million people in South Asia lacked access to electricity; and many millions more suffered from unreliable access. Even more people – 2.5 billion, most of whom are in rural areas – do not have options for clean cooking.[3] In addition, the COVID-19 crisis has further worsened energy poverty. Accelerating a rural energy transition will thus be key not only to reducing climate change but also to improving rural livelihoods. Reliable clean energy, such as solar power used for irrigation, can protect rural households against droughts and other adverse climatic events. For example, the Dhundi solar cooperative in Gujarat, India, allows farmers to sell back unused solar power to the grid at a guaranteed price. This constant source of risk-free income has incentivized

FIGURE 1 The linkages between rural energy access, water and food security, and ecosystem health



Source: IFPRI.

farmers to conserve groundwater and allows them to better weather drought and other adverse agricultural events.[4] A study in Bihar in eastern India assessed the impact of various drought-proofing programs on agricultural productivity and farmer welfare. It found that drought-relief programs and safety net programs were ineffective, as were subsidies on diesel for irrigation, due to delays, uncertainties, and high transaction costs. Solar-powered pump sets, however, were an effective drought-proofing strategy that allowed farmers to maintain yields during drought conditions.[5] Access to clean energy can also support new off-farm economic opportunities in agro-processing and other economic sectors that contribute to more diversified, resilient rural livelihoods.[6]

The cost of energy poverty is considerable, both for human and planetary health. Although its full impacts in rural areas remain unknown,[7] studies have shown that lack of clean energy access hampers agricultural productivity and stunts agriculture sector growth. It also stymies agribusiness growth; limits the production, storage, and consumption of nutritious, high-value foods; and places immense time burdens on women, contributing to their disempowerment.[8] Lack of access and use of clean energy also jeopardizes overall ecosystem health and biodiversity by directly contributing to deforestation, land degradation, and GHG emissions. One of many such pathways is through agriculture: lack of access to energy, including clean energy, reduces agricultural productivity,[9] while intensified agricultural systems lower emissions.[10]

Several studies show direct links between lack of electricity and poor health and nutrition outcomes. The use of traditional fuels for cooking causes more than 1.5 million deaths every year, mostly of women and children. Moreover, women and children are also often responsible for collecting fuel for cooking,[11] a time obligation that can deprive them of education or income-generation opportunities. While research on the linkages between energy access and nutrition remains limited, a few salient findings are emerging. A study in Nigeria looked at the relation between children's nutrition outcomes and energy access. Using nighttime light intensity as an indicator of electricity access and urbanization, the study showed that nighttime light is a significant predictor of stunting and chronic malnutrition (height-for-age z-scores [HAZ]) for children under the age of five through welfare impacts,[12] even after controlling for other factors known to influence stunting. Likewise, in rural Bangladesh, research found that electricity access can improve children's nutrition (using HAZ as the indicator).[13]

At the same time, use of fossil and biomass fuels rather than clean energy sources contributes directly to climate change. Reliance on fossil-fuel-driven pumps is a common response to clean energy poverty that contributes to climate change. In India, for example, fossil-fuel driven groundwater irrigation is estimated to account for 8 to 11 percent of total national GHG emissions.[14] On the other hand, increasing access to clean energy can increase agricultural productivity — and also reduce deforestation and forest degradation, thus helping to preserve biodiversity and even lessen zoonotic disease risk by reducing interactions between wildlife and humans — without adding to GHG emissions.[15]

CLEAN ENERGY INNOVATIONS

Clean energy innovations suitable for rural areas, including farming and small enterprises, are becoming more readily available. One important innovation is small-scale solar power technologies that can be used to pump water for domestic uses and for irrigation, which can support the production of high-value vegetables and fruits.[16] New solar technologies can also be used to cool poultry houses as well as milk containers for storage and transportation. These cold-chain advances can improve productivity and food safety and extend the shelf life of nutritionally dense and high-value foods such as milk, eggs, and green leafy vegetables, especially as temperatures are rising.[17] For rural entrepreneurs, solar driers can improve the quality and safety of harvested products, including fish and fruits. However, the upfront costs of solar technologies remain too high for most smallholder farmers, and rural lending is dominated by business and finance models that are designed for the purchase of seeds and fertilizers (which have lower costs and quicker returns on investment), but are not suitable for higher cost, longer-term investments in solar or other

clean energy equipment by small farmers or business owners.

Decentralized or distributed renewable energy (DRE) systems are another clean energy solution that is increasingly available and suitable for rural areas. These systems can provide locally generated electricity for farm production and drinking water systems. They can also provide electricity for public buildings such as medical facilities and schools. Microgrids can integrate electricity inputs from multiple sources, including solar photovoltaic panels, micro-hydropower systems, and diesel generators. With proper integration of storage and load management, systems operating at a local scale can power economic activities beyond the farm, substantially benefiting local economies. Such systems, however, generally require outside finance for initial establishment and creative finance models to ensure sustainability.[18]

OPPORTUNITIES TO ACCELERATE CLEAN ENERGY ACCESS IN RURAL AREAS

The costs of clean energy technologies have declined substantially over the last two decades,[19] but technology uptake has remained low in many rural areas that would particularly benefit from better energy access. In addition to substantial upfront investment costs, weak supply chains and services, inadequate financing mechanisms and financing ecosystems, complex technologies, and the high cost of borehole drilling services have been identified as limiting uptake.[20]

Food production remains the primary rural livelihood activity in low- and middle-income countries, and thus the most obvious entry point for the development of a thriving energy technology market. However, for widespread adoption to occur, critical investments are needed to establish enabling frameworks that can match potential users with appropriate water and energy systems; to develop institutions across the water-energy-food-environment sectors to ensure that adverse environmental impacts are reduced or avoided; to increase access and equity by developing appropriate finance mechanisms that are accessible to smallholder farmers and small entrepreneurs; and by strengthening women's agency in clean rural energy systems.

To accelerate rural access to clean, sustainable energy, we propose the following five steps:

IDENTIFY LOCATIONS FOR PRODUCTIVE USES THAT CAN JOINTLY SUPPORT ENERGY, WATER, AND FOOD SECURITY WITHOUT COMPROMISING ECOSYSTEM HEALTH. The identification of appropriate productive energy uses in the agrifood sector, particularly in places where promising energy and water sources and producers and next users are in close proximity, can accelerate clean rural energy access. Various recent efforts have focused on co-locating energy investments and productive users, primarily irrigation operations or agro-processing centers. To identify potential locations, the International Water Management Institute (IWMI) has developed an online solar suitability tool[21] using a GIS-based multi-criteria evaluation technique that accounts for solar irradiation, slope, groundwater levels, aquifer productivity, groundwater storage, groundwater sustainability, population, roads, and travel time to markets. A study conducted by IFPRI researchers analyzed the economic feasibility of solar irrigation across Africa, considering cropping patterns, costs of solar-powered pumps and alternative pumps, and a set of biophysical factors. Groundwater-fed solar irrigation was found to be cost-effective in southern and central Africa, but less so in countries that subsidize diesel fuel (Angola, Nigeria, and Sudan). Solar panels were also more economical than diesel pumps for more water-intensive crops.[22] Another study identified priority areas for on- and near-farm electricity using geospatial analysis.[23] And a study in Ethiopia focused on the economic benefits from alternative productive use investments, such as horticulture irrigation, grain milling, *injera* baking, milk cooling, bread baking, and coffee washing — estimating a joint potential to generate $4 billion annually following electricity rollout by 2025.[24] Additional income would be generated from the purchase of mechanized equipment. However, studies such as these are seldom incorporated into planning for energy systems, which tends to focus narrowly on optimizing energy systems rather than considering their impacts on rural livelihoods and well-being.

DEVELOP INSTITUTIONS ACROSS THE WATER-ENERGY-FOOD-ENVIRONMENT SECTORS TO

STRENGTHEN SYNERGIES AND REDUCE TRADE-OFFS. Many countries continue to develop energy strategies without considering potential synergies or trade-offs with either natural resources, including water and land, or other sectors and actors, such as food production. Single-sector strategies are likely to miss important synergies and ignore trade-offs associated even with cleaner energy technologies. This can lead to unnecessary costs and environmental damage. For example, the installation of large fields of solar panels can compete with agricultural production areas or natural habitats, thus affecting food security, livelihoods, and biodiversity. Similarly, unfettered development of solar-powered irrigation can lead to overexploitation and degradation of groundwater resources. With fuel-based technologies, fuel costs rise with the amount pumped and thus create an incentive for water conservation.[25] For solar technologies, however, there are no additional financial costs to pumping more water – so well-designed strategies and strong institutions are needed to protect against unsustainable water withdrawals and related environmental degradation.[26] To address this, institutions that jointly consider food, energy, water and environmental systems are needed. The Niger Basin Authority in West Africa is one example. The agency works directly with ministries of water, energy, agriculture, and environment in its nine basin countries and is currently developing a legal document to actively consider trade-offs across these sectors for more effective implementation of the Niger Basin Shared Vision for sustainable development.[27]

ENSURE EQUITABLE ACCESS TO ENERGY THROUGH INVESTMENTS, INCENTIVES, AND DIRECT SUPPORT. In addition to minimizing environmental damages from energy development, an enabling framework for broadening clean energy access to poorer farmers and entrepreneurs is needed. This is a tall order. Both Ethiopia (Box 1) and South Africa (Box 2) have been working toward accelerating clean energy access, with mixed results.

Ethiopia aims to ensure energy access for all by 2025. Despite this ambitious goal and considerable investment, more than half of Ethiopia's population still lacks access to reliable electricity, especially in rural areas, which remain dependent on fuelwood and kerosene. In South Africa, the Renewable Energy Independent Power Producer Programme (REIPPP)[28] allows private industries to produce clean electricity for both non-grid and grid systems (including feed-in of surplus energy generated). This has increased the development of photovoltaic solar energy systems for both individual and industrial use. Rural areas, however, lag behind in adopting these systems due to lack of funding, inappropriate business models, rural poverty, and a relative neglect of these areas. This is a missed opportunity, given that South Africa's rural areas offer both abundant space and sunlight to generate and use solar power.

BOX 1 THE CHALLENGES OF ACCELERATING ENERGY ACCESS IN ETHIOPIA

Most of Ethiopia's 115 million people live in rural areas, where only 29 percent have access to electricity.[a] The country has one of the lowest electricity consumption levels in the world, at just 80 kWh hours per capita, compared with 12,154 kWh in the United States.[b] Although the government is implementing various programs and strategies to achieve universal electricity access and has plans to become an important energy exporter, there are major challenges in extending access to rural areas. These include capacity, technological, and economic limitations, underdeveloped rural infrastructure, poor information sharing, and political barriers. The energy sector in the country lacks indigenous organizations that adapt international technologies or develop their own options for use in more remote areas.[c] Moreover, heavy regulation of the sector has limited private investments in this capital-intensive sector. Finally, transboundary political challenges linked to Ethiopia's flagship energy project, the Grand Ethiopian Renaissance Dam (GERD), have slowed other rural energy development projects.

BOX 2 SOUTH AFRICA'S ENERGY PROGRAMS

South Africa's Integrated National Electrification Programme (INEP), launched in the post-apartheid era, increased electricity access from 35 percent of the population in 1994 to approximately 88 percent by 2018.[a] The program, which includes free basic electricity for poor households, has reduced rural households' reliance on firewood and cow dung as energy sources. However, energy supply has not kept pace with growing demand, leading to frequent supply interruptions or "loadshedding," as parts of the electric grid are temporarily shut off. The country is also grappling with the need to reduce dependence on fossil fuel technology as well as with rising costs of electricity production.[b] One response has been the Renewable Energy Independent Power Producer Programme (REIPPP), which supports the use of clean technology for both small- and large-scale rural-based activities, including food production, postharvest processing, domestic water use, and water pumping for irrigation. However, poor farmers are unable to meet the program's requirements, slowing the expansion of rural clean energy. As a result, some rural communities have returned to using wood and dung as domestic fuels.

DEVELOP APPROPRIATE FINANCIAL INCENTIVES FOR UNDERSERVED RURAL POPULATIONS. In most rural areas of low- and middle-income countries, finance systems have not developed appropriate mechanisms to support investment in clean energy technologies by smallholder farmers and small entrepreneurs. Most credit facilities are designed for crop production — loans are small and require repayment within or following a single growing season. Energy technologies such as solar-powered pumps require larger loans and longer payback periods to be affordable by poor farmers. Also, given the potential of these technologies to lower the risk of default due to climate shocks, credit should be offered at lower rates. Few credit providers, however, have developed financial products targeted at clean energy technologies for rural clients. The development of appropriate financial incentives will require capacity building for both suppliers and smallholder farmers. Pay-as-you-go systems, where users pay for use time rather than the solar system, have become common for home solar systems, and are now being piloted for smallholder irrigation systems as well. However, the high seasonal variability of irrigation requires greater flexibility than is needed for home systems. A set of business models has been proposed for solar pumps in Ethiopia, including an outgrower or insurance scheme where agribusinesses working with contract farmers develop flexible payment mechanisms or even provide the pump for free, if the cost could be recouped through increased production.[29]

STRENGTHEN WOMEN'S AGENCY IN CLEAN RURAL ENERGY SYSTEMS. Women and men experience energy and water poverty differently because of their different assets and culturally and socially determined divisions of labor. Women are most often responsible for securing both water and energy sources for domestic use, affecting their availability for care work, income generation, and leisure.[30] However, technologies to secure access to water and energy for productive uses, such as agriculture and livestock rearing, continue to be aimed at male farmers. For example, most solar and other mechanized irrigation pumps are managed by men; this can contribute to women's disempowerment and lower incomes from the crops and livestock that women manage.[31] Depending on how energy, water, and irrigation systems are designed, implemented, and managed, women and men will benefit differently, with the burden on women potentially increasing rather than decreasing. Thus, for rural energy technologies to achieve their full potential, women-centered clean energy programs are needed. As an example, the Self-Employed Women's Association, a trade union of women working in India's informal sector, is running a solar irrigation pump program geared to its farmer members. To overcome women's key challenge of upfront down payments for energy equipment, the program facilitates separate loans for down payments

sourced from a second bank; this not only increases access by women farmers to this technology but also reduces banks' overall lending risks.[32] Similarly, GROOTS Kenya, a grassroots women's organization, developed a biogas program to support women members who could not afford the cost of electricity for cooking in selected rural districts.

UNLOCKING THE BENEFITS OF CLEAN ENERGY

Accelerating rural clean energy investments can unlock access to water resources, increase food security, expand rural employment, increase incomes, and build climate resilience by contributing to both adaptation and mitigation. Reducing rural energy poverty is also critical for social justice, human development, and planetary health. Despite growing evidence of the synergistic role of energy strategies in the water-energy-food-environment nexus, most energy plans continue to be developed in siloes, and therefore lead to sub-optimal outcomes. A stronger focus on processes and institutions, as well as incentives for social inclusion could help accelerate access and increase benefit streams and, importantly, reduce environmental damage by supporting clean energy access for all.