MODULE 5:

SOUND MANAGEMENT OF ENERGY FOR CSA

Overview

This section looks at the relationship between food and energy in a world where the climate is changing and competition for natural resources is increasing. This relationship is becoming stronger and more complex because the global agrifood system is almost entirely dependent upon fossil fuels and modern bioenergy is increasingly being looked to as an alternative to these fuels. Sound management of energy for and from the agrifood system could make a crucial contribution to making the transition to climate-smart agriculture and the achievement of food, climate and energy security. But this transformation can only happen if existing examples of energy-smart food systems can be scaled up significantly. Also required are adequate assessments of the effects of energy-based interventions in agrifood systems on sustainable development goals to guide decisions related to policy and practices.

Key messages

- In light of increasing and volatile fossil fuel prices, the dependence of agrifood systems on fossil fuels represents a major threat to food security and contributes significantly to climate change. The challenge of reducing this dependency on fossil fuels can be met by up-scaling of energy-smart food systems. These systems improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services in agrifood systems.
- More energy is generally used in post-harvest stages of the food supply chain, whereas most greenhouse gas (GHG) emissions occur in the pre-harvest stages. Nevertheless, there is greater synergy between energy-smart and climate-smart agricultural practices than may appear at first. This synergy can be created through resource-efficient farming practices that reduce pressures on land use change, lower emissions embedded in the production of agricultural inputs, lessen the reliance on fossil fuels and enhance the productivity and resilience of agro-ecosystems.
- Each intervention requires careful analysis. This must be done using a lifecycle analysis, which includes the intervention's indirect effects, to assess the synergies and trade-offs among the various sustainable development goals related to energy, climate, food security and water security.
- In developing countries, increased access to modern energy services in agrifood systems is often required to improve productivity and income, and advance economic and social development. However, an increase in energy consumption, even if based initially on fossil fuels, may result in lower absolute GHG emissions. For example, improved access and greater use of modern energy services may reduce deforestation as the demand for traditional wood fuels declines, or create new economic opportunities that displace unsustainable high-emission activities that are profitable only in the short-term, such as logging and charcoal production, or agricultural expansion. Increased access to energy is likely to reduce emissions per unit of food production or per unit of gross domestic product (GDP). The effect of increased energy access on climate change mitigation should be assessed according to a county's or community's current stage of development and the development model that is being followed. It should not be assumed that there is always a trade-off to be made between energy access and climate change mitigation.

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5.1 Introduction – Energy and the agrifood system

Global primary energy demand will increase by a third between 2010 and 2035, and today's developing countries will account for the majority of this demand (IEA, 2011a). Fossil fuels are expected to continue to meet the bulk of the primary energy requirements. However, the use of renewable energy is increasing and will continue to do so in the future.

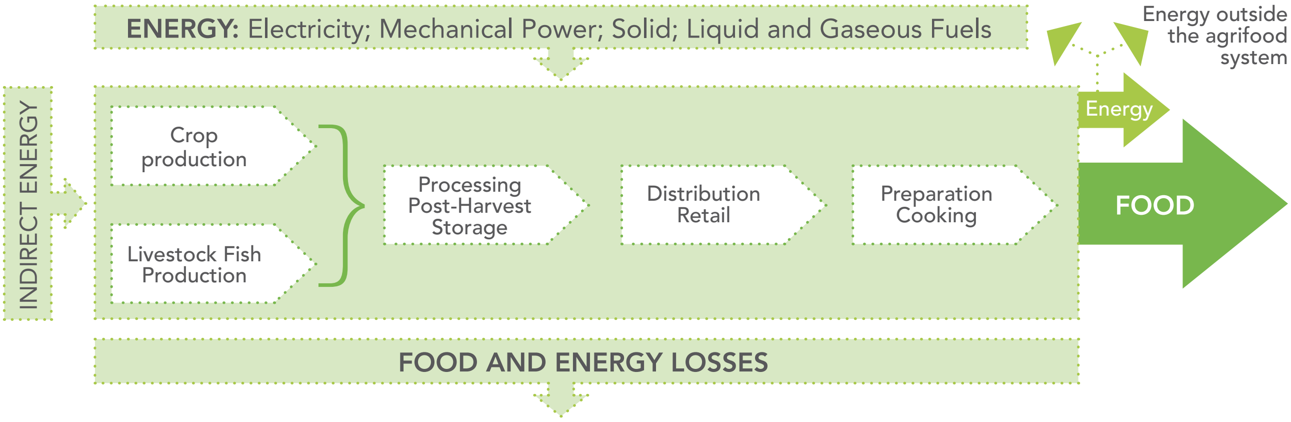
Over the last decade, crude oil prices have fluctuated around a generally steadily increasing trend line, from US$ 28 per barrel to US$ 120. There was one dramatic price spike in 2008. Conversely, the costs of renewable energy have been declining recently. This trend will continue in the coming decades, and renewable energy will become more and more competitive.

The gap between energy needs and access to energy is large, and demand will certainly increase as countries develop. The International Energy Agency (IEA) estimates that a fifth of the world's population lacks access to electricity and that two-fifths rely on traditional biomass for cooking. The use of biomass for cooking is a severe cause of high indoor air pollution, which has harmful health effects for rural households, especially for women (IEA, 2011a). Increasing energy access is essential if the poverty reduction targets set out in the Millennium Development Goals (MDGs) are to be met.

Agriculture and energy have always been closely interlinked. These linkages have changed and grown stronger over time. Agriculture, including forestry, has always been a traditional source of energy (through bioenergy), while fossil fuels have become a major input in modern agricultural production. The energy generated by the agrifood system can be partially used in the food supply chain or exported outside the system (e.g. through the sale of biogas produced on-farm to local households, or through the generation of electricity from residues to feed the national energy grid).

These two-way linkages between energy and agriculture - the energy **for** and **from** the agrifood sector, are illustrated in Figure 5.1.

Figure 5.1: Energy FOR and FROM the Agrifood System



Source: Based on FAO's current work being done through the Energy-Smart Food for People and Climate Programme (see FAO, 2011a and b), the food sector[1] currently accounts for around 30 percent of the world's total end-use energy consumption.[2] More than 70 percent of that energy is used beyond the farm gate (Figure 5.2). Countries with a high GDP use a greater portion of this energy for processing and transport. In low-GDP countries, cooking consumes the highest share.

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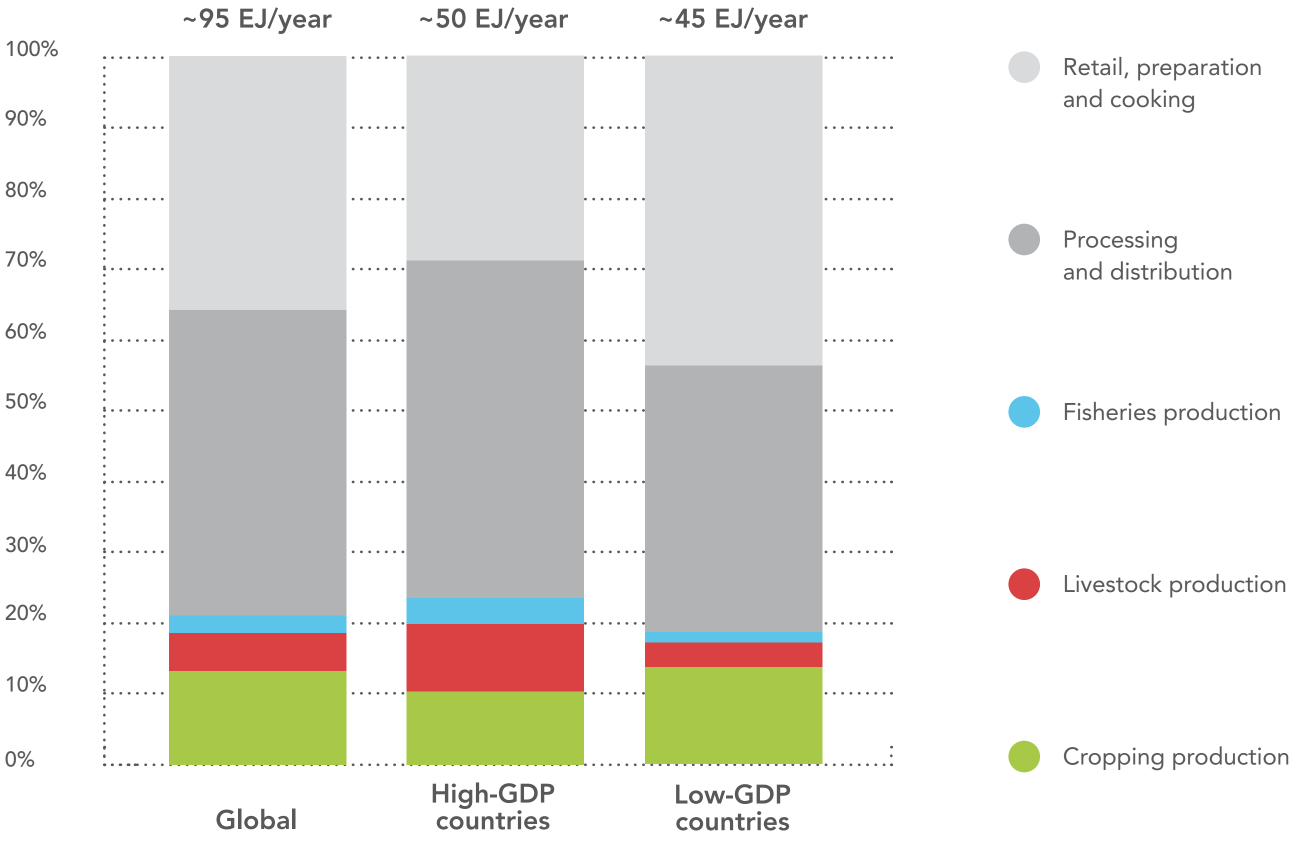
[1] In this context, food sector concerns only those parts of "agriculture" in the broad FAO sense (i.e. agriculture, forestry and fisheries) that produce food, as well as the food processing, distribution, retail, preparation and cooking phases.

[2] Energy includes direct energy used at the operational level primarily on farms and processing plants, for example for irrigation, land preparation and harvesting as well as indirect energy that is not directly consumed to operate farms, in fishing or processing plants but required to manufacture other inputs such as machinery, fertilizers and pesticides.

Figure 5.2
Indicative shares of final energy consumption for the food sector for high- and low-GDP countries



On the input side, the linkages between energy and agrifood systems have strengthened as agriculture has become increasingly reliant on chemical fertilizers, irrigation and machinery. Post-harvest activities, such as food storage, processing and distribution, are also energy-intensive. Consequently, higher and volatile energy costs have a direct impact on agricultural production costs and food prices. Over the last decades, the increased use of energy by the agricultural sector has significantly contributed to feeding the world. Energy from fossil fuels has increased farm mechanization, boosted fertilizer production and improved food processing and transportation. Between 1900 (when energy inputs were limited to low-level fertilization and rudimentary mechanization) and 2000, the world's cultivated area doubled, but the energy used in edible crops expanded six-fold. This greater productivity was made possible by an 85-fold increase in energy input per hectare (Smil, 2008). This transformation occurred in an area of cheap oil and where there were few concerns about climate change. However, since then times have changed.

Prices for nitrogen fertilizers and other fossil fuel-dependent inputs are closely related to the price of crude oil. Rising and volatile oil prices translate into higher and fluctuating food production costs. Farmers, in particular smallholder farmers, are the first to be affected. As a result, agrifood systems that are highly dependent upon fossil fuels pose serious challenges to development, and this could hamper food security in the future.

Food losses occur at all stages of the supply chain. About one-third of food produced is lost or wasted (Gustavsson *et al.*, 2011). The energy embedded in global annual food losses is thought to be around 38 percent of the total final energy consumed by the whole food chain (FAO, 2011 a and b).

As stated earlier, one of the greatest challenges the world now faces is to develop global food systems that can emit fewer GHG emissions, benefit from a secure energy supply, are be resilient to fluctuating energy prices, and continue to ensure food security and foster sustainable development. This calls for energy-smart food systems that:

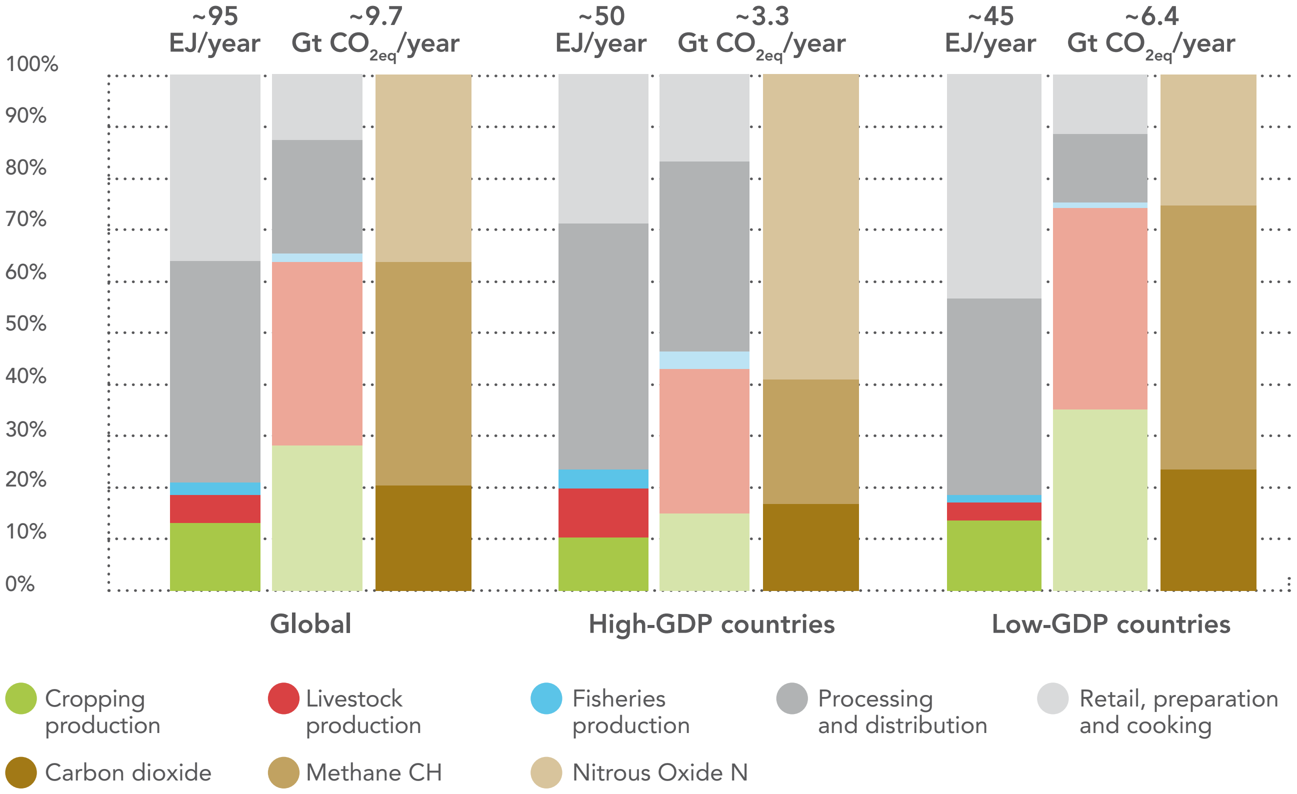
1. improve energy efficiency (measured in food output, preferably measured in nutritional units, per unit energy input) at all stages of the agrifood chain;
2. use diverse energy sources with an emphasis on renewable energy and contribute to renewable energy production through integrated food and renewable energy production; and
3. require improved access to modern energy services.

Bioenergy has a special role to play in relation to food security. Although biomass is often used in unsustainable ways, it is found almost everywhere and is currently, and for the foreseeable future, the most important source of renewable energy. It is used primarily for cooking and heating. In addition, agrifood systems not only use bioenergy, they also produce it. One instance is in integrated food-energy systems. However, putting bioenergy to use in an appropriate manner is more complex than with other types of renewable energy. If it is not well managed, bioenergy development may jeopardize food security and harm the environment. This is further discussed in Box 5.3.

5.2 Energy-smart food in the CSA context

The energy sector, which produces nearly 60 percent of carbon dioxide (CO$_2$) emissions, is the largest contributor to climate change (FAO, 2011a). The agrifood sector contributes over 20 percent of total GHG emissions, most of which originates from methane and nitrous oxide (see Figure 5.3). Globally, primary farm and fishery production[3] accounts for around 20 percent of the total energy demand for food, but produces 67 percent of the GHGs (FAO, 2011 a).

Figure 5.3
Shares of GHG emissions along the food supply chain with breakdown by energy consumption (by phase) and GHG emissions (by phase and by gas).



Source: FAO, 2011a

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[3] Primary production here includes cropping, pastoral and intensive livestock, aquaculture and fishing.

It is important to point out that these facts and figures relate to the entire agrifood chain, from 'farm' to 'fork'. They do not account for emissions related to land-use change, international trade (transport) or food waste despite the fact that GHG figures related to agriculture usually concern only behind-the-farm-gate activities (excluding fuel combustion and sewage waste) and often include land-use change impacts.[4]

In the following three sub-sections, we explore the potential for energy-smart agrifood systems to also be climate-smart and examine how it can fit with each dimension of CSA.

CSA objective: sustainable increases in productivity and income

Energy-smart strategies that cover the diverse range of food management options are complex and can involve making trade-offs. In this regard, some key points relating to primary production management practices should be emphasized.

- Methods used to save on inputs that are fossil fuel-dependent but also lower productivity, such as cutting back rather than optimizing the amount of fertilizer applied, are rarely beneficial and should be avoided.
- High-external input production systems do not necessarily have high energy intensities (megajoules per kilogram (MJ/kg) of product), especially when they lead to increased yields. Conversely, low-input systems can have relatively high-energy intensities when they produce lower yields.
- In promoting energy-smart food, balance needs to be maintained between improving access to energy sources and increasing the efficiency of available energy, as well as increasing the proportion of renewable energy. This balance must be based on local conditions and the economic trade-offs between the different options. Box 5.1 illustrates these trade-offs made in the deployment of machinery systems for small farms in Bangladesh.

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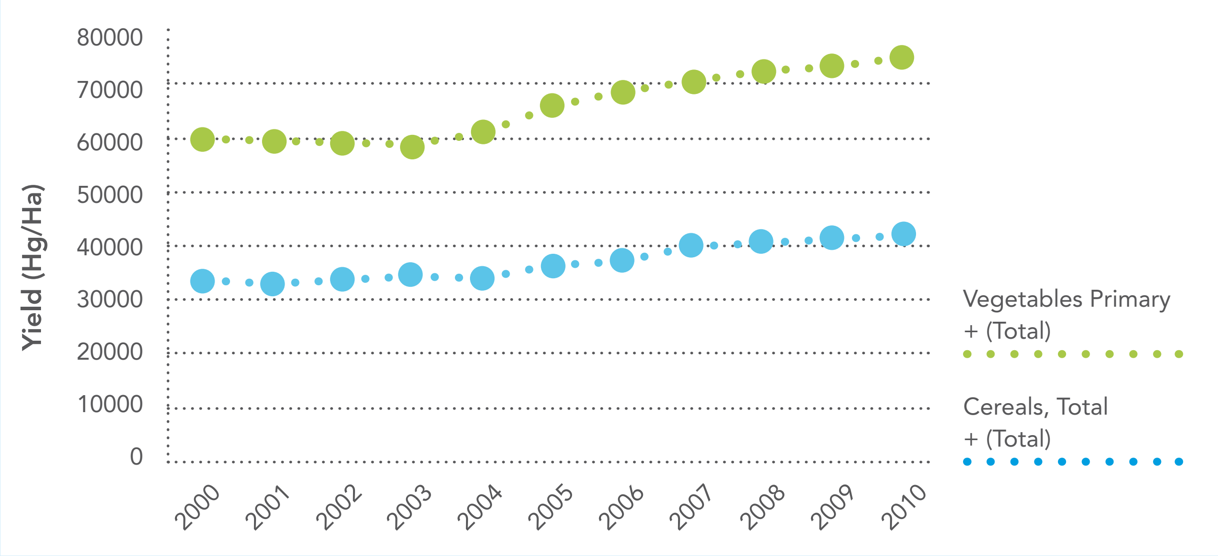
[4] Often LULUCF (land use, land use change and forestry) assumed emissions due to agricultural expansion are lumped together with agriculture sector emissions. In national GHG inventories prepared for reporting under the United Nations Framework Convention on Climate Change (UNFCCC), important pre-farm gate sources of emissions such as fertilizer production (industrial processes and energy sectors), on-farm fuel combustion (energy sector) or sewage waste (waste sector) are not included. But if the whole agrifood chain is considered, other sources of emissions must be added, such as those mentioned above and also post-harvest stages of the agrifood chain, in particular agro-industrial operations, food distribution, storage and preparation and the food waste component of landfill.

Box 5.1
Low-cost machinery systems for small farms in Bangladesh

The introduction in Bangladesh of small, mobile, diesel engines has increased food production (Steele, 2011). These demountable engines can be used for a range of applications, including powering small boats, tractors or trucks, generating electricity, and operating processing equipment and water pumps. Public policy changes enabled the import of innovative, Chinese-made, farm equipment. The diesel engines could be easily repaired by local mechanics and were less expensive than more sophisticated and more fuel-efficient machinery manufactured in India. The introduction of inexpensive Chinese technology led to the 'agrotractorization' of Bangladesh.

The extent of mechanization in Bangladesh can also be measured as the level of energy input. The available power in agriculture over the period of 1960 to 2007 increased by almost 500 percent: from 0.24 kilowatt per hectare (kW/ha) in 1960, to 0.61 kW/ha at the end of the 1990s, to 1.17 kW/ha in 2007 (Islam and Shirazul, 2009). The available power gradually increased from 0.24 kW/ha in 1960, grew moderately until the 1980s and then rose sharply in the '90s, reaching 1.17 kW/ha in 2007. Most of the agricultural machinery used in the country is either imported or locally manufactured. Farm machinery, such as weeders, threshers, winnowers and centrifugal pumps are developed and manufactured locally with local materials (APCAEM-ESCAP, 2010).

Figure 5.4
Cereals and vegetables yield increases in Bangladesh from 2000 to 2010



Source: FAOSTAT, 2012

In the early 1970s, when Bangladesh was characterised as a 'basket case' by some international development specialists, no one was forecasting that by 2010 the country would have one of the most mechanized agricultural economies in South Asia (Islam and Shirazul, 2009). Today 80 percent of primary tillage operations are mechanized. These operations are performed mainly by 300 000 small two-wheel tractors and a few (3 000) four-wheel tractors. There is a highly developed market for servicing tractors, pumpsets, threshers and other machinery derived from the use of small engines (Biggs and Justice, 2011).

The figure above indicates that from 2000 to 2007 external energy subsidies in agriculture increased by 60-70 percent for cereals and vegetables (per kg of product). However, yields (per unit of cultivated area) also increased by 20-25 percent. This made mechanized agriculture more profitable and gave farmers more time for other activities.

The Bangladesh private sector (as compared to the private sector in Nepal or India) focused on the imports of smaller-scale machinery. Presently, there are over one million small horsepower diesel irrigation pumpsets and nearly 400 000 diesel two-wheel tractors. In Bangladesh, the import value of soil machinery is consistently higher and continues to increase compared to the values of agricultural machinery and equipment such as harvesters and threshers, milking and dairy machinery and agricultural tractors. In 2007 Bangladesh started exporting some agricultural machinery, but most machinery is manufactured locally for local use. Seeing these results, Nepalese and Indian farm machinery manufacturers have recognized a new business opportunity. Small engines are now being sold mainly into low-cost, farm machinery markets in rural communities. Farm services have expanded as a result of the versatility and transportability of this equipment.

It is essential to consider affordability and cultural issues when deploying new or improved energy technologies. Domestic stoves account for a major part of energy consumption in the food chain, especially in developing countries. The dissemination of improved designs of domestic stoves succeeds mainly when micro-finance is available for the necessary capital investments. Traditional biomass cooking stoves may be less energy-efficient, less healthy and more labour-intensive than solar or biogas designs, but they are often more affordable, which is a critical factor for impoverished rural communities (Geoghegan *et al.*, 2008; UNDP, 2009). New stove designs also need to be culturally acceptable. Compared with open fires, the use of more efficient biomass cooking stoves can reduce by half the demand for traditional fuelwood (Chum et al., 2011). However, not all programmes to introduce these more efficient stoves have succeeded. This lack of success is often due to the informal nature of the fuelwood supply chain and a poor understanding of local cultures and their cooking habits. For example, users may prefer to cook with fuelwood during the cooler evenings rather than cook in the heat of the day with a solar oven.

CSA objective: strengthened resilience to climate change and variability

As a result of climate change, some farming practices may become less reliable as sources of income. For some farmers diversification to on-farm energy generation could be a coping strategy. With high and volatile fossil fuel prices, energy-smart food systems which improve access to modern energy services and increase energy diversity, contribute to energy security. This is not a climate change adaptation strategy, but it strengthens resilience, which is the broader term used in the definition of CSA. Reliance on local energy sources does not automatically enhance resilience to climate change (see Table 5.1). Tapping into local energy sources can increase incomes and expand the diversity of energy sources. This increases resilience to climate change. The use of biogas cookstoves illustrates both types of adaptation. Biogas cookstoves and their liquid fertilizer by-product can help ensure self reliance in household energy and at the same time they can reduce the amount spent on woodfuel and chemical fertilizers, as well as make gathering firewood less time consuming.

Although renewable energy plays a key role in future low-carbon plans aimed at limiting global warming, its dependence on climate conditions also makes it susceptible to climate change. This is also true for energy-smart food systems. For example, climate change will affect many aspects of renewable energy production, including: the cultivation of biofuel crops; water availability and seasonality for hydropower; atmospheric conditions for wind and solar energy; and variations in needs of energy for heating and cooling. As these impacts will increase significantly, the energy sector will have to adapt. The energy supply needs to be 'climate-proofed' as much as possible to ensure that energy use in the agrifood system can be climate-smart. Table 5.1 presents examples of adaptation measures to reduce climate change-related losses and risks in the energy sector. Several of these measures are similar to those promoted for climate change adaptation in agriculture and are relevant to CSA. Furthermore, while the table shows adaptation measures for individual energy classes, it should be noted that a diverse energy portfolio could be a way to reduce climate risk to energy supply.

The World Bank's Energy Sector Management Assistance Program (ESMAP) has developed a web tool called the Hands-on Energy Adaptation toolkit (HEAT) to assess the vulnerability of the energy sector to climate change and other factors (ESMAP, 2013).

Table 5.1
Examples of adaptation measures to reduce losses/risks in energy systems

ENERGY SYSTEM		TECHNOLOGICAL		BEHAVIORAL		
		“Hard” structural)	“Soft (technology and design)	(Re)location	Anticipation	Operation and maintenance
Supply	MINED RESOURCES including oil and gas, thermal power, nuclear power	Improve robustness of installations to withstand storms (offshore), and flooding/drought (inland)	Replace water cooling systems with air cooling, dry cooling, or recirculation systems Improve design of gas turbines (inlet guide vanes, inlet air fogging, inlet air filters, compressor blade washing techniques, etc.) Expand strategic petroleum reserves Consider underground transfers and transport structures	(Re)locate in areas with lower risk of flooding/drought (Re)locate to safer areas, build dikes to contain flooding, reinforce walls and roofs	Emergency planning	Manage on-site drainage and runoff Changes in coal handling due to increased moisture content Adapt regulations so that a higher discharge temperature is allowed Consider water re-use and integration technologies at refineries
	HYDROPOWER	Build desilting gates Increase dam height Construct small dams in the upper basins Adapt capacity to flow regime (if increased)	Change water reserves and reservoir management Regional integration through transmission connections	(Re)locate based on changes in flow regime		Adapt plant operations to changes in river flow patterns Operational complementarities with other sources (for example natural gas)
	WIND		Improve design of turbines to withstand higher wind speeds	(Re)locate based on expected changes in wind-speeds (Re)locate based on anticipated sea level rise and changes in river flooding		
	SOLAR		Improve design of panels to withstand storm or reduced loss of efficiency due to higher temperatures	(Re)locate based on expected changes in cloud cover	Repair plans to ensure functioning of distributed solar systems after extreme events	
	BIOMASS	Build dikes Improve drainage Expand/improve irrigation systems Improve robustness of energy plants to withstand storms and flooding	Introduce new crops with higher heat and water stress tolerance Substitute fuel sources	(Re)locate based on areas with lower risk of flooding/storms	Early warning systems (temperature and rainfall) Support for emergency harvesting of biomass	Adjust crop management and rotation schemes Adjust planting and harvesting dates Introduce soil moisture conservation practices Apply conservation agriculture for better drought and flood management

ENERGY SYSTEM	TECHNOLOGICAL		BEHAVIORAL		
	“Hard” structural)	“Soft (technology and design)	(Re)location	Anticipation	Operation and maintenance
DEMAND	Invest in high-efficiency infrastructures and equipment Invest in decentralized power generation such as rooftop PV generators or household geothermal units		Efficient use of energy through good operating practice		
TRANSMISSION AND DISTRIBUTION	Improve robustness of pipelines and other transmission and distribution infrastructure Burying or cable re-rating of the power grid		Emergency planning	Regular inspection of vulnerable infrastructure such as wooden utility poles	

Source: Adapted from ESMAP, 2011

CSA objective: contribution to climate change mitigation

Given the facts and figures above, energy-smart food systems may not appear to be very important for the third pillar of CSA which is GHG emission reduction and carbon sequestration. Primary production is responsible for most agricultural emissions, but most of the energy used in the agrifood sector is not for primary production. This is also true regarding the direct energy used in the agrifood chain. However, there are additional links that make energy-smart food systems important for CSA. Many of these links become apparent when considering the mitigation potential rather than current GHG emissions and energy consumption. Reducing energy use in the food chain will reduce CO_2 emissions. Figure 5.2 shows that, globally, these do not represent the major share of GHG emissions from the agrifood chain. However, there are other considerations that should be taken into account.

- The situation differs between high- and low-GDP countries. In high-GDP countries, post-harvest operations contribute the most GHG emissions, largely as CO_2. In low-GDP countries, most GHGs, largely methane and nitrous dioxide, are emitted on the farm.
- There is a correlation between nitrous oxide (N^2O) emissions from fertilizer application and energy use (and hence CO_2 emissions) in the production of fertilizer. Precision agriculture, including a more efficient use of fertilizer, will lower CO_2 and N_2O emissions and reduce the consumption of fossil fuels. Methane emissions can be reduced by using manure for biogas, which may also improve energy access or reduce the use of fossil fuels on farms. Growing trees on farms for energy purposes can also sequester carbon and displace fossil fuels. However, increasing energy efficiency in agricultural production may also increase profits, which could lead to agricultural expansion. As such, the resulting land-use change would lead to higher GHG emissions (even per unit of production). These considerations indicate that there are many links between energy-smart food systems and CSA beyond the reduction of CO_2 emissions from fossil fuels.

Box 5.2
Examples of the importance of energy-related GHGs beyond the farm gate in high GDP countries

As shown in Figure 5.3, the energy component associated with CO_2 emission is most relevant in the agrifood chain's post-harvest operations, and accounts for the bulk of emissions in high-GDP countries.

A recent study from the United Kingdom (UK) has shown that around 52 percent of the emissions occur in the post-farm stages of UK food production (see Figure 5.5). Similar figures can be observed for the United States, where around 54 percent of GHGs are emitted after the farm-gate (see Figure 5.6).

These results are shaped by a number of factors, including the definition of the boundaries of the food system. The inclusion of dishwashing or international food trade could significantly change the overall picture. For example, the net food trade in the UK's food system is responsible for around 24 percent of total emissions of the food chain, which lowers the relative proportion of emissions attributable to farming to just 32 percent.

Source: FAO elaboration based on UK DEFRA, 2010.

Figure 5.5
GHG emissions along the agri-food chain in the UK

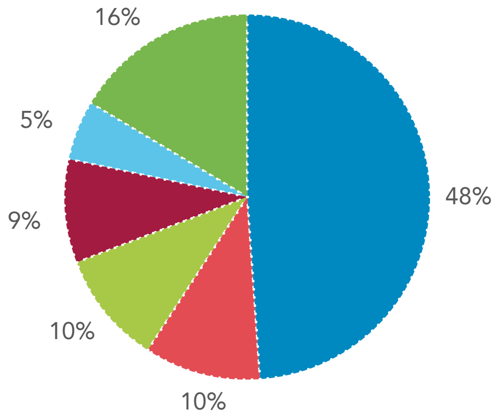
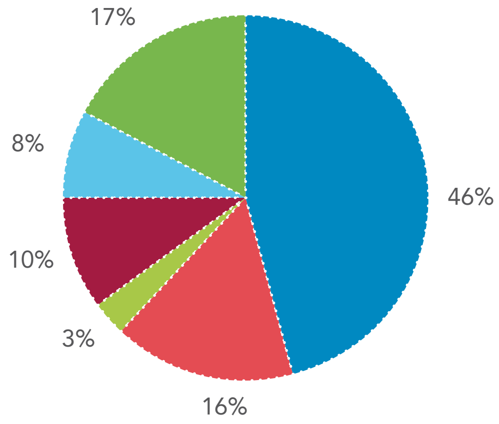


Figure 5.6
GHG emissions along the agri-food chain in the US



Source: FAO elaboration based on UK DEFRA, 2011

Source: FAO elaboration based on USDA, 2010 and US EPA, 2009

Efforts to achieve food and energy security in a climate-smart way will be accomplished through low-carbon approaches. This can be done either directly, through the increased use of renewable energy in the agrifood sector, or indirectly, through measures to increase energy efficiency (see Table 5.2). It is worth pointing out that many of these measures, in particular those that are carried out behind the farm gate, involve resource-efficient farming practices that are part and parcel of CSA. Implementing these measures would be a win-win solution from the point of view of both CSA and energy-smart food.

Table 5.2
Examples of energy efficiency improvements through direct or indirect technical and social interventions along the food chain

	Directly	Indirectly
Behind farm gate	Adopting and maintaining fuel efficient engines Precise water applications Precision farming for fertilizers Adopting no-till practices Controlled building environments Heat management of greenhouses Propeller designs of fishing vessels	Less input-demanding crop varieties and animal breeds Reducing soil erosion Reducing water demand and losses Using biofertilizers Efficient machinery manufacture Information and communication technologies to identify stock locations and markets
Beyond farm gate	Truck design and operation Variable speed electric motors Better lighting and heating Insulation of cool stores Minimizing packaging of food Improve efficiency of cooking devices and space heating	Improving road infrastructure Urban planning to reduce distances travelled to distribute and buy food Reducing food losses at all stages Changing diets away from animal products Lowering obesity levels Labeling of food products

Source: adapted from FAO, 2011a

Box 5.3
Can biofuels contribute to CSA?

Global liquid biofuel production has increased more than 500 percent since 2000. Production is projected to increase a further 50 percent by 2020 and increase even more by 2050.

Over the past five or six years policies have played a critical role in the rapid increase in liquid biofuel production, principally for transport purposes. Policy support for biofuels has been motivated by a desire to strengthen energy security, reduce GHG emissions, advance rural development and increase farmers' incomes. After the rapid introduction of new and expanded support measures, there is now a better evidence base for reviewing the impacts of increased biofuel production and reflecting on how policies might be adjusted to address changing goals and concerns.

Listed below are some possible contributions of biofuels to CSA objectives.

- Biofuels (in solid, liquid and gaseous forms) can help improve access to modern energy services for household and productive uses, which contribute to sustainable increases in productivity and income. A recent study on small-scale bioenergy initiatives (FAO, 2009) shows that this improvement can be achieved with minimum sustainability risks.
- Biofuels, especially small-scale production, can strengthen resilience to climate change and variability. However, they may also bring about their own climate risks by creating a link between energy security and crop yields. This risk is particularly high where feedstock diversity is low.
- The impacts on GHG emissions and carbon sequestration are more complex and the subject of much debate. Bioenergy is often considered to be CO_2-neutral because the generation of biomass by photosynthesis absorbs the same amount of CO_2 that is released by burning the biomass. However, this fails to consider the linkage between the carbon cycle and other natural cycles, including those of nitrogen, phosphorus and water. These elements are also required for photosynthesis and they are consumed whenever biomass is produced. Soil nutrients are consumed and need to be supplemented. These additions (e.g. fertilizer application) can result in GHG emissions, especially nitrous oxide. A full life cycle assessment has to be carried out that can take into account agricultural production and processing, as well as direct and indirect land-use changes.
- Some good practices that can improve the performance of biofuels in terms of climate change mitigation include:
  - agroecological zoning, to avoid biofuel development in high carbon areas (e.g. primary forests, peat land) and only promote it in areas of high land suitability;
  - the use of residues for biofuel production, as long as it does not affect their use for soil management or as animal feed; and
  - conservation agriculture, which is usually a low-carbon farming practice that can sometimes even sequester carbon.

More broadly, biofuel policies and programmes should act in synergy with programmes related to agricultural development rather than with policies that artificially support biofuel demand. A sound and integrated approach to bioenergy, particularly biofuel development, is required to reduce the risks and harness the opportunities related to bioenergy development. This approach requires:

- an in-depth understanding of the situation and the related opportunities and risks, as well as synergies and trade-offs;
- an enabling policy and institutional environment, with sound and flexible policies (e.g. targets and incentives) and means to implement these;
- implementation of good practices by investors and producers to reduce risks and increase opportunities, along with appropriate policy instruments to promote these good practices;
- proper impact monitoring and evaluation and policy response mechanisms; and
- capacity building and good governance in the implementation of the above.

To promote this sound and integrated approach, FAO has been developing a set of instruments which are part of FAO's Sustainable Bioenergy Toolkit: Making Bioenergy Work for Climate, Energy and Food Security (FAO, 2013).

Synergies and trade-offs between energy-smart food and climate-smart agriculture

As there are numerous synergies between CSA and energy-smart food, climate benefits can and do often accrue through the development of energy-smart food systems. However combining these objectives may also require some trade-offs. Table 5.3 presents examples of such potential synergies and trade-offs. It should be noted that this table presents a very broad picture and should be considered as a first approximation for summarizing the possible linkages between energy-smart food systems and CSA. These linkages are often quite complex and context specific, and as such, more research is needed in this area.

Table 5.3
Examples of possible synergies and trade-offs between energy-smart food and CSA objectives

		CSA objectives		
		Sustainable increases in productivity and income	Strengthened resilience to climate change and variability	Agriculture's reduced impact on climate change
Energy-smart food objectives	Increased energy efficiency	☑ General: Savings on energy costs (after up-front costs for technology have been paid) will result in increased profit if productivity is not excessively decreased Specific: Practices such as replacement of synthetic fertilizers with application of agricultural residues or manure, which require fewer external inputs and increase yields, can contribute to both increased energy efficiency and sustainable increases in productivity and income. Practices that reduce external energy inputs and (at least) maintain yields, such as reduced or zero tillage, will increase energy efficiency and sustainably increase income. If such practices are combined with others that increase yields (such as nitrogen-fixing cover crops or manure trees), this can contribute to both energy efficiency and sustainable increases in productivity and income. There is also much scope for enhanced post-harvest technologies and practices that contribute to both energy efficiency and sustainable increases in productivity and income, such as improved crop and food storage, packaging and distribution. Some high pressure drip irrigation systems may be less energy efficient than gravity irrigation for the same water efficiency: hence trade-offs between increased energy efficiency and water efficiency should be taken into account to ensure sustainability.	☑ General: Savings in energy costs will result in increased income available to enhance adaptive capacity Decreased dependence on energy inputs (especially fossil fuels) will tend to reduce vulnerability to shocks in energy prices Some "climate-proof" agricultural production and energy systems may result in lower energy efficiency Specific: Practices such as conservation agriculture that enhance crop cover, soil water retention and soil organic matter may increase resilience to drought and extreme weather events Irrigation tends to enhance resilience and may increase energy efficiency through its impacts on productivity	☑ General: Improvements in energy efficiency, whether due to lower embedded energy in inputs or on-farm fuel combustion, will reduce GHG emissions in the production chain However, increased energy efficiency may translate into greater profits, which may result in extensification of agriculture (so-called rebound effect), potentially bringing about CO_2 emissions from land use change that could even result in greater GHG emissions per unit of production Specific: Practices such as reduced or zero tillage, precision agriculture, replacement of synthetic fertilizers with agricultural residues or manure, elimination of pesticides through integrated pest management or enhanced distribution logistics that reduce fossil fuel combustion will generally lead to reduced GHG emissions, though full lifecycle assessment is required. Reduced or zero tillage, in combination with permanent crop cover, crop rotation and elimination of agrochemicals may also sequester carbon.

		CSA objectives		
		Sustainable increases in productivity and income	Strengthened resilience to climate change and variability	Agriculture's reduced impact on climate change
Energy-smart food objectives	Increased production and use of renewable energy in agrifood systems, including through integrated food-energy systems)*	? **General:** On-farm production of renewable energy can allow farmers to sustainably increase income through the sale of renewable energy to the grid or of biogas to the local market or through reduced purchases of fossil fuels. Potential land-use competition (energy versus food: e.g. solar panels on farm land, biofuels) Use of renewable energy systems may result in more expensive energy inputs (i.e. fossil fuel might be cheaper than renewable energy) **Specific:** On-farm production of biogas can allow use of a biogas by-product as a liquid fertilizer, which can increase yields and reduce environmental pollution. Integrated food-energy systems such as intercropping with leguminous crops or agroforestry may sustainably increase farm productivity and also provide energy. Excessive use of agriculture and forestry residues for bioenergy can compete with their role in increasing soil organic matter and hence damage productivity. Biofuel production could lead to increased pressure on water resources, reduced agrobiodiversity (where monoculture is used) and introduction of invasive species.	☑? **General:** Renewable energy will lead to decreased dependence on fossil fuels, so less vulnerability to fossil fuel market shocks. On-farm renewable energy production can Increase income diversification, so reducing dependency on crop yields and demand. Carefully-designed diversified energy portfolio can reduce climate vulnerability, but some types of renewable energy (e.g. wind, bioenergy, hydro) are vulnerable to climate variability. The degree to which new energy services are climate resilient depends on the energy source (see table 5.1). **Specific:** Excessive use of agriculture and forestry residues for bioenergy can compete with their role in improving soil management, which could decrease resilience to extreme weather events. The use of residues for bioenergy rather than animal feed and/or soil conditioner could result in decreased soil quality.	☑ **General:** Energy diversification will tend to replace fossil fuels with renewable forms of energy, but in the case of bioenergy, will only reduce net GHG emissions subject to use of good practices. **Specific:** Excessive use of agriculture and forestry residues for bioenergy can compete with their role in returning carbon to the soil; different bioenergy technologies lead to different levels of nutrient availability in the soil. Indirect effects of biofuel demand such as indirect land-use change and price-induced intensification can lead to net GHG increases. The use of residues for bioenergy rather than for animal feed could act as an additional source of displacement and potential land-use change

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* Integrated food-energy systems can be used to increase access to modern energy services (the third pillar of energy-smart food) as well as to increase production and use of renewable energy in agrifood systems (the second pillar) (Bogdanski *et al.*, 2010; Bogdanski, 2012).

		CSA objectives		
		Sustainable increases in productivity and income	Strengthened resilience to climate change and variability	Agriculture's reduced impact on climate change
Increased access to modern energy services	Increased access to modern energy services	☑ ? **General:** Availability of energy for productive use (both for primary production and value-adding processing) and reduction of food losses (e.g. through improved processing, packaging and storage) can enable improved use of natural resources and increased productivity and profits. Provision of modern energy services through renewable forms of energy is likely to lead to sustainable increases in productivity and income (particularly where locally produced), whereas if fossil fuels are used there could be productivity and income benefits along with negative environmental consequences. Trade-offs need to be assessed in the local context and taken into account. More affordable energy services may be less energy efficient (e.g. cheaper tractors may be less efficient).	☑ **General:** Increased access to modern energy services enables enhanced adaptive capacity through the ability to increase and diversify income, for example through adding value to primary production and through enhanced storage of products.	☒ **General:** Increased access to modern energy services will generally lead to increased energy consumption. This will often lead to increased GHG emissions (although these could be insignificant for some renewable energy sources). However, in the case where access to modern energy services displaces unsustainable use of wood for energy, the resulting reduction in deforestation and forest degradation could lead to reduced GHG emissions. Increased access to modern energy services may or may not lead to increased energy efficiency – this depends in part on the stage of development and level of energy consumption of a country/agri-food system (see above cell for energy efficiency versus climate change mitigation). **Specific:** Bioenergy technologies that retain more nutrients (e.g. anaerobic digestion) versus those that retain less nutrients (e.g. gasification and combustion).

Legend:
☑ = Synergy between energy-smart food and CSA objectives
? = Synergy between energy-smart food and CSA objectives with some significant caveats
☒ = No clear trend

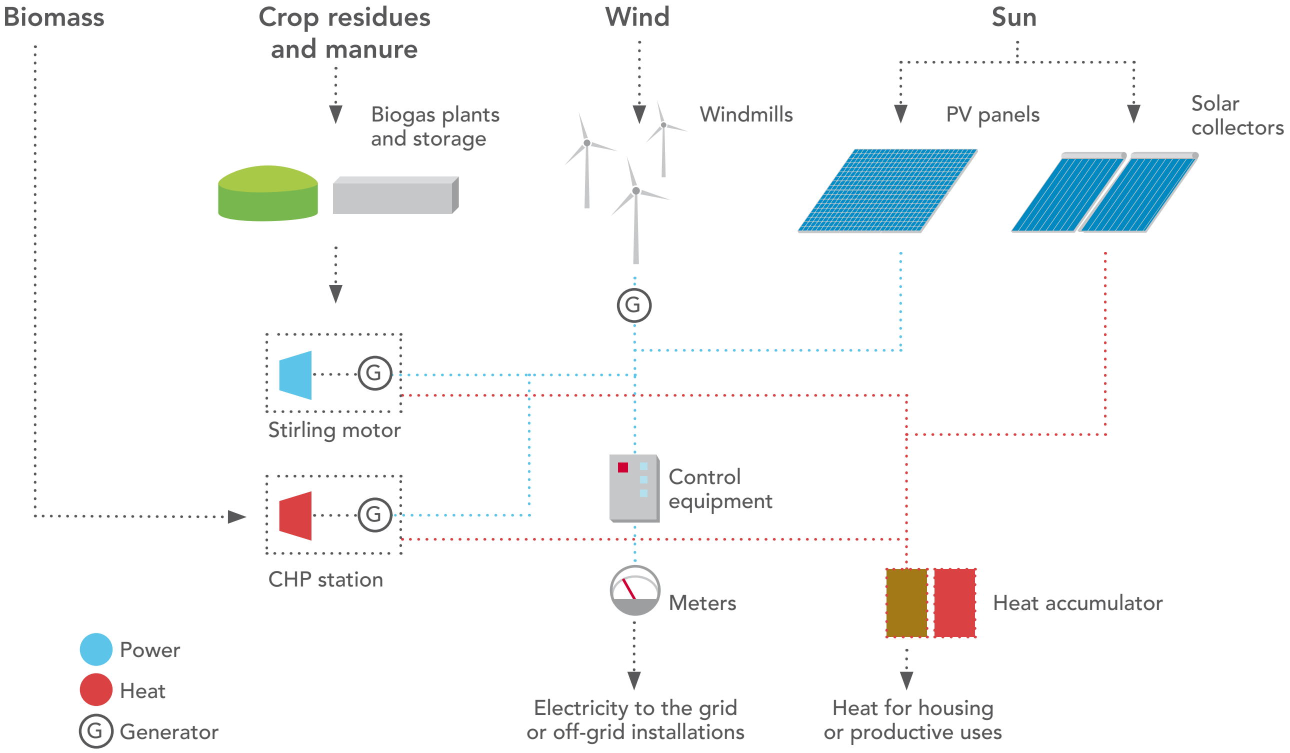
5.3 Moving forward – possible energy solutions for CSA

FAO projections to 2030 indicate that in developing countries the proportion of land cultivated by hand and with animal power will decrease. This shift in agricultural practices offers opportunities for increased productivity and reduced drudgery for farmers. However, expensive machinery and equipment are often unavailable to poor farmers. Innovative business and community models are required to ensure that smallholder farmers are able to access improved technologies (e.g. through rental schemes or cooperatives). The move to more highly mechanized farming systems is likely to reduce farm labour requirements and reduce employment opportunities in rural areas. Well-designed policies and programmes are required to create alternative employment opportunities along the agricultural value chain and in other non-agricultural rural livelihoods.

Technologies for energy-smart food and CSA

A mix of appropriate energy technologies, equipment and facilities in farming communities is necessary to make the gradual shift to energy-smart food systems. The nature of this mix will depend on natural conditions, infrastructure and skills available in the labour force. There are many technologies that can be part of energy-smart food systems, including: wind mills, solar collectors, photovoltaic panels, biogas production units, power generators, equipment for bio-oil extraction and purification, fermentation and distillation facilities for ethanol production, pyrolysis units, hydrothermal conversion equipment, solar-, wind or bioenergy-operated water pumps, renewable energy-powered vehicles, monitoring systems, information and communication technologies (ICT), cooking stoves, equipment for water supply, distribution and purification. These technologies add value to production near the source of raw materials. They can also be combined on the same farm in integrated food-energy systems as shown in Figure 5.7.

Figure 5.7
An integrated approach to renewable energy for farming systems



It is difficult to identify energy-smart food 'hot-spots' and intervention priorities with data that is currently available. Different food chains are subject to very different processes and require different types of energy inputs. In particular, more research is required on the relationships between energy use, yields and production costs in various agricultural systems and settings.

Field efficiencies[5] can be up to 90 percent in tilling and cultivating; 65-70 percent in fertilizing and grain harvesting. However, results depend on yields and plot size. Fuel consumption is typically 600-1 200 megajoules per hectare (MJ/ha) for mouldboard ploughing; 200-4 900 MJ/ha for disking; 80-160 MJ/ha for planting; 150-300 MJ/ha for ammonia application; 100-200 MJ/ha for cultivating; and 250-500 MJ/ha for grain harvesting (Smil, 2008).

Farming systems where there are typically low energy needs and extensive fields for farming and grazing, like those in Australia or New Zealand, can operate with energy requirement as low as two or three gigajoules per hectare (GJ/ha). The energy requirement for input-intensive agriculture in countries such as the Netherlands or Israel can reach up to 70-80 GJ/ha (Smil, 2008).

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[5] The work obtained from energy invested.

On a per calorie of food output basis, China, with its high cropping ratio, extensive irrigation and intensive fertilization, now has a more energy-intensive agriculture sector than the United States or the European Union. After the farming reforms of 1978 in China, nitrogen (half of which comes from inorganic fertilizers) has provided about 60 percent of the nutrient in cropping. Over 80 percent of the country's protein requirement has been derived from crop production. The agriculture sector is highly dependent on fossil fuels, but has been able to feed about 8.5 people per hectare and up to 15 people in populous provinces. This result is also attributable to a national diet with little animal proteins.

Inefficient use of nitrogen fertilizers leads to losses that are usually above 50 percent and sometimes can amount to 60-70 percent of applied nutrients (Cassman *et al.,* 2002). In many areas, increasing the efficiency of fertilizer application so that it results in optimal plant growth with minimal inputs would significantly improve the energy balance of food production. It would also help protect the environment and cut costs for farmers. However, in some areas, such as in Africa, reaching optimal energy efficiency in food production may require the application of more fertilizer to increase yields. Curbing soil erosion could be another important method to reduce fertilizer losses.

Water efficiency is becoming a priority in irrigation. However, achieving greater efficiency in irrigation may require more energy. Drip irrigation, for example, which increases the efficiency of water use, requires energy to pressurize the water. Much of the energy needed for irrigation is often used for pumping operations. Extending irrigation in remote areas requires appropriate energy technologies, such as solar powered pumps that can save manual labour in off the energy grid rural areas. Irrigation efficiency can be as high as 95 percent; good field practices have average efficiency rates around 65-75 percent while furrow irrigation can only achieve 30-40 percent efficiency. In Asia, irrigation efficiency could potentially be doubled (Smil, 2008).

Liquid fuels are usually required for soil preparation. The amount of energy required for this is influenced by weather conditions (wet or dry soils), soil compaction and other factors. The single most energy-consuming operation in a cropping cycle is soil tillage for land preparation, particularly ploughing. Consequently, reduced tillage cropping systems, particularly no-till systems, have become particularly attractive in times of high energy costs. Practices, such as zero tillage used in conservation agriculture, have the potential to bring about significant energy savings that can even reach up to 40-50 percent (Doets *et al.,* 2000; SCCA, 2012). An example from Brazil of these potential savings from conservation agriculture is given in Table 5.4. Energy savings are primarily due to the reduction of external inputs, which are usually energy-intensive.

Table 5.4.
Total energy inputs per crop per hectare for conventional (regular) agriculture (RA) and conservation agriculture (CA) for the complete microcatchment of Lajeado São José, Brazil

	Conventional Agriculture				Conservation Agriculture			
	Maize	Soya	Beans	Wheat	Maize	Soya	Beans	Wheat
Herbicide input (MJ/ha)	1514	1018	254	0	603	603	603	0
Machinery input (MJ/ha)	525	693	227	604	404	513	77	483
Fuel input (MJ/ha)	1625	2167	1673	1450	645	709	454	470
Human labour input (MJ/ha)	0	28	71	0	0	28	71	0
Total input (MJ/ha)*	3664	3906	2226	2054	1653	1854	1205	953
Total input system (MJ/ha)**	2962				1416			

*= sum of energy inputs for herbicide, machinery and fuel

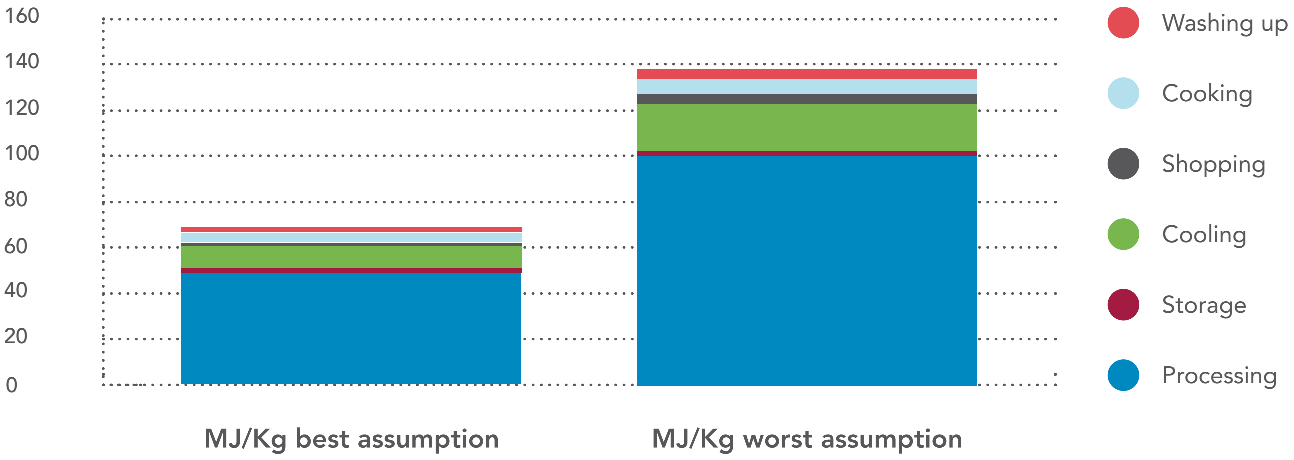
**= sum of energy inputs per average hectare

Source: Doets et al., 2000

A number of technological solutions exist to minimize energy use. These solutions include reducing the rolling resistance and slippage of combine harvesters (e.g. improving tractor tires). Energy conservation in greenhouses, animal houses and agricultural buildings is also a major area of intervention. Energy use can be minimized through a greater deployment of heat pumps (mostly of mechanical compression type, which are driven by electric motors) and heat recovery systems. Both of them can also provide dehumidification services and cooling. Air-to-water heat pumps or water-to-water heat pumps, possibly combined with geothermal energy sources can significantly increase energy efficiency in all operations that require heat. Pipe heating, heated floors, infrared heating and air heating are all technological options that can also be considered. The proper construction, insulation and correct ventilation of buildings and greenhouses are some of the most economic energy-efficient interventions.

A best and worst assumption of energy intensity per unit of produce can be made for all activities that are part of the agrifood chain. These activities are not included under the agricultural sector in the Intergovernmental Panel on Climate Change (IPCC) GHG accounting system but instead are under the industrial processes or energy sectors. These intensities are presented in Figure 5.8.

Figure 5.8
Best and worst assumption of energy intensities in the post-harvest stage of the food chain



Source: FAO, 2011a

Important opportunities for reducing energy dependency can be found in the drying, conditioning and storing of produce and in improving the fuel efficiency of field machinery. For grain drying, modern continuous flow dryers can be operated with much lower levels of energy than conventional dryers. Reduced energy use can also be achieved through the insulation of dryers, the recirculation of heat recovery of out-going air and improved instrumentation and automatic control. Combined (warm and cold air) dryers further reduce heat demand, but require a continuous and reliable electricity source for fans. Also available is dielectric heating technology, which can significantly reduce the energy needed for processing agricultural products. Typical rates of 600-750 kilojoule per kilogram (kJ/kg) of dried grain are needed to store products with 14 percent moisture, with liquefied petroleum gas (LPG) and electricity as the principal energizers. This rate goes up to 3-6 GJ/ha for corn (Smil, 2008).

Solar power (photovoltaic or solar heaters), wind and geothermal energy are all sources of energy that are available today for both large and small applications. They are particularly suitable for remote rural areas.

Worldwide, the use of biomass for heat and power could save significant amounts of carbon. However, the bioenergy would have to be carbon neutral, and there is debate as to whether this would be the case (see Box 5.3). Co-firing of biomass with coal could save nearly 0.5 gigatonne of carbon (GtC) per year at fairly modest costs (FAO, 2010). Savings in the traditional biomass and charcoal sectors could amount to another 0.5 GtC. Considerable efforts would be required in this sector to address the higher investments involved, the complex socio-economic and cultural issues, and the transaction costs associated with equipment and the reliable supply of biomass (FAO, 2010).

Examples of progress being made to realize the transformation towards energy-smart food include:

Behind the farm gate:

- Significant improvement in energy efficiency has been made through precision farming in industrial agriculture and through conservation agriculture.
- Renewable energy has been used on farms. The increased use of solar pumps in irrigation systems is one example. In addition, bioenergy is being used in integrated food-energy systems (Bogdanski, 2012). Examples include: biogas in integrated crop-livestock systems, particularly in Asia; intercropping with perennials such as pigeon peas to produce wood for on-farm energy purposes in Africa (Bogdanski and Roth, 2012); and more complex food-energy systems, such as the Tosoly farm in Colombia (see Box 5.4). Another example can be found in the use of suspended solar panels in agrophotovoltaic systems (see Box 5.5).

Beyond the farm gate (see also Module 11 on post-harvest management and food chains):

- Renewable energy is also being used in food processing activities. For example, in Sri Lanka woody biomass is used to dry spices. This innovation has diversified income streams and has increased revenue for a range of local operators in the spice market chain. In addition to selling by-product fuel wood from pepper plants to the dryer operators, small-scale growers are now able to sell mature spices that can be dried and preserved (FAO, 2009).
- The United Kingdom's 'war on food waste,' 'waste implementation programmes' (UK DEFRA, 2003) and similar initiatives have improved the energy efficiency in agrifood systems by reducing food losses.
- The promotion of clean cooking stoves in many parts of the world has made food preparation more energy efficient and healthy.

Box 5.4.
An integrated food-energy system in Colombia

TOSOLY Farm in the Colombian foothills north of Bogotá, is a highly integrated farm that produces food and energy for family consumption and for sale in a crop and livestock system. The cropping is based on sugar cane (feed for pigs, food and energy), coffee and cocoa (food and energy), and multipurpose trees. Sugar cane is cultivated on 1.5 ha of the seven ha farm. Tree crops include coffee, cocoa, forage trees and forage plants for timber and fuel, including for shading the coffee.

The livestock and fuel components are chosen for their capacity to utilize the crops and by-products produced on the farm. The sugar cane stalk is fractionated into juice and residual bagasse. The tops, including the growing point and some whole stalk, are the basal diet for cattle and goats. The juice is the energy feed for pigs and the source of 'sweetener' for the farm family's cooking. The bagasse is the fuel source for a gasifier that provides combustible gas for an internal combustion engine linked to an electric generator. The goats are the means of fractionating the forage trees, consuming the leaves, fine stems and bark as sources of protein. The residual stems are an additional source of fuel in the gasifier. The goat unit has ten breeding does and two bucks. There are three pens for two crossbred cows and their calves, which are kept for the production of milk, meat and manure.

The pig unit has a capacity for 40 growing pigs and five sows. Forty hens and six ducks are raised for eggs and meat in foraging, semi-confined systems. Rabbit production, a new venture on the farm, applies the principles of 100 percent forage diets developed in Cambodia, Viet Nam, and the Lao People's Republic.

A horse transports sugarcane and forages. All high-moisture wastes are recycled through plug-flow, tubular plastic (Polyethylene) biodigesters. Pig and human excreta are the feedstock for four biodigesters. Waste water from coffee pulping, washing of dishes and clothes go to a fifth biodigester. Effluents from all eight biodigesters are combined and recycled to the crops as fertilizer. The pens for the goats and cattle have clay floors covered with a layer of bagasse to absorb the excreta. Periodically, this manure is applied to the crops as fertilizer and a source of organic matter.

Most of the energy on the farm (about 100 kilowatt hours per day [kWh/day]) is produced by gasification of the sugarcane bagasse and the stems from the mulberry and Tithonia forages. The 800 W installed capacity of photovoltaic panels are estimated to yield 8 kWh daily. The eight biodigesters produce 6m3 daily of biogas, two-thirds of which are converted to electricity (6 kWh/day) using it as fuel in the same internal combustion motor generator attached to the gasifier. The remainder is employed for cooking. Low-grade heat energy produced by the solar water heater and the wood stove are not included in the energy balance.

After deducting the electricity used to drive the farm machinery and to supply the house (11 kWh/day), the potentially exportable surplus is 104 kWh daily. At the current price of electricity (US$0.20/kWh), this would yield an annual return of US$7 600. Annually, the gasifier produces 4.4 tonnes of biochar, which is returned to the soil. Assuming that 65 percent of carbon in the biochar is not oxidized in the soil (Lehmann, 2007), then the effective sequestration of carbon dioxide is in the order of 11 tonnes annually.

Source: Preston, 2010

Box 5.5.
An agrophotovoltaic farm in Italy

In 2011, an agrovoltaic installation was inaugurated in Mantua, Italy. 'Agrovoltaic' technology is a production technique that uses and integrates existing technologies in new ways. It offers farmers the possibility to continue cultivating their lands while producing clean energy. This also allows farmers to partially shade their land, which permits the cultivation of a wider range of crops.

The agrophotovoltaic installation, which makes use of recycled and non-pollutant technologies and materials, consists of a series of photovoltaic panels suspended 5 meters above the ground. These panels produce renewable electricity with a power capacity of 2.4 megawatts (MW). The installation, realized by REM (Revolution Energy Maker), a group of Italian entrepreneurs who operate at the national and international level in the sector of electricity production, is also equipped with a series of accessories that offer additional useful options. One of these options is a wireless control system that lets users change the panels' inclination and monitor ground temperature and relative humidity.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The installation satisfies energy producers' needs for photovoltaic units to generate renewable energy and farmers' needs for arable land. It allows land-owners to diversify their incomes, and preserve and optimize the use of the landscape. By permitting an automatic and programmed management of water distribution and irrigation, this type of installation offers significant advantages for agriculture and the environment.

The system requires 4 to 5.5 hectares to produce a peak power of 1 MW to install and occupies at most two percent of the land. Thanks to the omnidirectional dual-axis tracking of the photovoltaic panels, the agrovoltaic system increases the production of clean energy by 30 percent, compared with fixed panels. The structure can integrate new automatic systems that support farming, such as systems for watering, the distribution of fertilizers and phytosanitary inputs and cultivation protection (e.g. anti-hail and shading nets, anti-frost systems). Each tracker can be equipped with a valve control system that allows an external source to control spray irrigation. The pumping and the daily biaxial movement would allow the water to disperse evenly.

These examples show that the transition to energy-smart food practices is already under way. Currently however, the pace of change is slow. For these practices to have a large-scale impact, significant scaling up is required.

Policies and institutions for energy-smart food and CSA

The promotion and scaling-up of energy-smart food practices requires innovative supportive policies and institutions. CSA policies and institutions that promote low-carbon farming practices are relevant to energy-smart food production, as many of these practices promote energy efficiency and renewable energy. Particular attention should be paid to ensuring participatory gender-sensitive decision-making processes on issues related to modern energy services. For bioenergy, it is especially important to consider the security of land tenure for local farmers. Some examples of policies specifically related to energy efficiency and renewable energy are summarised in Table 5.5.

Table 5.5
Examples of policy instruments to promote energy efficiency and renewable energy

Energy efficiency	Renewable energy
The introduction of freight truck fuel economy standards and payload limits Minimum energy performance standards (MEPS) for machinery is used in food systems Energy performance labels on appliances Vehicle speed restrictions Packaging recycling regulations Higher charges for landfill disposal of organic wastes Capacity building, research, education and communication	Promotion of renewable energy markets Financial incentives, such as tax exemption, feed-in tariffs and tradable certificate-based renewable energy obligations Standards, permits and building codes Alternatives to landfill with an energy component (e.g. incineration with energy recovery methane capture from landfill) Capacity building, research, education and communication

Source: FAO, 2011a

Energy-smart food interventions that lead to reduced CO_2 emissions (renewable energy or energy efficiency interventions) can make use of many of the climate change financial mechanisms discussed in Module 14 on financial instruments and investments. In addition, there are financing sources especially targeted for renewable energy use, energy efficiency and increased energy access. These include: innovative business models like energy service companies (ESCOs)[6]; financial instruments, such as feed-in-tariffs; tradable certificates; integrated municipal arrangements; and public-private funding schemes.

Thailand is a country that has enacted several policies that are favourable to renewable energy. Regulations were adopted in 2002 to simplify the grid connection requirements for small electricity generators up to 1 megawatt (MW) (World Bank, 2011). This and other policies led to the development of integrated sugarcane and rice biorefineries that produce food, ethanol, heat and electricity. In addition, organic residues were returned to the soil, increasing soil fertility. By 2008, 73 biomass projects using a variety of residues, including bagasse and rice husks, had been developed with an installed capacity of 1 689 MW (IPCC, 2011).

Implementing such policies requires innovative institutional mechanisms. Again, it should be noted that agricultural institutions that promote low-carbon agriculture also contribute to the production of energy-smart food. The division of labour and financial instruments are other elements that must be taken into account by institutional mechanisms that work to promote concern about integrated food-energy systems (FAO, 2011a). Examples in this are listed below.

- In parts of the United Kingdom where farmers are producing wheat, a bioelectricity plant buys the straw through a subsidiary company that collects the farmers' straw. Seventy percent of the fuel needed to run the bioelectricity plant comes from the straw feedstock, the rest from another feedstock and natural gas. In this system, farmers produce wheat and leave energy matters to more competent players (Bogdanski *et al.*, 2010).
- At the district model biogas farm in China, farmers cultivate crops and are not responsible for raising pigs and producing the biogas themselves. Instead, the farmers contribute money to the district pig farm for purchasing the pigs. The district farm is responsible for raising the pigs and generating the energy. The farmers get in return yearly dividends from any sales of pigs, cheap biogas and cheap liquid fertilizer from the district farm.
- In Bangladesh, two innovative business schemes are tapping into the private sector's needs for biofertilizer to drive the development of household biomass production for energy (ISD, 2010). One scheme seeks to create a steady supply of bioenergy through a cattle-leasing programme. Programme participants, who

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[6] An energy service company is a commercial business providing a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, energy conservation, power generation and energy supply, energy infrastructure outsourcing and risk management.

are mainly women, receive funding to purchase a cow and a calf from an organic tea farm. The women then repay the loan through the sale of milk and dung. In the second scheme, still in its pilot phase, households receive loans from the organic tea farm to pay for setting up a biogas system. The households repay the loan by selling dung and/or the slurry to the tea farm. Once the biogas installation has been completely paid for, the households have the option to continue selling the slurry and dung to the farm.

- 'Fee for service'[7] schemes, such as ESCO, leasing or concession arrangements schemes are other options for financing energy-smart food.

The need for cross-sectoral coordination in bioenergy development is illustrated by the example from Sierra Leone presented in Box 5.6.

Box 5.6

Bioenergy addressed through a cross-ministerial platform in Sierra Leone

Sierra Leone, a post-conflict resource-rich country, is classified as a low-income food-deficit country. Seventy percent of the population lives below the poverty line and 35 percent are undernourished. Agriculture is a key sector of the economy. The country depends heavily on imported fossil fuels, fuelwood and charcoal for household energy, and the population has minimal access to electricity. Currently, modern bioenergy is not produced in Sierra Leone, but a number of investors are moving into the country. Bioenergy development in such a fragile environment can involve major risks, but may represent an opportunity to attract much needed investment in agriculture. Agriculture-led growth through bioenergy investments could reduce poverty, stimulate the economy and increase access to energy. However, the process for achieving this needs to be clearly understood and carefully managed. The inclusion of smallholder farmers, social protection, and sustainable resource management are key elements in the process.

The Ministry of Energy and Water Resources (MEWR) formally requested the technical support of FAO to assess the potential for sustainable bioenergy development in the country using the Bioenergy and Food Security (BEFS) approach. A first step was the establishment of an interministerial working group, the Bioenergy and Food Security Working Group (BEFS WG). Its first activity was to identify the country's main concerns and challenges for bioenergy development as well as the country's immediate needs and longer-term requirements. One of these immediate needs is to have information that would allow Sierra Leone to screen and direct investors coming to the country. The working group is currently developing a set of guidelines for sustainable bioenergy investment. As land grabbing is becoming a major concern in Sierra Leone, the guidelines will address the issue of community inclusion and conflict management. In the longer term, there is the need to identify the country's potential for sustainable bioenergy development, cover data and information gaps, and address long-term institutional requirements and training needs both at policy and technical levels.

A multi-partner programme for scaling up energy-smart food

Shifting to more energy-smart food systems is an important step towards reaching the broader CSA goals. Decision-makers need to adopt a long-term view to make the needed paradigm shift to food systems that are energy-smart and contribute to climate change mitigation and adaptation as well as food security. Although this shift will not be fully accomplished in the short term, there is no time for delay. The key question at hand is not, 'If or when we should we begin the transition to energy-smart food systems?', but rather 'How can we get started and make gradual but steady progress?' The shift towards energy-smart food systems will be gradual and can only be achieved through sustained efforts. Understanding and implementing energy-smart food systems is a complex multidisciplinary task that requires a multipartner programme. Towards this end, the Energy-Smart Food for People and Climate was launched in 2012. It aims to help countries promote energy-smart agrifood systems through the identification, planning and implementation of climate-smart measures that integrate energy, water and food security.

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[7] Fee-for-service (FFS) is a payment model where services are unbundled and paid for separately.

5.4 Conclusions

This module has introduced the concept of energy-smart food system and its important role in transitioning to climate-smart agriculture. One of its main conclusions is that the dependence of agrifood systems on fossil fuels represents a major threat to food security and contributes significantly to climate change. The challenge of reducing this dependency can be met by up-scaling of energy-smart food systems which improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services in agrifood systems. The case studies of the module indicated how different technological solutions and integrated systems in distinct contexts can be both energy- and climate-smart. They presented e.g. low-cost machinery, biofuels, integrated food-energy systems, modern technology and new type of cross-sectoral collaboration needed for energy-smart food systems. It was emphasized, however, that in addition to synergies between energy-smart food and CSA objectives there are also possible tradeoffs which need to be recognized. The module ended by stating that the shift to the new approach requires long-term vision and commitment as well as multidisciplinary efforts, but there is no time for delay.

Notes

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Acronyms

APCAEM	Asian and Pacific Centre for Agricultural Engineering and Machinery
BEFS	Bioenergy and Food Security Approach
BEFS WG	Bioenergy and Food Security Working Group in Sierra Leone
CA	Conservation agriculture
CO_2	Carbon dioxide
CSA	Climate-smart agriculture
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
FFS	Fee-for-service
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	Gigajoule
GtC	Gigatonne of carbon
HEAT	Hands-on Energy Adaptation toolkit
ICT	Information and communication technologies
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISD	Institute for Sustainable Development
Kg	Kilogram
kj	Kilojoule
kWh	Kilowatt hour
LPG	Liquefied petroleum gas
MDG	Millennium Development Goal
MEPS	Minimum energy performance standards
MEWR	Ministry of Energy and Water Resources in Sierra Leone
MJ	Megajoule
MW	Megawatt
N_2O	Nitrous oxide
RA	Conventional (regular) agriculture
REM	Revolution Energy Maker
UK DEFRA	United Kingdom's Department for Environment, Food and Rural Affairs
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture

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