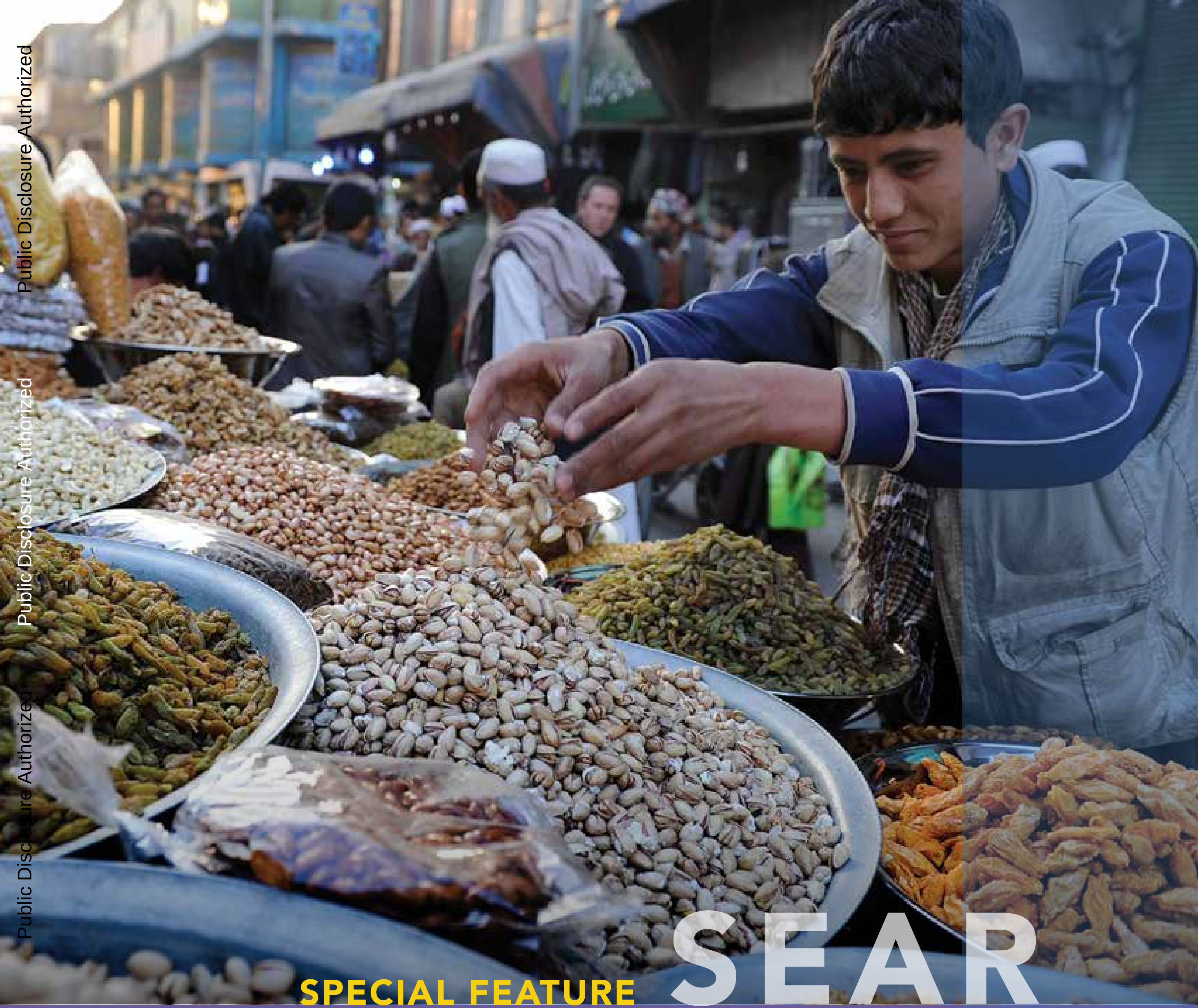

SPECIAL FEATURE SEAR

ENERGY ACCESS

FOOD AND AGRICULTURE

Olivier Dubois, Alessandro Flammini,
Ana Kojakovic, Irini Maltsoglou, Manas Puri,
and Luis Rincon, FAO

SEAR

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ENERGY ACCESS
FOOD AND AGRICULTURE

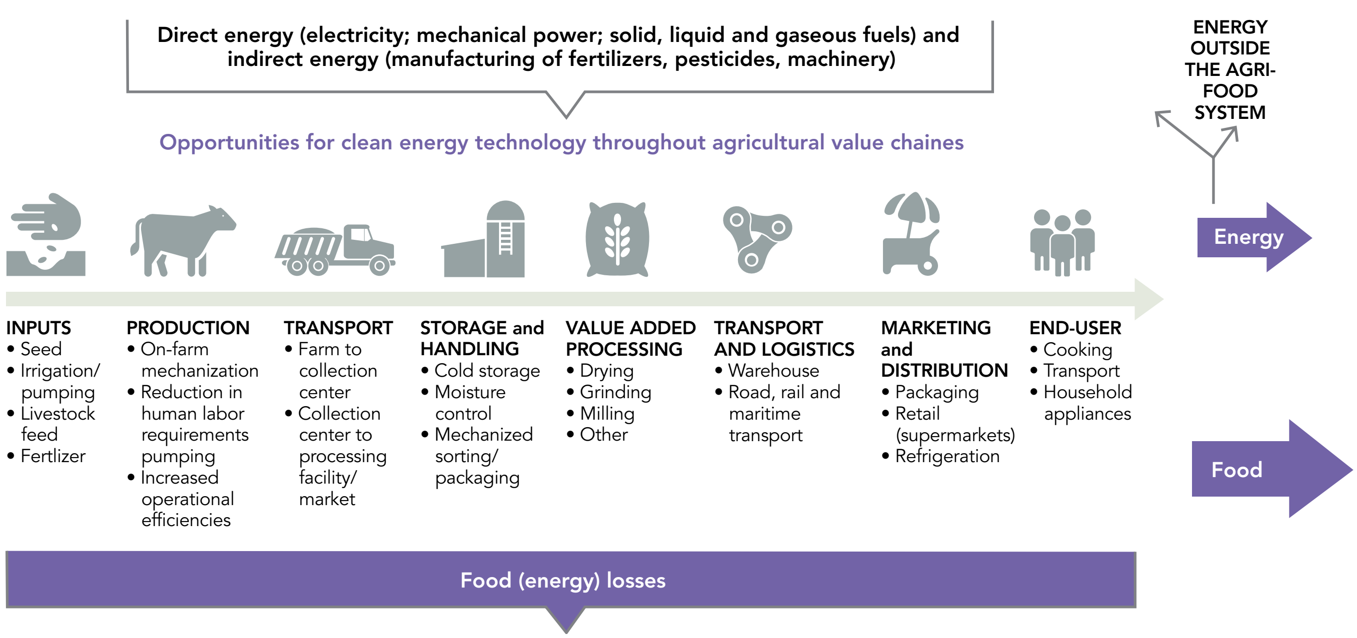
Olivier Dubois, Alessandro Flammini, Ana Kojakovic, Irini Maltsoglou, Manas Puri, and Luis Rincon, Food and Agriculture Organization of the United Nations

INTRODUCTION

Over the past century countries have been able to meet ever-higher food demands thanks to the availability of cheap fossil fuels in agriculture. But there is reason to worry about how much longer this situation can continue. If inexpensive fossil fuel ceases to be available, it will be extremely difficult to boost food production enough to meet projected food demand by 2050 (FAO is projecting a 60 percent food demand increase over 2006-07 levels). In addition, the use of fossil fuels has resulted in food systems becoming a major source of greenhouse gas (GHG) emissions, with significant contributions to global climate change. At the same time, changing climate patterns can cause severe droughts or floods and changes in water availability and soil quality, which may have a severe impact on agri-food systems. In some cases these changes can also alter energy needs. A lack of rainfall can lead to farmers resorting to the use of groundwater for irrigation, which requires energy for pumping; gradual land degradation can result in farmers using more chemical fertilizers, which require energy to manufacture.

Against this backdrop, the global community has been looking for ways to create a global food system that can support both food security and sustainable development or "energy-smart food systems", which (i) improve access to modern energy services, (ii) rely more on low-carbon energy systems, (iii) use energy more efficiently, and (iv) are deployed through a water-energy-food nexus approach. These systems take advantage of the fact that agri-food chains—which cover the manufacturing of inputs for farming, transport, processing, storage, and distribution of farm products, and food preparation—are not only a consumer of energy but also a producer of energy (figure 1). Currently, various energy-smart food systems are being

FIGURE 1 Energy to and from the food value chain



Source: FAO/USAID, 2015

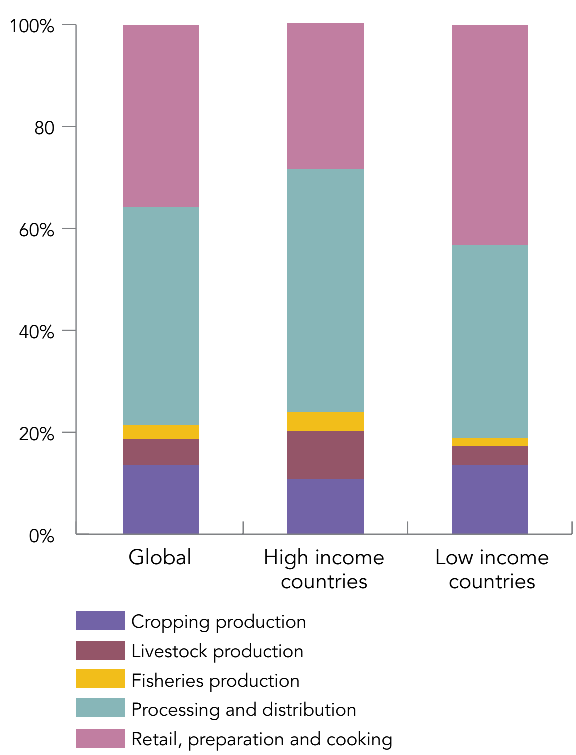
experimented with around the world, and the next major hurdle will be scaling-up the best ones.

ENERGY REQUIRED FOR THE AGRI-FOOD CHAIN

Energy is needed in all steps along the agri-food chain, both directly (for production, processing, and transport) and indirectly (for manufacturing of fertilizers, agro-chemicals, and machinery), although a significant amount of energy is lost through food losses. The agri-food sector is responsible for around one third of the world's total final energy demand (figure 2). In high-GDP countries, about 25 percent of the total is consumed before reaching the farm-gate (including fisheries), 45 percent in food processing and distribution, and 30 percent in retail, preparation and cooking. In low-GDP countries, a smaller share of energy is used on the farm and a greater share for cooking (FAO, 2011a). Moreover, energy is responsible for about 35 percent of GHG emissions from agri-food chains (excluding land use and land use change emissions), or about 26 percent if land use changes are included (FAO, 2011a). Household income levels are closely tied to the choice of and use of cooking fuels: low-income households depend on solid biomass[1] (like crop waste, dung, and wood fuel), while more affluent households use liquid fuels, which are cleaner and more efficient, as the sole fuel or in conjunction with woodfuel.

FIGURE 2 Poorer countries use a greater share of energy for cooking

(Indicative shares of final energy consumption of the agri-food chain including direct and indirect energy inputs)



Source: (FAO, 2011a).

Note: EJ = exajoule. Production for fisheries, livestock, and cropping are seen as occurring "behind the farmgate."

In recent decades, traditional forms of energy inputs have been largely displaced by fossil fuels as agri-food systems have become more industrialized and farm and food processing enterprises have become more intensive (a process still continuing in many countries). Hence the provision of modern energy services—like heating, cooling, transport of goods, water pumping, lighting, animal welfare, and mechanical power—have become largely dependent on fossil fuel inputs. For agriculture (crops and livestock), fishing, and forestry production, the demand for energy over the past decade has been steadily rising, with the main energy inputs coming from electricity and diesel fuel and a small rise in renewables. However, the total value of agricultural gross production has risen faster than the sector's total energy consumption, leading to a slight reduction in energy intensity at the global level (figure 3).

At the regional level, big differences exist. In Europe, between 2000 and 2012, there was a 20 percent reduction in agricultural energy intensity, and there were slight reductions in North America and Asia—but in Africa, there was a significant increase. These trends have continued over the past three decades, with the increase in average annual fossil fuels demand for agriculture in Africa, Central and South America, and Asia being only partially offset by decreases in Europe, while demand remained quite stable in North America and Oceania (figure 4).

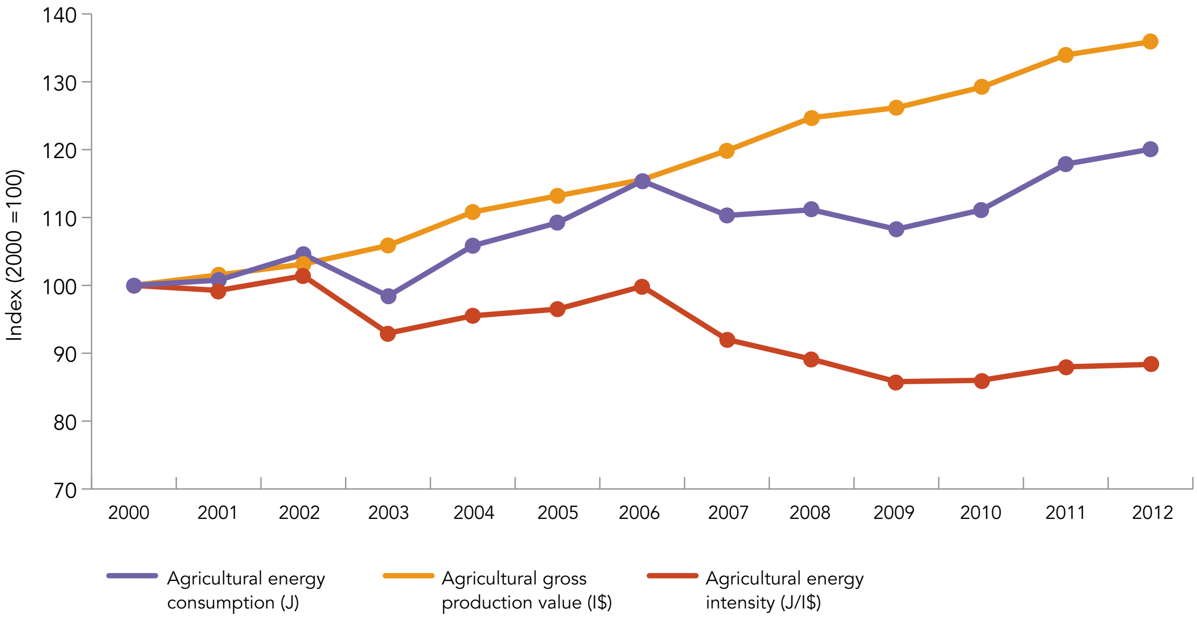
LEVELS OF ACCESS TO MODERN ENERGY

Energy access in the agriculture sector is critical to ensure that agriculture production can meet the growing food demand. Many small, remote rural communities remain without access to modern energy services due to poor road infrastructure and lack of an electricity grid. This shortfall affects not only food production and processing but also food preparation—where a major amount of the energy spent along the food chain is concentrated, especially in the poorest countries.

In developing countries, most households' energy is provided by traditional solid biomass (figure 5) such as woodfuel and cow dung. Women and children are generally responsible to collect and provide for household energy, which has negative consequences for their health as cooking based on traditional biomass is linked to indoor air pollution and carrying heavy woodfuel loads. Considerable time is also spent on woodfuel collection, which can range from less than an hour to almost 8 hours per day (Practical Action, 2014). Even where electricity distribution lines have been built, supply may be very unreliable, with frequent outages and fluctuating power quality. In such locations, diesel-generators are often employed to produce electricity, or renewable energy systems have been developed (such as solar, small-scale hydro, or wind power systems).

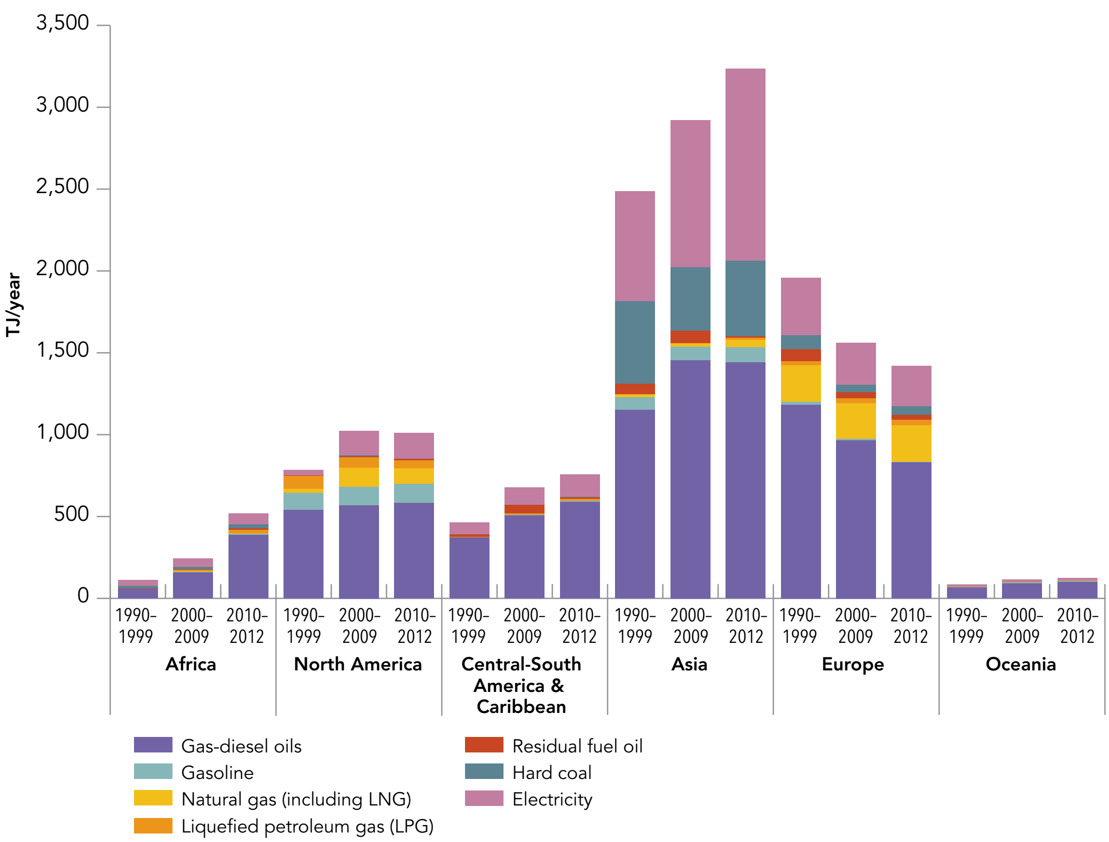
The energy gaps in smallholder agriculture and related rural enterprises are extremely difficult to quantify, given that energy sources and uses are so diverse and diffuse, scattered across millions of small farms and communities. But some of the headline statistics give a hint of the scale

FIGURE 3 Agriculture is continuing to demand higher levels of energy
(Rate of increase, 2000–2012)



Source: Elaborated on the basis of FAOSTAT, 2015.
Note: J = joules; I$ = international dollars (2006-07).

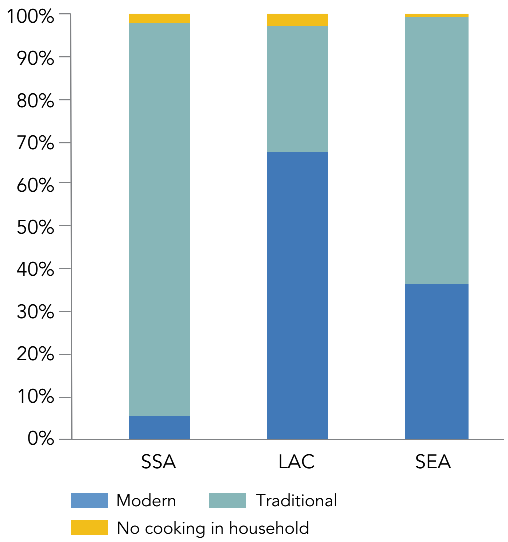
FIGURE 4 Developing regions lead in higher fossil fuel demand
(Decadal energy demand increases in the food production sector by world region and energy source.)



Source: FAO and USAID, 2015.

FIGURE 5 Developing countries still depend heavily on traditional solid biomass

(Share of households with access to modern and traditional cooking facilities)



Source: Elaborated on the basis of USAID DHS 2008–2014 data.

of the problem, and examples of this can be found in sub-Saharan Africa (IIED 2014):

- Most farm power relies on human effort (65 percent) or animal power (25 percent), with a minority from engines (10 percent)—much lower than for other developing regions, where engines constitute 50 percent of farm power.
- Just 4 percent of cropland is irrigated, compared with 39 percent in South Asia and 29 percent in East Asia.
- An estimated 10–20 percent of grain is lost after it is harvested at an annual cost of $4 billion—equal to the value of cereals imported each year.

These energy gaps matter greatly because access to modern energy for agro-processing can contribute significantly to the economic and social makeup of developing countries. And greater agriculture productivity and efficiency is a primary driver for food security, income generation, development of rural areas, and poverty reduction (Practical Action, 2012). The goals should be to enable a smallholder farmer to:

- Increase productivity and yields via improved efficiency of land preparation, planting, cultivation, irrigation, and harvesting.
- Improve processing, providing better quality and quantity of products and requiring less time and effort for cooking, heating, storage, preservation, or transformation into higher quality products, thus adding value.
- Earn more from the produce through better market access and new market opportunities (like access to information about pricing).

But for these goals to be met, there needs to be better and more affordable energy supplies. An increase in the amount of energy used, and access to a wider range of appliances providing energy services—which will also necessitate better access to land, water, seeds, knowledge, market for produce, and appropriate local technical support services (such as a network of repair services). .

SUPPLYING ENERGY IN A MORE SUSTAINABLE WAY

A top priority now for the global community is to find more sustainable ways of producing energy and make it accessible to farmers. One way to do this is by applying low-carbon and renewable energy solutions to agriculture—known as energy-smart food systems—to replace fossil fuels. This is already increasingly taking place in the heating, cooling, and power sectors, and to some degree in the transport sector (through the growing use of biofuels and electric vehicles). In remote rural areas where no electricity grid connection exists, stand-alone mini-grid solutions are increasingly being constructed, particularly where they offer the potential to boost local economic development because of more intensive agricultural and food processing activities.

Fortunately, a range of energy technologies and practices are common to many food chains, which provide opportunities to increase access to modern energy and/or reduce fossil fuel demand—two intertwined objectives. These include both renewable energy and energy efficiency measures, such as those illustrated below (FAO and USAID, 2015):

Conservation agriculture. This is an approach to manage ecosystems for improved and sustained productivity by minimizing mechanical soil disturbance, providing permanent soil cover to maintain moisture content, and diversifying crop species grown in rotation. Reduced energy can result from less fuel used for tillage, less power for irrigation, and less indirect energy needed for weed control per unit of produce.

Irrigation. Water pumping for drinking water, irrigation, and food processing consumes a lot of energy, usually by the use of either electricity or diesel for internal combustion engines, to power the pumps. Solar and wind-powered pumps are growing in popularity and should be encouraged where the potential for solar and wind energy exists. Energy demands for irrigation can be reduced by:

- Using gravity supply where possible.
- Using efficient designs of electric motors.
- Sizing pumping systems to the crop's actual water requirements.
- Choosing efficient water pump designs that are correctly matched to suit the task.
- Performing pump maintenance regularly.
- Using low-head distribution sprinkler systems or drip irrigation in row crops.

- Reducing water leakages in all components of irrigation systems.
- Monitoring soil moisture to guide water application rates.
- Choosing appropriate and drought resistant crop varieties.
- Using weather forecasts when applying water on a rotational basis to different fields.
- Varying irrigation rates across a field to match the soil and moisture conditions by using automatic regulation control systems based on Global Positioning Systems (GPS).
- Conserving soil moisture after application through mulch and tree shelter belts.
- Maintaining all equipment, water sources, and intake screens in good working order.

Storage and refrigeration. Cooling and cold storage are used widely to maintain food quality both after harvesting and processing and to reduce losses along the supply chain. Refrigeration systems depend on reliable electricity supply systems, although new technologies such as solar absorption chillers are reaching the market. Other sources of renewable electricity can be used on both small and large scales. For cold stores, reducing energy demand is possible through such measures as increasing the insulation, keeping access doors closed, and minimizing the heat load at the end of the processing phase of the cold chain.

Fertilizers. Energy embedded in the production of inorganic fertilizer (including nitrogen, phosphorous, NPK, and potash blends) is significant. Farmers can save indirect energy by reducing the amount of fertilizers applied and more accurate application methods. Recommendations include:

- Growing nitrogen-fixing legume crops as green crops.
- Selecting an NPK fertilizer of the desired nutrient value after undertaking soil or leaf analysis.
- Applying at the calibrated rate as determined by the soil or leaf analysis test results.
- Applying smaller amounts whenever the crop can respond to give greater productivity.
- Applying liquid fertilizers, including through injection, directly into irrigation water (fertigation).
- Using organic manures where available in line with good agricultural practices, including the effluent arising from food processing plants and the sludge from biogas plants.
- Using precision agriculture techniques based on GPS controlled equipment and an assessment of soil type variations.

Transport and distribution. Given the fluctuating prices for fossil fuels, transport and distribution are particularly vulnerable components of the food chain. The key elements in this category are distance and markets. Air-freighting fresh food across the world to meet demand for out-of-season products is highly energy dependent compared with supplying local markets with fresh food when available. Transport of food commodities (such as milk powder or rice in bulk), and fruit and vegetables (such as apples, bananas, potatoes, and carrots), at times under controlled atmosphere or refrigeration, can be relatively cheap with a low-carbon footprint per ton. In rural areas, better roads can help reduce the energy and time needed to take fresh products to markets and hence improve local livelihoods.

Field machinery. Tractors and machinery can produce similar power outputs using less fuel where engines are maintained, tire pressures are correct, unnecessary ballast for the task is removed, and the operator understands how to optimize tractor performance through correct gear and throttle selection as well as the use of the hydraulic systems. A well-trained operator can save up to 10 percent fuel and 20 percent of time sitting on the tractor as well as reduce damage to soil through compaction or wheel-slip.

Food processing. Processing of food at either the small-to-medium enterprise or large business scale requires energy for heating, cooling, lighting, packaging, and storing. The energy needed for such "beyond the farm gate" operations globally totals around three times the energy used "behind the farm gate." In many processing plants, an energy audit by a trained specialist would identify cost-effective opportunities to reduce energy consumption while increasing throughput and quality. Heat (such as for hot water, pasteurized milk, greenhouses, dried fruits and vegetables, and canned food) is normally produced by combusting natural gas, coal, oil, and biomass, or from electrical resistance heaters. To reduce energy demands, the heat can be used more efficiently, and heat losses within a system can be reduced by heat exchangers taking heat out of milk to pre-heat water. In all cases, the heat can be provided from solar thermal, geothermal, or modern bioenergy heat plants, or from efficiently designed heat pumps.

Renewable energy. This type of energy can substitute for fossil fuel inputs for heat and electricity all along the value-added chain where good local resources exist. It can be achieved using grid electricity with a growing share of renewables, or installing solar photovoltaic (PV), solar thermal, wind power, or bioenergy for heat and power on the farm or at the processing plants. Since organic wastes are often produced both on-farm and at the processing plant, investments in anaerobic digestion plants to produce biogas that can be used to provide heat, power, or transport fuels are being widely deployed.

Fishing. The fishing industry can become more energy-smart along the entire food chain, particularly by reducing fuel consumption of large and small fishing vessels. This will help the industry cope with the volatility and rising trends of fuel and energy prices and ensure fish remain available at accessible prices. For example, fouling (marine weed growth on the hull of a fishing vessel) can contribute to an increase in fuel consumption of up to 7 percent after only one month and 44 percent after six months, but it can be reduced significantly through the use of anti-fouling paints. In addition, reducing 20 percent of the speed in a fishing vessel could reduce up to 51 percent of fuel consumption.

It is worth pointing out that the development of energy-smart technologies like those mentioned above can often lead to tradeoffs, including:

- Between energy efficiency and efficiency in the use of other inputs (for instance, flood irrigation requires much less energy but is much less water efficient than drip irrigation).
- Between energy efficiency and access to energy (for instance, expensive energy efficient tractors versus second-hand, more affordable but much less energy-efficient ones; efficient biogas cookstoves versus woodfuel ones).

The Water-Energy-Food Nexus Assessment methodology proposed by FAO (FAO, 2014), discussed further in this section, helps address such tradeoffs and seeks synergies.

ENERGY DERIVED FROM THE AGRI-FOOD CHAIN

So far, we have stressed that energy is a key factor affecting agriculture and that potential options should be considered to enhance the sustainability of agricultural production and supply. However, agriculture, like other biomass-related economic sectors, offers the potential to produce biomass-based fuels. These biofuels (which are produced using residues, by-products, or products from the agri-food chain) can generate energy—called bioenergy—to supply various stages of the agricultural value chain, produce energy for external users, and, once exported, generate additional income for the agriculture sector and producers. As such, they can initially supplement, and potentially substitute for, fossil fuels used in activities like transport, heating and cooking, and rural and industrial electrification (Fang, Z., 2013).

Biofuels can come in three forms and types (FAO, 2004):

- *Gaseous biofuels* (biogas, and syngas) are produced from agricultural residues, woody residues, or dedicated plantations through anaerobic digestion, gasification processes. Additional purification stages allow obtaining biohydrogen and biomethane. These biofuels can potentially replace fossil fuels such as natural gas, LPG, and heating oils.
- *Liquid biofuels* (methanol, ethanol, butanol, biodiesel, bio-oil, and straight vegetable oil) are produced from crops and other feedstock types (including biomass residues and algae). They can potentially replace fossil fuel alternatives such as diesel, petrol, propane, and LPG. The most common alternatives for liquid biofuel production are fermentation, transesterification, and pyrolysis or Fischer-Tropsch processes.
- *Solid biofuels* (charcoal, briquettes and pellets) comprise a transformation of biomass (like woody biomass and crop residues) into more efficient fuel options through densification or pyrolysis processes. They can be used as intermediates for more valuable biofuels production or the potential replacement of fossil coals, LPG, and propane. They can also substitute for fuelwood, especially in areas with deforestation problems.

These different forms of bioenergy use various feedstock that can be grown or collected from diverse environments and can then be converted through a range of processing pathways and technologies, which together characterize the specific bioenergy pathway. In India, electricity is being generated by gasifying rice husks (see Box 1).

BOX 1

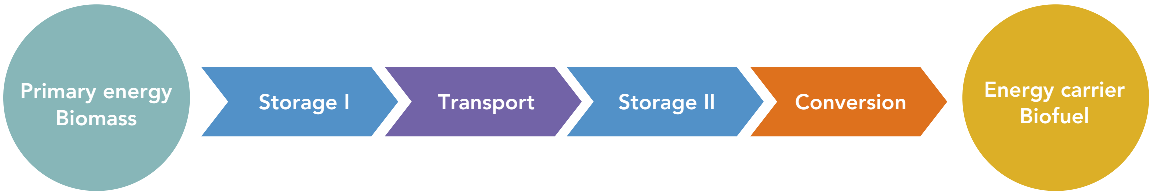
Using Rice Husks for Rural Electrification in India

Many parts of rural India are not connected to the electric grid, forcing millions of people to depend on solid biomass or diesel/kerosene for lighting, cooking, and heating. Yet India produces large amounts of agricultural residues like rice husks. Husk Power System (HPS) provides electricity in remote, rural villages in India through small-scale systems that generate and distribute power cheaply. Each system consists of a 30–50 kilowatt power plant that runs entirely on rice husks, generating electricity through biomass gasification. A simple distribution micro-grid connects subscribers directly to the plant using insulated wires strung from bamboo poles. The gasifier systems are built only in locations where rice husks are available and accessible.

HPS plants offer competitive prices for husks year-round so that farmers have an incentive to supply them to ensure that electricity remains available in their villages. HPS provides electricity at a levelized cost[2] of around $0.20 per kilowatt hour, which can likely drop to $0.15–0.16 as utilization increases. In Bihar, HPS has installed 84 mini-power plants, providing electricity to over 200,000 people spread across 300 villages, and employing 350 people. Each plant serves around 400 households, saving approximately 42,000 litres of kerosene and 18,000 litres of diesel per year, thereby significantly reducing indoor air pollution and improving health conditions.

Sources: Husk power systems (http://www.huskpowersystems.com) and International Finance Cooperation (IFC) http://www.ifc.org/wps/wcm/connect/1b7be8004d332ecb8976cdf81ee631cc/Husk+Power.pdf?MOD=AJPERES

FIGURE 6 A generic bioenergy pathway



Source: (FAO, 2014).

The experience of those countries that have succeeded in reducing hunger and malnutrition shows that economic growth does not automatically ensure success—the source of growth matters, too. Growth originating in agriculture, especially in the smallholder sector, is at least twice as effective in benefiting the poor as growth in non-agricultural sectors. This is not surprising since most of the poor in today's developing countries live in rural areas, where their incomes are directly or indirectly tied to agriculture. Given these potential benefits, what is crucial to understand is how the bioenergy sector should be developed to ensure that the positive effects are secured and that the natural resource base is not over-exploited. This development option should always be screened against other development options, if any, to ensure the optimal use of resources. FAO's Bioenergy and Food Security (BEFS) approach helps countries understand which bioenergy options exist for them.

The actual production of bioenergy requires biomass to be grown/produced, harvested/collected, transported, aggregated, stored, and—depending on the final use, biomass type, and the conversion technology—pre-processed before being converted into energy (figure 6).

Any assessment of biomass resources must account for competing uses and environmental sustainability issues to provide an accurate picture of the potential availability of a country's biomass resources so as to avoid creating conflicts with other biomass users. The assessment should also cover the sustainable availability of biomass resources (including seasonal patterns) and the techno-economic viability of the biomass technology—and be linked to energy needs for the agri-food system. In this way, policy makers can get a complete picture of bioenergy production and its interlinkages with other sectors.

Also important to weigh is how the biofuel is produced. Each biomass type requires a specific technology pathway to be converted into a biofuel, which will have a specific potential energy end use (FAO 2010). Figure 7 illustrates some of the combinations that exist in terms of the pathways going from biomass to energy—with the biomass options including oil crops, sugar and starch crops, lignocellulosic biomass, and wet biomass.

Modern combustion, gasification, and pyrolysis are largely mature thermo-chemical conversion technologies, although improvements in performance and conversion efficiencies are always being sought. They are similar in how matter is modified to obtain energy, but differ in how energy potential is released. In combustion technology, biomass is burned to produce heat, which can be used directly or passed through electro-mechanical devices to generate electricity. But in gasification and pyrolysis, biomass is chemically modified to generate more advanced fuel forms (such as syngas and bio-oil). These advanced biofuels have a higher energy potential and can thus generate more energy compared to the initial biomass. Depending on the energy end use, these fuels are burned in boilers, modified diesel engines, or gas engines to generate heat and electricity.

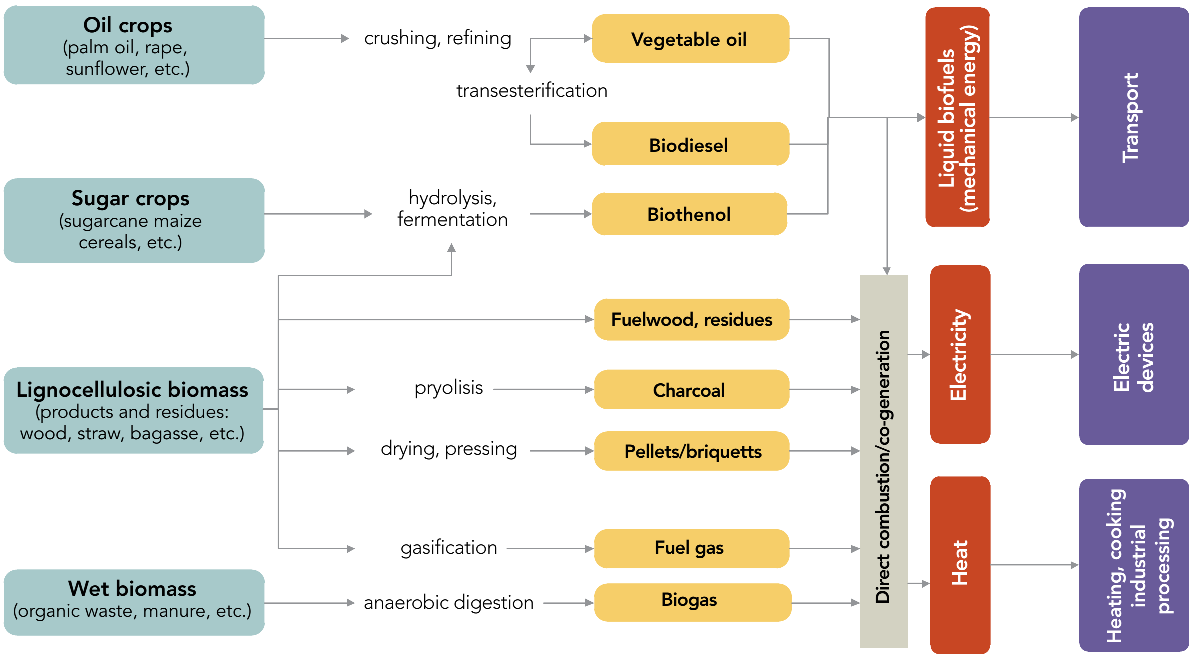
Along these lines, cogeneration systems (CHP) allow producing heat and power simultaneously through a combination of different technologies arranged to extract energy contained in biomass or advanced biofuels more efficiently. When the generated heat is fully utilised, a CHP system can reach total efficiency (thermal and electrical) of 80 percent (or even more).

Anaerobic digestion is a technology used for producing biogas—comprised mainly of methane and carbon dioxide—by microbial digestion of organic matter under anaerobic conditions. Any biodegradable material (like manure, crop residues, green crops, food processing residues, sewage sludge, organic fraction of municipal waste, or a mixture thereof) can be used as feedstock. The biogas can be used directly in households for cooking, heating, and lighting—or when produced on a larger (industrial) scale, for heat or CHP via gas engines or turbines.

Liquid biofuels used in transport are obtained through different chemical and biological pathways according to the main replacement fuel and the level of processing required. Straight vegetable oil (SVO)—the simplest liquid biofuel—is obtained by extracting oil from oilseeds and slightly purified to increase its shelf life. It is directly used in modified diesel engines for either rural electrification or trucks. Further processing of extracted vegetable oils (using a chemical route known as transesterification) can produce biodiesel, which can serve as a clean-burning replacement for diesel fuels. Conversely, sugar, starchy, or lignocellulosic feedstock can be converted through fermentation and additional steps into ethanol or butanol, which can be used to replace petrol.

Bioenergy has a wide range of uses depending on the specific needs and production scale required. Thus, it is possible to find small-scale rural electrification options where small gasification units attached to gas engines are used to supply energy to nearby smallholders. There are also community biogas projects, where independent dairy farmers collect manure from farms to provide a community biogas digester to produce local electricity for heating and cooking. Other interesting applications are found in bio-

FIGURE 7 Possible bioenergy pathways



Source: Adapted from AEBIOM.[3]

mass-based agro-industries such as rice mills, corn mills, or tea factories—where biomass feedstock is transformed into a number of value added products, and biomass residues are used to self-supply the plant energy needs, with extra energy quantities available for export. Box 2 contains three more bioenergy examples: (i) biogas production and use in the milk industry in Pakistan, (ii) the use of wastewater from coffee production to generate electricity in Honduras, and (iii) the burning of bamboo dust to produce energy in Ethiopia.

In the specific case of bioenergy from agricultural biomass (such as crop and livestock residues), biomass offers a viable way to produce energy from surplus residues. Here the emphasis is on the need for the residues to be surplus residues (that is, residues net of other essential uses in agriculture). To be used in a sustainable way, residues must only be removed when they do not hamper soil quality or compete with other uses (like animal feed). In some regions, the combination of crop, management practice, soil, and climate, work together to produce more than is needed to maintain soil health—enabling excess residues to be converted into energy.

However, it is important to discern in what systems residue harvest for energy purposes is possible, or even beneficial, and at what rates. This is often true for tropical and sub-tropical climates where the soil organic carbon pool is below the critical level. In some cases, trade-offs can be found when too much crop residue can create problems (like diseases and fires in dry areas) or residues substituted with alternative sources for soil protection and livestock feed (like cover crops). In others, win-win solutions are possible, such as biogas and use of its by-product as bio-fertilizer, or using soil amendments such as biochar produced from residues. The literature that addresses the trade-offs between competing uses of crop residues is relatively scant, but FAO has developed tools that address this issue at both territorial and operational levels.

USING AGRI-FOOD CHAIN TO SUPPORT THE ANCHOR-LOAD MODEL

In the context of sustainable biomass supply, it is vital to make the business profitable so that it can attract potential investors. One critical factor affecting production scale and potential profitability is determining the potential consumer demand—although this can be difficult to determine in developing countries, due to lack of information, irregular consumption patterns, and ability to pay. For that reason, private energy enterprises in these countries are increasingly using the A-B-C model for electricity production and mini-grids distribution.

This approach involves identifying three different groups of customers—Anchor, Business groups, and Community members. Within the groups, anchor load is predictable and offers a guaranteed source of revenue for the project developer, whereas business group and community members are usual customers. The anchor customers with a base load demand for energy such as telecommunication infrastructure (tower base stations), agriculture (water pumping and food processing) makes sure that the energy provider has consistent demand for energy making the investment viable. Local households and businesses are then connected to the micro-grid in collaboration with partner social entrepreneurs who provide energy access through locally tailored and feasible business models like energy kiosks. The community benefits from direct access

BOX 2

Bioenergy Examples Around the World

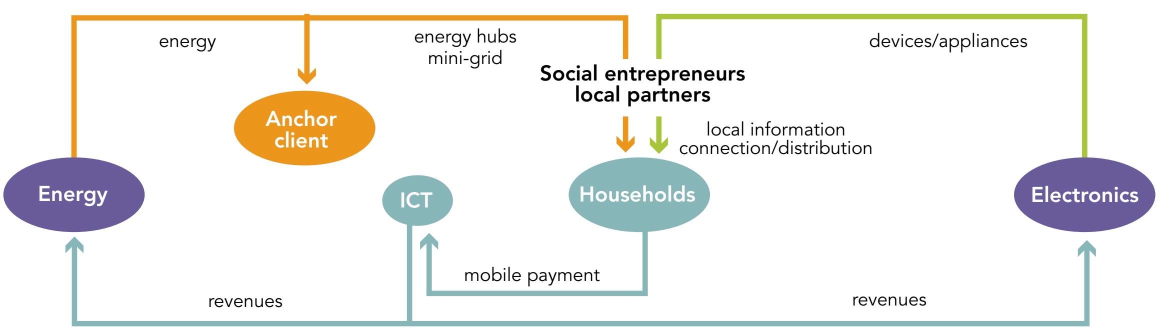
Milk chilling with biogas in Pakistan
In the Punjab region in Pakistan, biogas plants have been installed on 3 farms that have around 100 cows each. The biogas facility uses cow dung as feed stock and produces electricity of between 32kWh to 64kWh, depending on the size of the bio digester (50m3 and 100 m3). This amount is sufficient to run milk chillers with capacities of 500 litres (12kWh) and 1,000 litres (20.8 kWh) for 8 hours. The excess energy is used for lighting purposes and to power other equipment (like fodder cutters or fans).

Electricity production from coffee wastewater in Honduras
Coffee production is a dominant industry in Honduras, generating around a million direct and indirect jobs. COCAFELOL (La Cooperativa Cafetalera Ecológica La Labor) – which produces, processes, and exports coffee – has installed a bio-digester to process the wastewater generated in the processing of coffee berries. The biogas is used to run an electricity generation system of 14 kW capacity, which is enough to replace the energy consumed in the mill's administrative area.

Bamboo dust use in Ethiopia
In Ethiopia, African Bamboo is developing an energy self-sufficient friendly bamboo-flooring factory, called ThermoBoo. The bamboo first undergoes a chemical free process in which decay factors, such as rot and insects, are virtually eliminated. The treated bamboo is then, further processed into sturdy panels to be sold domestically and internationally. Bamboo dust is a by-product of the process and is combusted to generate energy. This is an innovative technology that has the potential to produce surplus energy for the region.

Sources: Wisions of Sustainability, 2013 http://www.wisions.net/files/uploads/SEPS_Summary_SG016_Pakistan_Biogas_manure_milk_chilling.pdf; Productive Biogas: Current and Future Development, 2014 http://www.snv.org/public/cms/sites/default/files/explore/download/snv_fact_productive_biogas_2014_final.pdf

FIGURE 8 Framework to increase energy access based on anchor client



Source: : World Economic Forum, 2013.

to energy and the wider impacts of enabled economic activity, reduced health impacts, and reduced environmental damage (World Economic Forum, 2013). Figure 8 illustrates how an anchor load system can work, drawing on the telecommunication industry, which is currently a user of the model. The same approach and structure could be applied to the agribusiness sector, where, for instance an agri-processing facility can act as an anchor customer.

Such a framework brings together energy providers such as utilities and energy service providers and industries that need reliable and cost-efficient energy for their operations. The idea hinges around an anchor customer that guarantees energy demand over an extended period, making it viable for the project developer to invest in building a mini grid or other forms of energy infrastructure. For instance, OMC Power,[4] a company that develops mini grids to electrify rural villages in India, identified its main anchor customers as owners of telecom towers that need energy around the year. In this regard, OMC has signed an agreement with Bharati Infratel to electrify its telecom towers by providing micro-power for the next 10 years. For commercial establishments and other community users, OMC Power has devised a concept called "micro-power business-in-a-box" where community entrepreneurs are engaged in the village electrification process. Micro-power from OMC ranges from a 1.2 to 3.6 kilowatt load, and beyond. For rural consumers, it has a pre-paid system based on subscription, where a rural consumer is charged a monthly rental of $2 per month. (GNESD, 2014).

SCALING UP ENERGY-SMART SOLUTIONS FOR AGRI-FOOD CHAINS

To scale-up the uptake of sustainable energy solutions, practices, and behaviors, it is important to align available solutions with local settings. Interventions require a people-centered "bottom-up" approach, and they need to be better tailored to local contexts, as experiences from energy as well as agricultural mechanization have shown. This means addressing the following questions (Energypedia): (i) For what purpose is energy required?; (ii) Which equipment and systems would be needed to produce energy?; (iii) Will the system be economically viable in the identified context?; and (iv) How can local capacity to run and maintain the systems be built?

Production of bioenergy from agricultural residues is one promising way in which access to energy can be increased in rural areas. But like other agricultural activities, bioenergy can compete for labor and natural resources and thus the benefits to be accrued have to be closely investigated to ensure food security is not hampered. In fact, some of these concerns can be addressed by well-designed policies and land management practices. What needs accessing is whether agriculture residues are available once other uses are accounted for (such as feed, fodder, and soil nutrients). If unused residues are available, this option can also allow mitigating climate change impacts by avoiding residues to be burnt in the field. All options need to be environmentally and financially sustainable. The overarching key principle is to ensure that the agrifood system and energy systems are integrated.

A value chain analysis can help point out energy needs and opportunities to identify bottlenecks to productivity, or where energy could have the highest impacts on income and cost-effectiveness. In certain contexts, needs assessments should place a strong emphasis on gender. After all, about 43 percent of the agricultural workforce in developing countries is made up by women, but they mostly have less access to productive assets than men. If this access of women would increase, the respective yields could be increased by 20-30 percent (FAO, 2011b). The real needs vary hugely across different farming systems. Smallholders are a heterogeneous group, working with diverse farming systems—and vary with crops, locality, context, culture, and agro-ecological zones. Sometimes, significant improvements can be reached through low-cost, "traditional" technology (like treadle pumps), as opposed to modern energy services.

One way to analyze energy interventions is by using a Water-Energy-Food Nexus approach, which entails the following (FAO, 2014):

- Addressing interactions that take place in the context of global drivers (such as demographic change, urbanization, technological advancements, trade, diversification of diets, and climate change) to meet different and often competing social, economic, and environmental goals, along with interests of different sectors that rely on the same limited resources.
- Assessing the impact of specific interventions from a nexus perspective (how much water is needed to produce energy and how much energy to pump water) vis-à-vis the status of the context where these interventions are implemented. The Nexus Assessment methodology developed by FAO can be used to this effect.

A nexus approach requires inclusive, multi-stakeholder institutional arrangements. Such arrangements need to address a variety of issues, including the division of labor,

BOX 3

Peru's Solar-Powered Drip Irrigation System

In Peru, like in many other countries, irrigation is done by flooding the field with seasonal water or using gravity fed systems. In places where farmers can afford to buy a pump, irrigation relies on diesel/gasoline-powered pumps. A University of Massachusetts project provides an inexpensive, low-pressure, 12-volt diaphragm pump that is connected to a 250 watt solar photovoltaic array. A prototype of the system was installed in January 2008 in Turripampa, Peru.

Researchers report that water delivery by drip lines at the plants' root level is 40 percent more efficient per unit land area than traditional flood irrigation in furrows, since less water is lost due to evaporation and seepage in the sandy soils. Liquid fertilizer can also be applied to the field through the drip lines, reducing labor and energy costs. In addition, depending on the crop cycle, drip irrigation can allow up to three harvests per year instead of just one in the rainy season, generating enough income to quickly pay for the system. Growing asparagus, a drought resistant cash crop, enables the small farmer to pay back the $1,500 initial investment in two years.

Source: (Barreto et al., 2009).

financial schemes, technical support services, and business models. Division of labor and clear financial arrangements between farmers and energy operators are required to ensure the quality and the expansion of energy-smart farming systems. For example, under outgrower schemes, farmers take responsibility for what they do best, which is farming, while others deal with the specialized needs of energy production (FAO, 2011a). Another lesson lies in the need to involve users strongly in project design to ensure a needs-based approach. One concrete idea is to implement energy literacy campaigns to help people understand opportunities, articulate their needs, and demand high quality services from government and providers (IIED, 2014).

Where renewable energy resources are available, it is feasible to use agricultural land to both produce food and generate energy. Food processing plants often have biomass co-products suitable for generating bioenergy, and renewable energy systems in rural areas can provide several co-benefits for landowners, businesses, and rural communities (FAO, 2011a).

At this point, knowledge gaps still exist about economically viable delivery models for different energy needs in farming, as well as the role of the private sector in providing energy services to smallholders. Innovative institutional arrangements and financing mechanisms that involve several types of partners are required to support the development of the renewable energy sector (IIED, 2014). But for all types of energy services, past experience has shown that no single institutional model reliably provides better success rates than others (GIZ, 2011). Three market-oriented business models systems have recently gained currency (GIZ, 2011):

- *Energy service companies (ESCO):* Private operators who typically own the energy production and supply equipment, and charge for energy services on a fee-for-service basis. The business risk in terms of energy supply is fully undertaken by the ESCO.
- *Leasing, or hire-purchase:* Private leasing company retains ownership of the energy production and supply systems until the customer has completed payment over the lease period.
- *Concession model:* A concession for fee-for-service operations is signed between the private service provider and the government. This approach is very recent and has faced several types of implementation challenges

Scaling-up successful experiences will require bringing together approaches and experiences of the energy and the agri-food sectors—with an emphasis on energy needs and challenges in smallholder farming. Such an integrated approach is essential for tackling the challenge of increasing access to modern energy for smallholders, while supporting a transition to more environmentally sustainable food and energy systems.

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NOTES

1. Biomass is material of biological origin (excluding material embedded in geological formations) that is transformed into fuel. Through an array of conversion technologies, it can be converted to produce heat, electricity, and transport fuels (FAO, 2004).
2. The levelized cost is the total costs (including capital investments, operating costs, and financing costs) divided by the total energy output over the lifetime of the plant. For more, see: https://www.eia.gov/conference/2013/pdf/presentations/namovicz.pdf
3. (http://www.aebiom.org/blog/category/about_us/about_bioenergy/, last accessed: April 2015)
4. Source: http://www.omcpower.com/.

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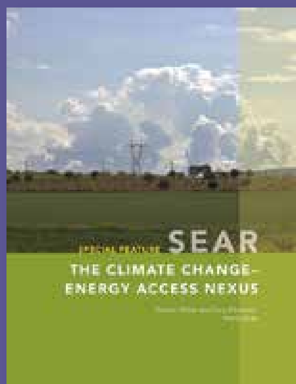

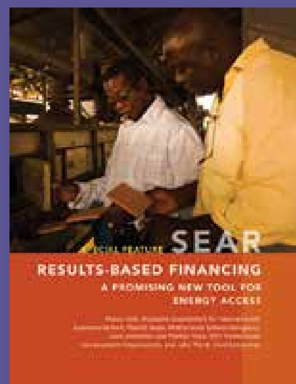

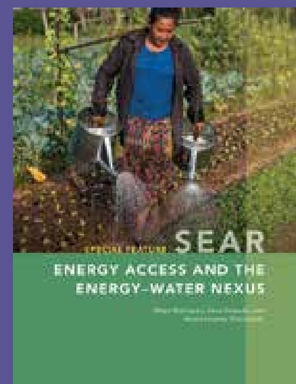

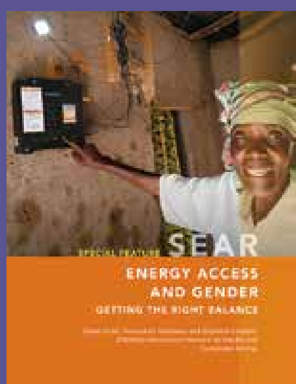

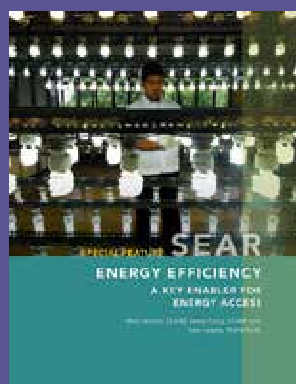

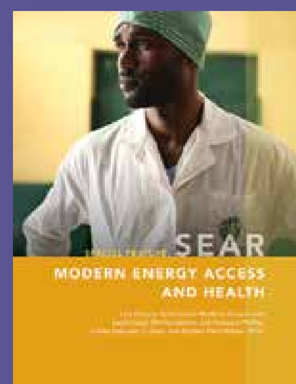

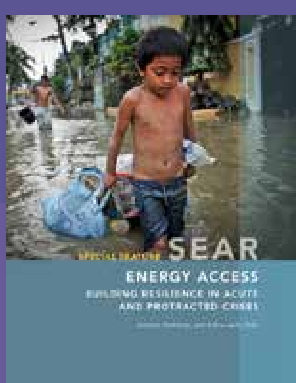

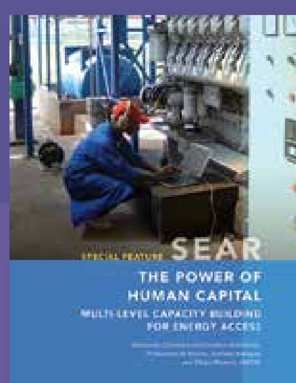

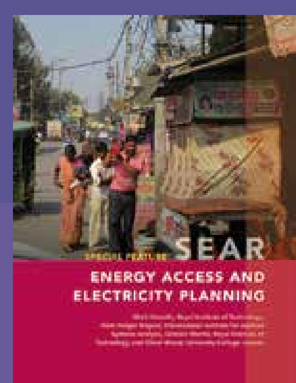

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