WFP
World Food Programme
SAVING LIVES
CHANGING LIVES

The role of clean energy in food value chains

Smallholder farmers (SHFs)—who make up 80% of farms in sub-Saharan Africa[1]—play a central role in food production, yet face persistent poverty and food insecurity. Most rely on small plots, manual labor, and rain-fed agriculture, with women comprising over half the workforce.

It's no coincidence that fewer than one in three people in rural areas have access to electricity, as this represents a fundamental obstacle to development, including agricultural productivity[2]. Investing in sustainable energy—particularly solar—can transform rural economies by creating youth employment, and making farming more viable. Energy access is essential to increase production, reduce post-harvest losses, improve market access, and build food security and resilience.

"Sustainable energy powers opportunity. Yet more than 1 billion people – one in seven people globally – lack electricity to light their homes, refrigerate their food or conduct business" - Sustainable Energy for All[3].

This note explores how clean energy can serve as **an enabler** across different stages of food value chains, identifying key services, barriers, and programmatic entry points for sustainable impact.

ENERGY SERVICES

Energy underpins every stage of the agri-food value chain—from land preparation to market access—yet remains largely overlooked in agricultural development:

Energy for food production. In Sub-Saharan Africa, where only 6% of cultivated land is irrigated[4], limited access to affordable electricity for water pumping means that farmers largely depend on increasingly unpredictable rainfall, insufficient or untimely irrigation, resulting in crop stress, reduced yields, delayed cropping cycles, and in some cases, complete crop failure—particularly under increasing climate variability. Without energy for tractors or tillers, farmers rely on labor-intensive practices that

1 https://www.fao.org/family-farming/detail/en/c/289255/

2 Energy access investment, agricultural profitability, and rural development: time for an integrated approach, https://pure.iiasa.ac.at/id/eprint/17524/

3 https://www.seforall.org/energy-access

4 2014, IFAD "Fulfilling the promise of African agriculture", https://www.fao.org/family-farming/detail/en/c/380877/

September 2025

limit land cultivation area, delay harvests, and reduce yields. Mechanization constraints both land use intensity and labor productivity, especially during peak seasons when timing is critical. Manual labor limits cultivated area to ~1.5 ha per year, compared to 4 ha with animal traction and 8 ha with mechanized equipment[5]. Women, who often bear the brunt of manual labor in agriculture and are also less able to perform heavy tasks, are disproportionately affected by lack of energy to power mechanized work. Improving access to energy can significantly reduce the physical burden on women and free up time for other income-generating activities, and social engagement in the community.

This energy gap not only limits production but also leads to significant post-harvest losses, hindering overall value.

Energy for post-harvest management. One-fifth of food produced for human consumption is lost or wasted each year globally along the agriculture value chain. This amounts to one billion meals a day[6]. According to FAO, recovering just one-fourth of all lost food would serve to end global hunger[7]. In most developing countries, food waste occurs during the early and middle stages of agricultural value chains, from production to retail. This stems from limited cold storage, inefficient harvesting, inability to process crops into more stable and higher value products or quickly transport them to wider markets.

A range of energy services along the agri-food value chain is represented in Table 1. While **mechanized labor** enables efficient land clearing, tilling, preparation and harvesting, **water pumping** facilitates land irrigation, water distribution and lifting and aquaculture. **Biodigestion** systems generate both thermal energy and nutrient-rich sludge that can be used as biofertilizer. **Energy-powered storage and post-harvest handling** include milling, grinding, and de-husking. Perishables are preserved through refrigeration, freezing, drying, smoking, pasteurization, and packaging. Quicker **transport** maximizes trading opportunities by bringing goods to the best markets in a timely and affordable way. Energy also powers **connectivity and effective communication**, enabled by devices such as mobile phones, radios and TVs that connect farmers to market information, weather alerts, and financial services. These devices, crucial to adapt to climate change, all need plugging or charging.

TABLE 1. ENERGY SERVICES ALONG AGRI-FOOD VALUE CHAINS

VALUE CHAIN STAGE	ENERGY SERVICE
Food production	Land clearing, tilling & preparation, fertilizing, harvesting, water pumping & irrigation, biogas and biofertilizer generation
Food processing	Milling, grinding, de-husking, pressing
Food preservation	Refrigeration, drying, smoking, pasteurization, canning, sealing
Transport	Cold chain, eVehicles
Communication	Solar charging systems for communication devices, phones, radios, internet

5 2006, FAO "Farm power and mechanisation for small farms in sub-Saharan Africa" Sims, B. et Al. and J. Kienzle., https://openknowledge.fao.org/items/3ccc1135-9251-4d3a-86b7-1f8ef5c6012a

6 UNEP Food Waste Index Report 2024, https://www.unep.org/resources/publication/food-waste-index-report-2024

7 https://www.fao.org/in-action/seeking-end-to-loss-and-waste-of-food-along-production-chain/en/

Despite the relatively high up-front capital investment, these technologies enable greater returns for agricultural output and often have short payback periods. Renewable sources of energy such as solar, hydropower and wind have become more favorable than fossil fuels due to higher efficiency, reliability and considerably lower operational expenses, while producing less GHG emissions. Switching from diesel to solar water pumps can save farmers up to $2,110 per year in operational costs in some contexts[8]. From an environmental viewpoint, the agri-food system is responsible for about a third of global greenhouse gas emissions, due to its reliance on fossil fuels and inefficient biomass use[9] (e.g. firewood for cooking, heating, or crop drying), contributing to deforestation and air pollution.

THE ROLE OF ENERGY ACCESS PROGRAMMES IN WFP

WFP's procurement for food assistance programmes provides farmers with a reliable income that enables investments in mechanization and improved productivity, laying the groundwork for agricultural transformation.

In Honduras' Home-Grown School Feeding (HGSF) programme for example, the regular food basket is complemented with locally purchased fresh and diversified food, such as vegetables and eggs. In Kenya, schools are able to purchase fresh food locally, thanks to WFP's cash support transferred to their bank accounts.

However, the broader diffusion of HGSF's approach is limited by local smallholder farmers' capacity to meet food's quality and quantity demand, which can be substantially improved also through boosting energy access.

A value chain analysis in Sierra Leone highlighted that "lack of appropriate machinery and tools needed for processing, presents the biggest strain on the cassava value chain, a main income source for many farmers — men and women — across the country". Storage and processing gaps also limit rice production, while challenges in transportation and cold storage affect the inclusion of protein-rich legumes in HGSF meals. The analysis further emphasized the need to extend the shelf life of fresh food and improve fish smoking techniques to reduce the environmental impact on forests.

Through its Smallholder Agricultural Market Support (SAMS) programmes, WFP increases smallholder farmers' resilience by promoting inclusive access to markets, providing agricultural inputs and training, fostering aggregation systems, and expanding access to energy services and equipment. Over 1.9 million smallholder farmers in more than 52 countries benefit from WFP's agriculture market development activities which offer stable market opportunities, enhance income security, and drive productivity. Integrating affordable and sustainable energy solutions into these efforts further accelerates food systems transformation.

8 Best, S. (2014). Growing Power: *Exploring energy needs in smallholder agriculture*, https://www.iied.org/16562iied

9 Our World in Data, How much of global greenhouse gas emissions come from food?

COMMON CHALLENGES OF ENERGY PROGRAMME DESIGN

Energy programming consists of delivering supporting interventions that, by addressing market barriers, enable private sector actors along local energy value chains to provide energy services to end users.

In regions stricken by complex operating environments, poverty, isolation, or affected by social instability and conflict, such as urban slums, remote rural villages, displaced people's camps and war zone areas, markets fail. Developing or reviving local value chains is complex and costly, which leads development actors to procure and directly distribute energy products and services to beneficiaries, bypassing the disrupted local markets. Albeit effective and potentially cheaper, this approach does not yield a lasting impact, as it leaves the underlying system unchanged or even worsened. Not only does it distort, undermine and further weaken existing local markets, delaying recovery but it also ignores users' preferences and diversity by providing a one-fits-all solution. Importantly, the absence of connection between supplier and end users prevents after sale services, such as operations and maintenance, and substitution at the end of life. In addition, it falls short of creating a value chain for energy equipment with technicians able to repair it and owners willing to invest in maintaining it. Users' participation with own resources in the choice and purchase of products increases their inclination to value, maintain and use the product acquired. Other typical weaknesses that can aflict energy programmes are:

- "*technology-centred design*" that focuses on the selection of products and equipment, underestimating the importance of thinking through the whole energy delivery model.
- *"solution-centred design"* that starts from a preferred solution and bypasses critical steps such as needs assessment, contextualization, and market mapping to identify ongoing activities and opportunities.

Instead, enabling the delivery of energy products and services sustainably, requires for development actors to strengthen existing delivery networks and work in collaboration with the local private sector. Delivering energy products and services without resorting to free distributions requires reinforcing value chains that can sustainably function within their enabling environment and socio-cultural context. Beneficiaries reached through energy market systems are regarded as "customers" who can express their needs and wants through an active choice. In much the same way as Cash-Based Transfers for food enable beneficiaries to choose what food they prefer, energy vouchers allow customers to acquire what is most relevant to them.

APPROACHES TO SUSTAINABLE ENERGY PROGRAMMING IN AGRICULTURE

Designing interventions that deliver energy access in a sustainable way, for the long term, entails understanding how energy value chains should work and what prevents them from being effective. The analysis of energy value chains starts from:

- the recognition of **energy gaps** in food value chains
- the selection of **energy services** that can fill those gaps
- the identification of **barriers** that prevent those energy services from being delivered to end users
- the design of **supporting activities** to address those market barriers.

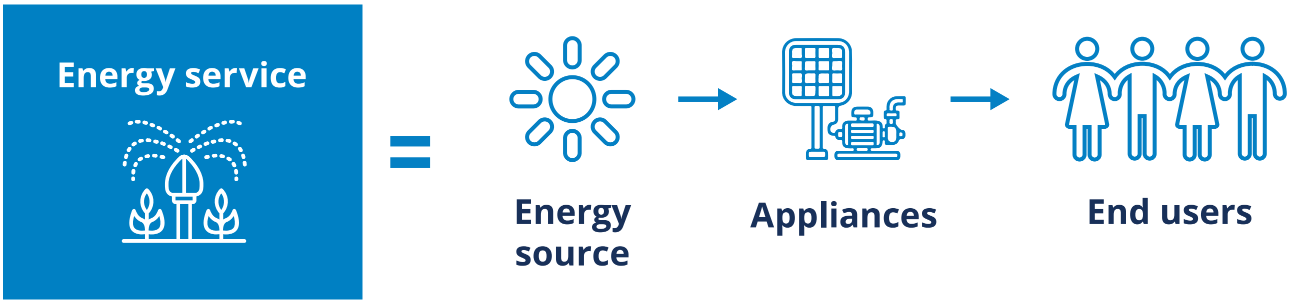

Figure 1. Energy services (e.g. regular crop watering) are functions (e.g. irrigation) powered by energy sources (e.g. solar) and performed through appliances (e.g. water pumps) to meet the needs and wants of end users (e.g. higher, more regular crop yield).

ENERGY GAPS, SERVICES, BARRIERS AND SUPPORTING ACTIVITIES

Common energy gaps or energy needs, such as low food production levels or inadequate food processing and preservation, leading to lower quality food and high post-harvest losses, are identified in conversation with governments and communities. Energy gaps are filled by **energy services** (e.g. cooking, lighting, heating, cooling, irrigating, de-husking, milling), defined here as functions powered by energy sources (e.g. solar radiation, wind, oil, gas, biomass) and performed through appliances (e.g. cookstoves, lanterns, fridges, mills, water pumps) that use an energy source that meet the needs and wants of end users (i.e. households, institutions and agri-food businesses or farmers). To address energy gaps sustainably, energy services need to be economically affordable, environmentally and financially sustainable, available where needed, convenient for the end user and surrounded by an ecosystem that ensures sustained use (e.g. maintenance, repair and end of life substitution). Energy gaps are caused by **energy barriers** or obstacles, that prevent energy value chains from being functional and effective in delivering energy services to end users. There are understandable reasons (the barriers) why underserved communities lack access to energy, including low purchasing power, low population density, isolation, poor infrastructure (e.g. roads, electricity and gas grids, mobile telephone network and internet), adverse laws and regulations, lack of local skills, lack of transparency in rules and regulations, lack of upfront financing for suppliers and users, often worsened by exchange rate volatility. Each barrier can be addressed by governments, development organizations and, to some extent, market forces, by building, restoring or strengthening energy market systems through **supporting interventions**. Addressing barriers to strengthen energy value chains is a long term, sustainable alternative to creating artificial, temporary delivery activities that bypass and weaken local markets.

The list of supporting interventions aimed at addressing barriers and unleashing energy services becomes the set of project activities that make WFP programmes energy sensitive.

Approaches to addressing barriers in the value chain vary greatly and can for example include some of the supporting interventions /activities in Table 2.

TABLE 2. SUPPORTING ACTIVITIES TO HELP ENERGY MARKETS THRIVE

BARRIER	SUPPORTING INTERVENTION
Lack of investment capital (farmers cannot afford to purchase equipment)	Enable access to finance by creating linkages with credit institutions or saving groups.
Lack of awareness (farmers do not have knowledge of energy solutions and equipment)	Organize communication and awareness campaigns. Enable technology and knowledge transfer. Support private sector to present alternatives.
Lack of access to energy products (farmers do not know where or how to buy appropriate, good quality equipment)	Build market linkages between local vendors and suppliers.
Lack of distribution network (suppliers are reluctant to expand in rural areas with weaker commercial opportunities)	Attract suppliers through incentives (result-based financing) or increase demand through SMART subsidies.
Low end user affordability	Introduce access to credit and subsidies for the most vulnerable by designing smart subsidy schemes (e.g. partial, targeted to most vulnerable, phasing out). Attract financing institutions in the targeted area.
Lack of regulatory framework / import regulations are too complex, custom taxes are too high	Advocate with Government by documenting evidence on the benefits of the action. With partners, help governments to develop conducive energy strategies and plans.
Lack of investment finance	De-risk investment by ensuring demand with dedicated vouchers, allocating guaranty funds, etc.
Low quality of energy products	Map the market system to identify reliable local, regional or national actors and good quality products that meet international standards or certifications by renowned entities.
Lack of after sale services and appliances service	Work with enterprises that operate PV solar systems and energy services. Help local enterprises and farmers to develop economically viable business models that can pay for maintenance and replacement.
Energy services are economically unsustainable	Adopt market-based approaches emphasizing the need to balance costs and benefits of energy services.

ANNEX I – EDM a tool to designing sustainable energy services

A valuable tool to explore energy value chains in detail, and identify barriers that may prevent their successful functioning, is the **Energy Delivery Model (EDM) Canvas**[10]. The EDM is a guiding framework to map how energy products are delivered, starting from production, through marketing, distribution and the end-use, also considering the surrounding enabling environment and socio-cultural factors that influence end users' choices.

Figure 2. The Energy Delivery Model Canvas

The EDM helps governments and development actors to identify energy services that meet the needs of beneficiaries in a sustainable manner, based on the local context, and to design supporting interventions that make the service viable. This involves:

- **Analysing** the opportunities and risks of each potential solution that addresses end users' needs and wants
- **Economically balancing** costs and benefits
- **Understanding which resources, processes and stakeholders** are required to deliver it
- Knowing the **enabling environment** in which energy services operate, and
- **Identifying the external supporting interventions** that will enable the sustainable functioning of the service.

10 An approach to designing energy delivery models that work for people living in poverty, https://www.iied.org/sites/default/files/pdfs/migrate/16551IIED.pdf

VALUE CHAIN

The energy value chain forms the backbone of the EDM Canvas, connecting energy solutions to the people that need them. It carries a Value Proposition to the End Users through a Delivery Structure while Accounting for economical balance. It encompasses governance, financing options, payment systems, management and ownership structures across the supply chain.

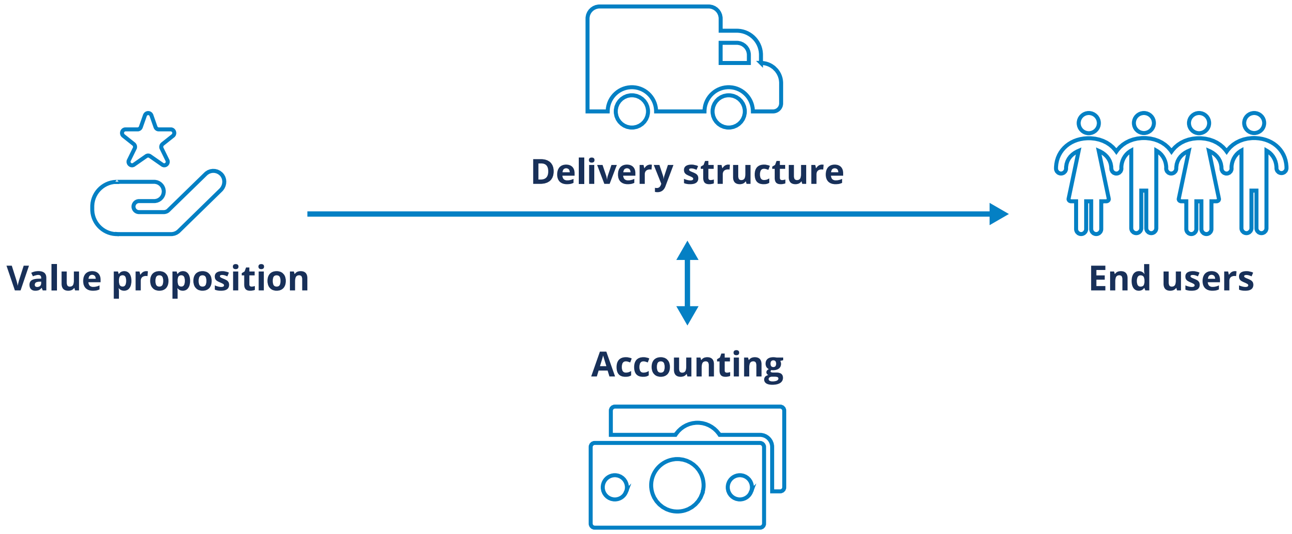

Figure 3. Energy value chain

End Users can be households, refugees and host communities, institutions (schools), farmers and local entrepreneurs such as processors and retailers in the agrifood industry. Also relevant is the **Socio-cultural context** in which they live, which describes how people interact and work together including behaviours, preferences, norms, tacit knowledge and power dynamics in groups and households. The **Value Proposition** is the proposed business idea and/or collection of products and services that is offered to meet end users needs and that makes the product or service valuable to the end user (e.g. irrigation). Proposed solutions (e.g. solar water pumping) must be better than what they displace (e.g. manual water lifting) either because they solve an existing problem or they create an extra benefit (e.g. makes the service cheaper, more efficient, convenient, easier to use or more performant, aspirational or simply accessible in the last mile). End users are reached through the **Delivery Structure** which is the set of activities, resources and networks of partners that are needed to deliver the energy product or service to the end user (e.g. the manufacturers of water pumps, their production facilities and companies they buy components from, the transport companies, importers, retailers, marketing and customer service activities, such as last mile shops etc). **Accounting** looks at the economic sustainability of the model. The solution must be financially viable to continue to exist in the market, meaning that service providers involved in the value chain must have enough revenues to cover the costs incurred to deliver the service and make a profit (e.g. the extra profit made through irrigation must generate enough income to cover for the upfront investment costs and operation of the solar irrigation system). However, the cost benefit analysis must also consider wider socio-environmental impacts. Energy products or services that bring broader benefits to society (e.g. increased national food sovereignty and security), can therefore be fully or partially subsidized. As a warning, it is useful to know that the vast majority (90%) of new businesses fail in the first 3 years because they do not understand their costs/revenue balance and what it will take to create the goods and services they offer.

ENABLING ENVIRONMENT AND SUPPORTING INTERVENTIONS

The **Enabling Environment** represents the set of norms, regulations, infrastructure and conditions surrounding the value chain (e.g. import taxes on components of solar photovoltaic systems, presence of telephone network to enable pay go payment systems, local presence of education facilities for electricians etc).

Supporting interventions are implemented by actors external to the value chain (i.e. governments and aid organizations) to build a well-functioning market system. These range from building market linkages, providing access to finance, delivering capacity building and more. The role of WFP is that of designing interventions that consist of all the necessary supporting interventions needed to build a viable value chain. These activities form the basis of a project proposal.

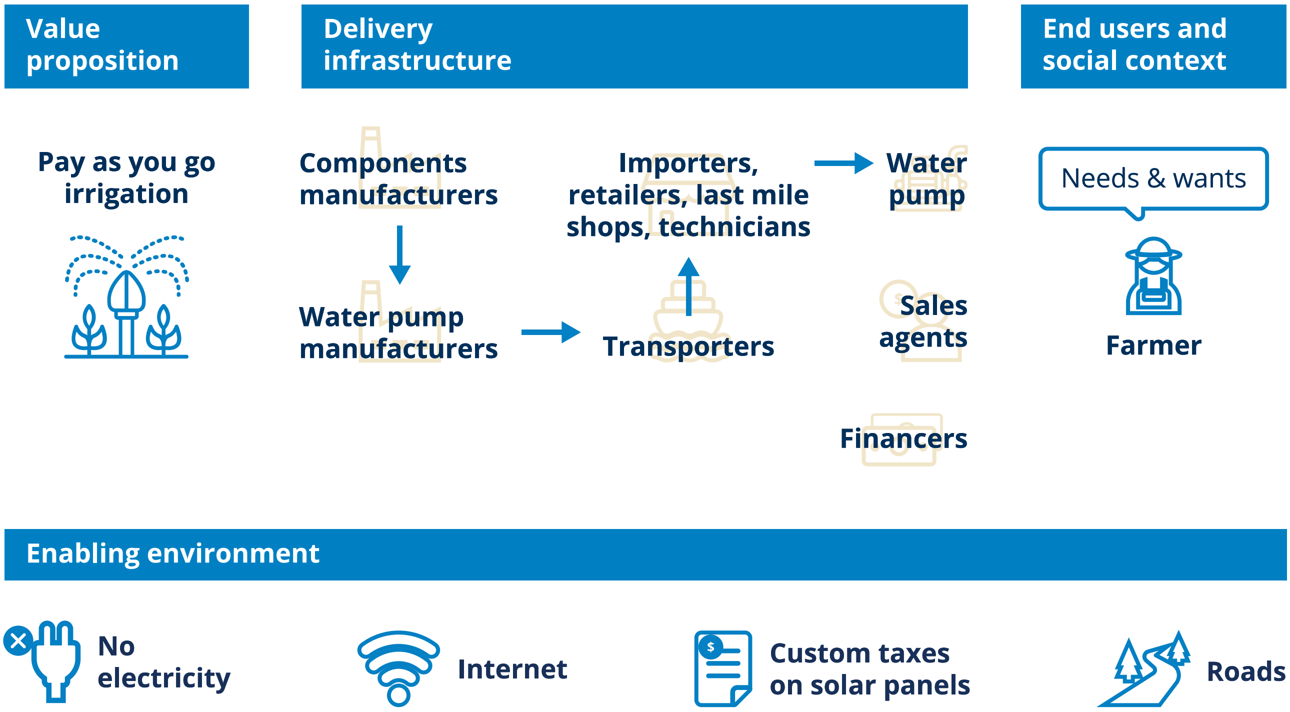

Figure 4. An example of value chain for irrigation

CLIMATE AND RESILIENCE SERVICE (PPGR)

World Food Programme
Via Cesare Giulio Viola 68/70,
00148 Rome, Italy - T +39 06 65131
www.wfp.org/energy-for-food-security

Photo page 1: WFP/Michael Tewelde
Photo page 3: WFP/Fredrik Lerneryd
Photo page 3: WFP/Badre Bahaji
Photo page 4: WFP/Richard Mbouet
Photo page 7: WFP/Madagascar CO
Photo page 8: WFP/Tsiory Andriantsoarana