B9 Management of energy in the context of CSA

Overview

This module 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 as the global food system, which is almost entirely dependent upon fossil fuels, looks more and more towards renewable energy as an alternative to these fuels. The sustainable management of energy for and from food chains could make a crucial contribution to the transition to climate-smart agriculture and achieving food, climate and energy security. But this transformation can only happen if already existing examples of energy-smart food chains are significantly scaled up. Also, in order to guide decisions related to policy and practices, assessments need to be made of the effects of energy-based interventions in food chains on the sustainable development goals.

Chapter B9.3 details how energy is used in food chains and how the sector can produce energy. Chapter B9.4 links the objectives of the energy-smart food programme with those of climate-smart agriculture. Chapter B9.4 presents possible energy solutions for climate-smart agriculture. Section B9 - 4.4 illustrates possible synergies and tradeoffs associated with these linkages.

Key messages

- Energy is needed for every stage in the food chain. However, food chains can also produce energy. The linkages between energy and food production have changed and grown stronger over time.
- The food sector currently accounts for around 30 percent of the world’s total end-use energy consumption, and much of this energy comes from fossil fuels. More than 70 percent of the energy used in food chains is consumed beyond the production stage.

- Methane and nitrous oxide are the predominant greenhouse gases emitted from food chains (excluding emissions from land-use change). Most carbon dioxide emissions from food chains are associated with energy use, and these emissions account for about one-third of the total emissions from food chains.
- To address the challenges of climate change, the development of food chains must be detatched from its current high dependency on fossil fuels. Reducing this dependency can be met by scaling up energy-smart food chains. These are chararcterized by improved energy efficiency, increased use and production of renewable energy, and an expanded access to modern energy services. Energy-smart food chains can be realized by following an approach that connects the use and consumption of water, energy and food — the water-energy-food nexus.
- Interventions require careful analysis to assess the synergies and trade-offs among the various sustainable development goals related to energy, climate, food security and water security. This is particularly true for reaching the objectives of the energy-smart food and climate-smart agriculture.
- The extent to which increased energy access, better energy efficiency and/or more use of renewable energy in food chains will affect climate change mitigation and/or adaptation depends on the particular context. Therefore, these impacts should not be assessed by using modelling techniques but by gathering evidence derived from local or national circumstances and through inclusive stakeholder consultations.

Introduction

Scope

The scope of this module covers the links between energy used for, and and generated by, food chains and climate-smart agriculture. This module is intended for general public practitioners and decision-makers whose work relates to energy used in food chains and the energy that these chains can produce.

Objective

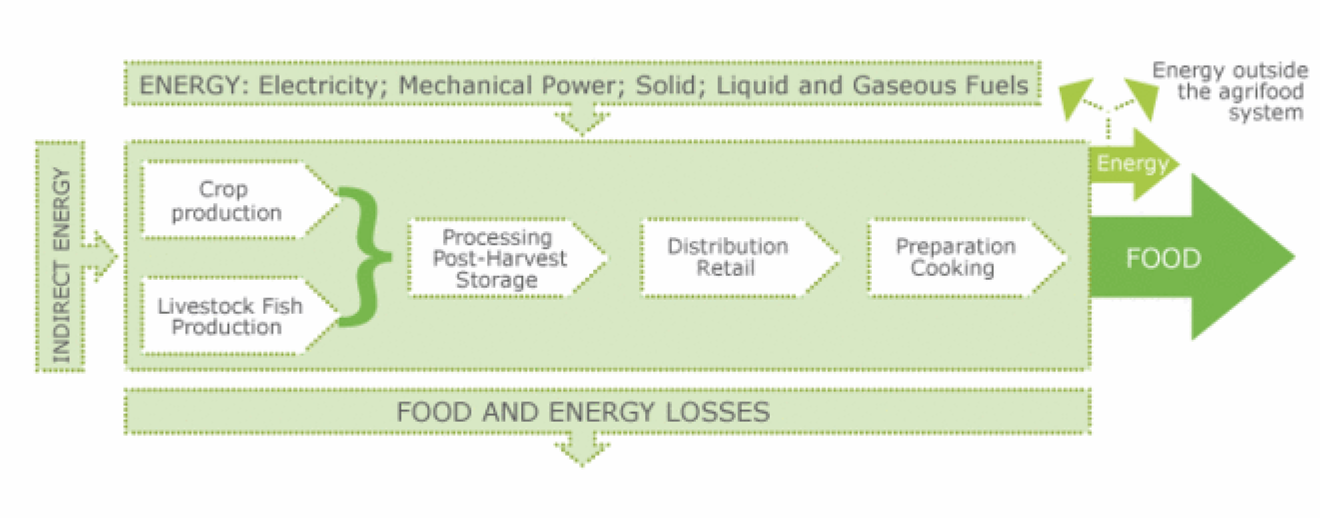
The objective of this module is to illustrate the linkages between climate change and the energy consumed in agrifood chains and the energy that can be generated from food chains.

Energy and food chains

Energy is needed at every stage of the food chains. The relationship between energy and food production have evolved and grown stronger over time. Fossil fuels have become a major input in modern agricultural production. However, agriculture and forestry have always been a traditional source of energy generated from biomass. The energy generated by agrifood chains can be partially used in food production. It can also by exported outside the agrifood chain, for example, through the sale of biogas produced on farms to local households, or through the generation of electricity from agricultural residues that can be fed into the national energy grid.

Figure B9.1. Energy FOR and FROM Agrifood Chains

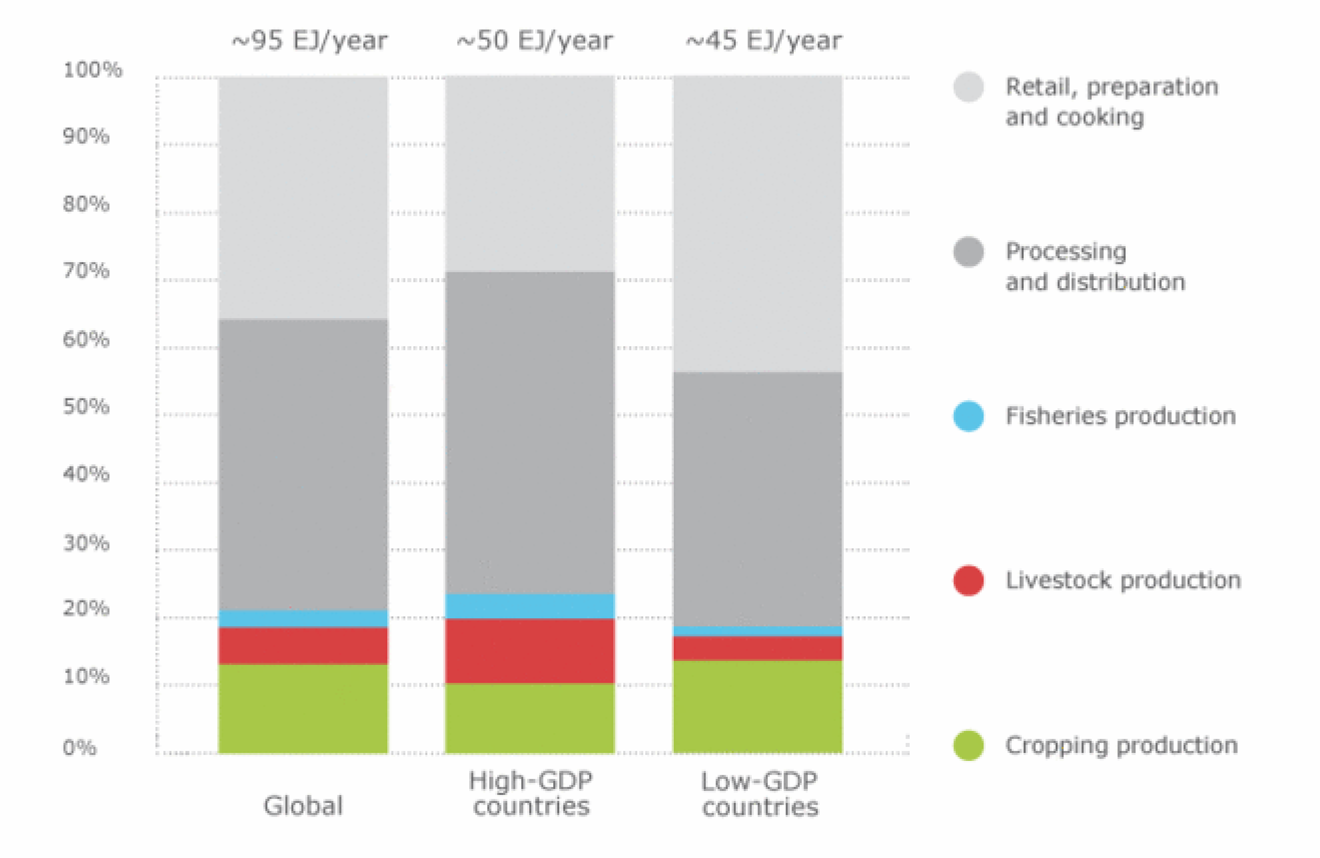
These two-way linkages between energy and agriculture — the energy **for** and **from** agrifood chains —[i], are illustrated in Figure B9.1.



Source: Authors

The FAO Energy-Smart Food for People and Climate Programme (FAO, 2011a; FAO, 2011b), estimates that the agrifood sector currently accounts for around 30 percent of the world's total end-use energy consumption[ii] and much of this energy comes from fossil fuels. More than 70 percent of this energy is used beyond production (Figure B9.2). In countries with a high gross domestic product (GDP) most of this energy is used for processing and transport. In low-GDP countries, cooking consumes the highest share.

Figure B9.2. Indicative shares of final energy consumption[iii] for the agrifood sector for high- and low-GDP countries



Source: FAO 2011a

The connections between energy and food chains have grown stronger as agriculture has become increasingly reliant on mineral fertilizers, irrigation and machinery. Post-production activities, such as food storage, cooling, processing and distribution, are also energy-intensive. Prices for nitrogen fertilizers and other fossil fuel-dependent inputs are closely related to the price of crude oil. Consequently, the costs of energy have a direct impact on the production costs of the agricultural sectors and food prices, in particular in the case of medium to large farms. Over the last decades, the increased use of energy by the agrifood sector has significantly contributed to feeding the world. Energy from fossil fuels has expanded mechanization of the agricultural sectors, boosted fertilizer and feed 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 arable area doubled, and the energy content of 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 era when oil was inexpensive, and there was little concern about climate change. Times have changed.

The high use of fossil fuels is a key contributor to climate change. As a result, agrifood chains that are highly dependent upon fossil fuels pose serious challenges to development. This dependancy could also hamper food security in the future.

Business-as-usual development would lead to simultaneous increase in the needs for water, energy and food by more than 40 percent by 2030. This development scenario is clearly unsustainable. A sustainable approach must focus on the water-energy-food nexus, and address trade-offs and capitalize on synergies in the use of these resources (FAO, 2014).

Food losses occur at all stages of the supply chain. About one-third of the food that is produced is lost or wasted (FAO, 2011c). The energy embedded in global annual food losses amounts to around 38 percent of the energy consumed by the whole food chain (FAO, 2011a; FAO, 2011b).

One of the world's greatest challenges is to develop global food chains that emit fewer greenhouse gas emissions, have a secure supply of energy, are resilient to fluctuating energy prices, make efficient use of water, energy and land, and can continue to ensure food security and foster sustainable development. This calls for energy-smart food chains that:

1. Ensure adequate access to modern energy services where needed in agri-food chains; and achieve this through:
2. Better energy efficiency, which would be measured in the amount of food produced (preferably calculated in nutritional units) per unit of energy consumed;
3. Gradual introduction of renewable energy use diverse energy sources, with an emphasis on renewable energy, and integrate food production and the generation of renewable energy;
4. Sustainable bioenergy; and
5. A water-energy-food nexus approach in work related to the above-mentioned objectives.

Bioenergy has a special role to play in safeguarding food security because it can be obtained from the same feedstocks as food. 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. Biomass is the main source of energy for cooking in many developing countries and it is also used for heating. Agrifood chains not only use bioenergy, they can produce it. 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 by increasing competition for resources. It could also harm the environment, if land is deforested to establish biofuel plantations or if forests become degraded through the unsustainable collection of wood for fuel. These issues are considered in Box B9.1.

Box B9.1 Can biofuels contribute to climate-smart agriculture?

The International Energy Agency projects that the production of biofuels will provide 27 percent of global transport fuels by 2050 (IEA, 2011). Since 2010, policy support measures have played a critical role in the rapid increase in biofuel production, principally for transport. This support has been motivated by a desire to strengthen energy security, reduce greenhouse gas emissions, advance rural development and increase the incomes of agricultural producers. After the rapid introduction of new and expanded support measures, there is now a broader evidence base for reviewing the impacts of increased biofuel production and determining how policies might be adjusted to address changing goals and concerns.

Listed below are some possible contributions biofuels can make to climate-smart agriculture.

- Biofuels in solid, liquid and gaseous forms can improve access to modern energy services for household uses and agricultural production. In this way, they can contribute to sustainable increases in productivity and income. A study on small-scale bioenergy initiatives (Practical Action Consulting, 2009) shows that improvements in bioenergy production can be achieved with minimum risks to sustainability.
- Biofuels, especially when produced on a small scale, can strengthen adaptation to climate change by increasing local energy self-sufficiency. However, they may also bring about their own climate risks by changing the way land is used and increasing the competition between different uses of biomass (e.g. energy, soil management, animal feed)
- The impacts of bioenergy on greenhouse gas emissions and carbon sequestration are complex and the subject of much debate. Bioenergy is often considered to be carbon-neutral because the generation of biomass by photosynthesis absorbs the same amount of carbon dioxide that is released when the biomass is burned. However, this does not take into account the connections between the carbon cycle and other natural cycles, related to nitrogen, phosphorus and water. These elements are also required for photosynthesis and are consumed whenever biomass is produced. Soil nutrients are taken up by plants and need to be replenished. Replenishing these nutrients (e.g. through fertilizer applications) can produce greenhouse gas emissions, especially nitrous oxide. To understand how bioenergy development may affect emissions, a full life cycle assessment, which considers agricultural production and processing, and the direct and indirect changes in land use, must be carried out.
- Some good practices that can improve the performance of biofuels in terms of climate change mitigation include:

1. agroecological zoning, which can ensure that biofuel development is avoided in high carbon areas (e.g. primary forests, peat land) and promoted in areas where the land is highly suitable;
2. the use of crop residues for biofuel production, whenever this is compatible with their use for soil management (soil fertility improvement, mulching) and/ or as animal feed; and
3. conservation agriculture, which is generally a low-carbon farming practice that can sometimes 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 development, particularly biofuel development, is required to reduce risks and harness opportunities. This approach requires:

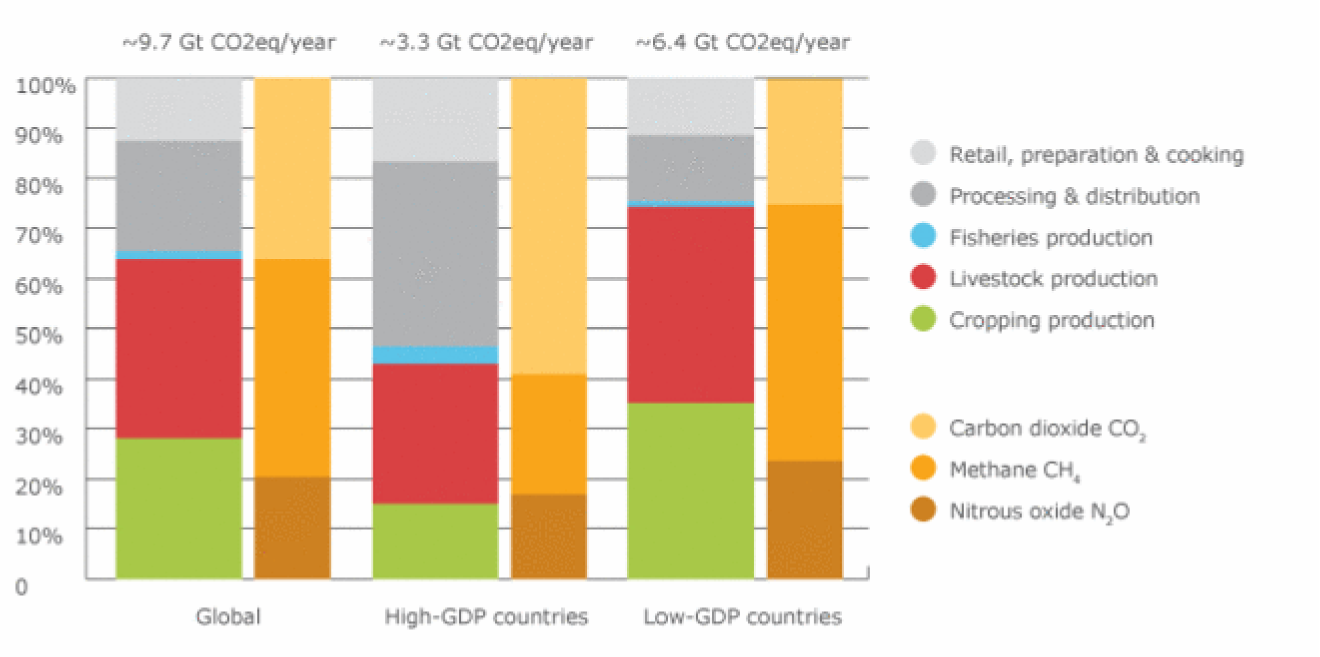
- an in-depth understanding of the situation, the related opportunities and risks, and synergies and trade-offs;
- an enabling policy and institutional environment, with sound and flexible supportive policies (e.g. targets and incentives) and the means to implement them;
- the implementation of good 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 tools which are part of *FAO's Sustainable Bioenergy Toolkit: Making Bioenergy Work for Climate, Energy and Food Security* (FAO, 2013).

Energy-smart food in the Climate-Smart Agriculture context

Figure B9.3 shows the relative contribution of each sector to total greenhouse gas emissions from the agrifood system. These figures relate to the entire agrifood chain, from 'farm' to 'fork'. However, they do not account for emissions related to land-use change, international trade (transport) or food waste. Methane and nitrous oxide are the predominant greenhouse gas gases emitted from agrifood chains, excluding those associated with land-use change. Most carbon dioxide emissions from agrifood chains are linked to energy use. Globally, these emissions account for more than one-third of total emissions from agrifood chains (FAO, 2011a).

Figure B9.3. Shares of greenhouse gas emissions along the food supply chain with breakdown by (i) food chain phase and (ii) type of greenhouse gas.



Source: FAO, 2011a

The following sections consider the potential for energy-smart agrifood chains to be climate-smart and the ways in which these chains can contribute to each dimension of climate-smart agriculture.

B9 - 4.1 Climate-smart agriculture objective: sustainable increases in productivity and income

Increases in productivity achieved through , inter alia, mechanization, feed and/or pasture management, irrigation and the increased use of fertilizers and pesticides imply an increase in the use of energy, usually fossil fuels. 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 production management practices should be emphasized.

- Methods that save on inputs derived from fossil fuels but reduce productivity (e.g. cutting back rather than optimizing the amount of fertilizer applied) are rarely beneficial and should be avoided.
- High-external input production chains do not necessarily have high-energy intensities (megajoules per kilogram of product), especially when they lead to increased yields. Conversely, low-input chains can have relatively high-energy intensities if yields are low.
- Given the preceding two points, it is appropriate to measure energy intensity by establishing a ratio between the amount of energy used and the amount of production, rather than between the energy used and the number of units (e.g. hectares, cattle heads) used for production. This form of measurement ensures that improvements in energy intensity do not lead to reductions in food production. This ratio also allows for a better understanding of when reductions in the use of energy (e.g. lower use of fertilizer) do not negatively impact food production, and when less energy use per hectare reflects negatively on productivity (i.e. less production per hectare).
- In promoting energy-smart food, a balance needs to be maintained between improving access to energy sources and increasing the efficiency of available energy. This balance must be based on local conditions and the economic trade-offs between the different options. For instance, in developing countries, domestic stoves account for a major part of energy consumption in the agrifood chain. Compared with open fires, the use of more efficient biomass cook stoves can reduce the demand for traditional fuelwood by half (Chum *et al*., 2011). However, while traditional biomass cook stoves are less energy-efficient, less healthy and more labour-intensive than modern ones, they are often more affordable, which is a critical factor in impoverished rural communities (Geoghegan *et al*., 2008; UNDP and WHO, 2009). For this reason, the dissemination of improved domestic stoves often succeeds when micro-finance is available for capital investments. New stove designs also need to be culturally acceptable. 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.

B9 - 4.2 Climate-smart agriculture objective: strengthened resilience to climate change and variability

As the climate changes, some agricultural practices may no longer be able to provide a reliable source of income. For some agricultural producers, diversifying their activities to include on-farm energy generation may be a potential coping strategy. Energy-smart food chains, which improve access to modern energy services and can increase energy diversity, can also contribute to energy security, which can in turn strengthen resilience. Tapping into local energy sources can also increase incomes. This also increases resilience to climate change. The use of biogas cookstoves illustrates both types of adaptation: greater self-reliance and higher income. Biogas cookstoves and their liquid fertilizer by-product can help ensure self-reliance in household energy and at the same time, reduce the amount spent on woodfuel and chemical fertilizers, and make gathering firewood less time consuming.

Although renewable energy plays a key role in future low?carbon plans to limiting global warming, the generation of renewable energy depends on climate conditions, which makes it susceptible to climate change. 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 energy needs for heating and cooling. These impacts are expected to increase significantly, and 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 becomes climate-smart. Table B9.1 provides examples of measures to reduce climate change-related losses and risks in the energy sector. Several of these measures are similar to those that are promoted for climate change adaptation in agriculture and are relevant to climate-smart agriculture. While the table shows adaptation measures for specific energy classes, it should also be noted that a diverse energy portfolio may also be a way to reduce climate risk to the 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 B9.1. Examples of measures to reduce losses/risks in energy chains

Adapted from Ebinger and Vergara, 2011

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

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	

B9 - 4.3 Climate-smart agriculture objective: contribution to climate change mitigation

Reducing the use of fossil fuels in the food chain will reduce carbon dioxide emissions. Figure B9.3 shows that, globally, about one-third of greenhouse gas emissions from agrifood chains come from direct energy use (excluding those from land-use change). Most of these emissions occur beyond the farm gate, and they are higher in high-GDP than in low-GDP countries. Box B9.2. illustrates the situation for the United Kingdom and the United States.

Box B9.2 Examples of the importance of energy-related greenhouse gases beyond the farm gate in high-GDP countries

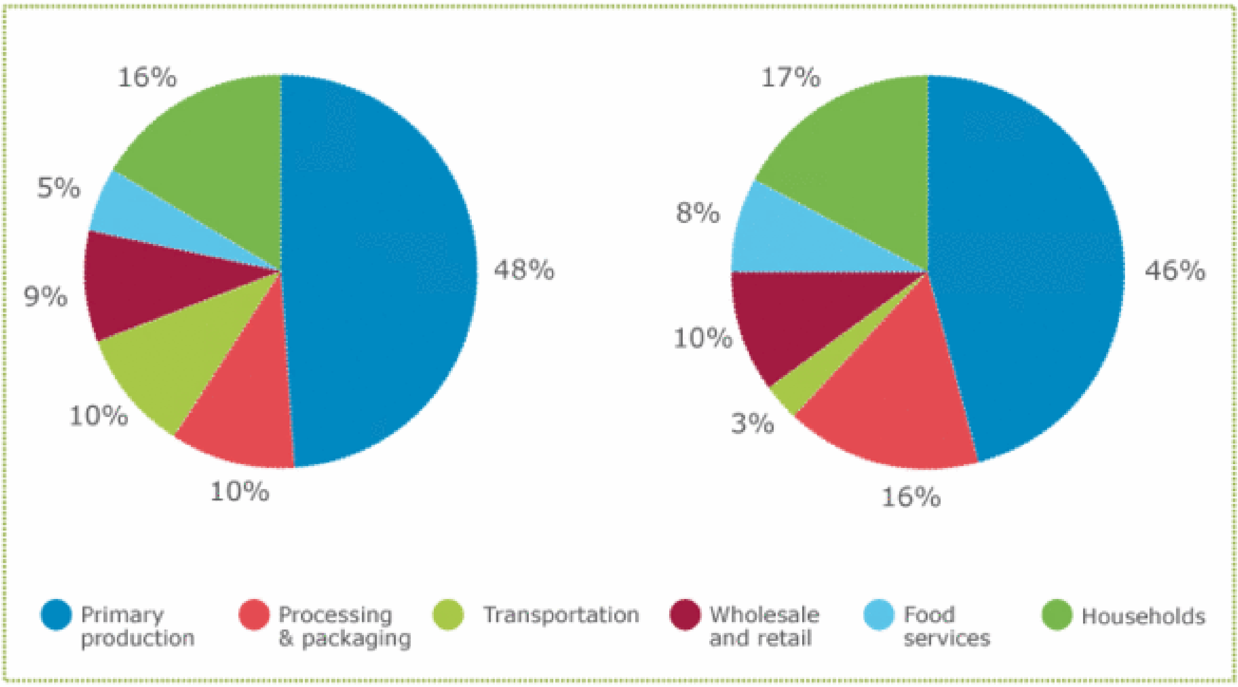
As shown in Figure B9.3, the agrifood chain, carbon dioxide emissions linked to energy use are mostly associated with post-harvest operations. In high-GDP countries, post-harvest operations account for the bulk of emissions from the agrifood chain.

Figure B9.4 shows that in the United Kingdom around 52 percent of the emissions occur in the post-farm stages of food production (DEFRA, 2011). The situation is similar in the United States, where around 54 percent of greenhouse gases are emitted after the farm gate (see Figure B9.5).

These findings are shaped by a number of factors, including how the boundaries of the food system are defined. For instance, the inclusion of dishwashing or international food trade could significantly change the overall picture. For example, the net food trade in the United Kingdom’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.

Figure B9.4. Greenhouse gas emissions along the agrifood chain in the United Kingdom.

Figure B9.5. Greenhouse gas emissions along agrifood chain in the United States.



Source: FAO elaboration based on DEFRA, 2011). Source: FAO elaboration based on Canning et al., 2010 and EPA, 2009)

However, the links between energy-smart food chains and climate-smart agriculture go well beyond the reduction of carbon dioxide emissions from fossil fuels. There is also a correlation between nitrous oxide emissions from fertilizer applications and energy use (and hence carbon dioxide emissions) in the production of fertilizer. Precision crop production, including a more efficient use of fertilizer, will lower carbon dioxide and nitrous oxide emissions and reduce the consumption of fossil fuels. Methane emissions can be reduced by using manure for biogas, which may also improve access to energy on farms and reduce the use of fossil fuels. Growing trees on farms for energy purposes can also sequester carbon and provide an alternative to fossil fuels.

In developing countries, increased access to modern energy services in agrifood chains is often required to improve productivity and income, and advance economic and social development. An increase in energy consumption, even if based initially on fossil fuels, may also result in lower absolute greenhouse gas emissions. For instance, improved access and greater use of modern energy services, may reduce deforestation if it leads to reduced demand for traditional wood fuel. Modern energy services can also 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.

Increasing energy efficiency in agricultural production may also increase profits, which could drive further agricultural expansion or intensification. In this situation, the resulting land-use change would lead to higher greenhouse gas emissions, even when calculated per unit of production.

B9 - 4.4 Synergies and trade-offs between energy-smart food chains and climate-smart agriculture

Combining the objectives of energy-smart food and climate-smart agriculture is possible, but it is likely to require some trade-offs. Table B9.2 presents a broad overview of the possible synergies and trade-offs between energy-smart food chains and climate-smart agriculture. These linkages are often quite complex and context-specific. More research is needed in this area.

Table B9.2. Examples of possible synergies (in italic green) and trade-offs (in bold red) between energy-smart food and climate-smart agriculture objectives

Climate-smart agriculture objectives Energy-smart food objectives	Climate-smart practices for sustainable increases in productivity and income	Climate-smart practices for climate change adaptation	Climate-smart practices for climate change mitigation
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**	General: Savings in energy costs 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 chains may result in lower energy efficiency	General: Improvements in energy efficiency, whether due to lower embedded energy in inputs or on-farm fuel combustion, will reduce fossil energy needs - hence greenhouse gas emissions in the production chain Increased energy efficiency may translate into reduced costs, hence greater profits. But these may result in extensification of agriculture (i.e. the so-called rebound effect), potentially bringing about carbon dioxide emissions from land use change that could even result in greater greenhouse gas emissions per unit of production

	Examples : - Practices such as replacement of synthetic fertilizers with application of crop residues or manure contribute to both increased energy efficiency and sustainable increases in productivity. - Practices that reduce external energy inputs while maintaining or increasing yields, such as Conservation Agriculture, increase energy efficiency. The combination of no-till with a crop rotation that provides and recycles part of the nutrients contributes to both energy efficiency and sustainable production intensification. - 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. - Drip irrigation chains that require a lot of energy may be less energy efficient than gravity irrigation; which in turn are less water-efficient Hence one should take into consideration trade-offs between increased energy efficiency and water efficiency through a water-energy-food nexus approach to ensure sustainability.	- 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 positive impacts on productivity	Examples : Practices such as Conservation Agriculture, precision agriculture leading to optimized use of agrochemicals , replacement of synthetic fertilizers with crop residues or manure, elimination of pesticides through integrated pest management or enhanced distribution logistics that reduce fossil fuel combustion will lead to reduced greenhouse gas emissions.,. Conservation Agriculture.

Increased production and use of renewable energy in agrifood chains, including through integrated food-energy chains)[i]	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 chains may result in more expensive energy inputs (i.e. fossil fuel might be cheaper than renewable energy)	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,* **although 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).	General: Energy diversification will tend to replace fossil fuels with renewable forms of energy. But, t in the case of bioenergy, it will only reduce net greenhouse gas emissions if good land use practices that reduce the risk of conversion of carbon rich land (e.g. primary forests or peat land) are promoted
	Examples : - 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 chains 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.	Examples : - 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 nutrition/protection compromise** *But biogasproduces biofertiliser as sub-product*	Examples : - Use of agriculture and forestry residues for bioenergy can compete with their role in returning carbon to the soilIndirect effects of biofuel demand such as indirect land-use change and price-induced intensification can lead to net greenhouse gas 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

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 greenhouse gas emissions (although these could be insignificant for some renewable energy sources).** *However, when access to modern energy services displaces unsustainable use of wood for energy, the resulting reduction in deforestation and forest degradation could lead to reduced greenhouse gas 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).
			Examples : - Bioenergy technologies that retain more nutrients (e.g. anaerobic digestion) versus those that retain less nutrients (e.g. gasification and combustion).

Moving forward - possible energy solutions for climate-smart agriculture

B9 - 5.1 Technologies for energy-smart food chains and climate-smart agriculture

This chapter deals with generic considerations on energy-smart food chains. Energy solutions regarding specific agricultural production and post-harvest practices and technologies are found in module B.1 and module B.10, respectively.

In farming communities, a mix of appropriate energy technologies, equipment and facilities is necessary to make the gradual shift to food chains that are both energy-smart and climate-smart. The nature of this mix will depend on biophysical conditions, infrastructure and the capacities of the labour force. There are many technologies that can be part of energy-smart food chains. These include: 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 chains, information and communication technologies, fuel-efficient cooking stoves, and equipment for water supply, distribution and purification. These technologies add value to agricultural production near the source of raw materials. They can also be combined on the same farm in integrated food-energy systems, which are briefly presented in module B5.

With the data that are currently available, it is difficult to identify energy-smart food 'hot spots' and intervention priorities. Different agrifood chains require different types of energy inputs. More research is particularly required on the relationships between energy use, yields and production costs in various agricultural chains and settings.

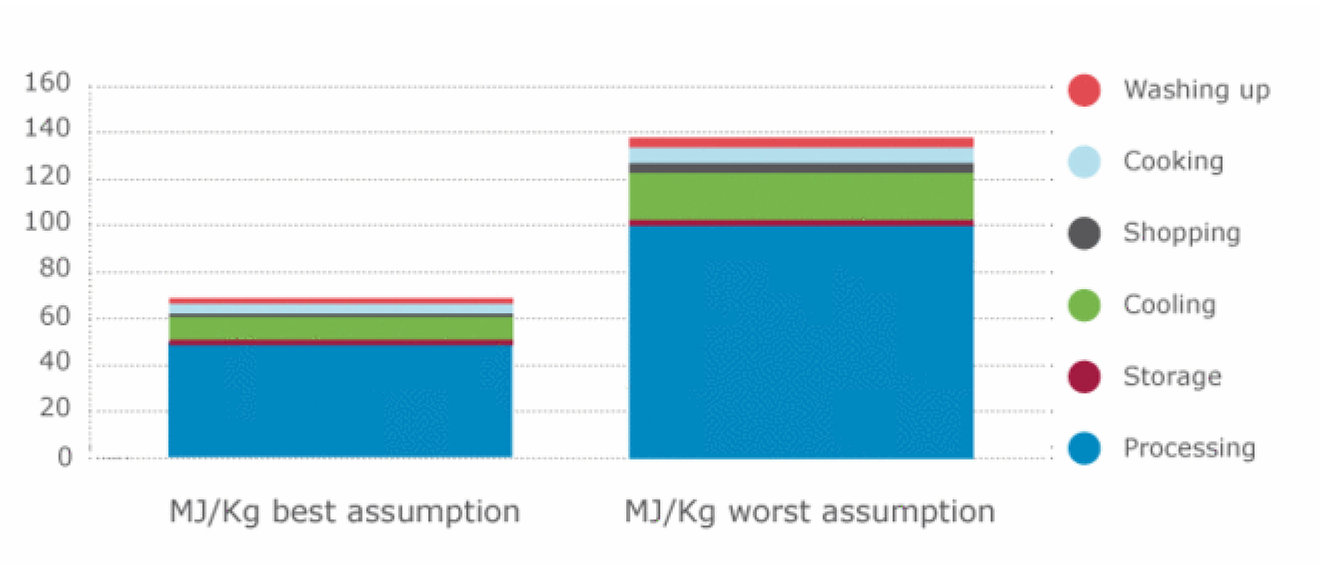
Farming systems with generally low energy needs and extensive crop and/or livestock production systems, like those in Australia or New Zealand, can operate with energy requirements as low as two or three gigajoules per hectare. The energy requirement for input-intensive agriculture in countries such as Israel or the Netherlands can reach up to 70-80 gigajoules per hectare (Smil, 2008).

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 crop sector than the United States or the European Union. In China, after the 1978 farming reforms, nitrogen (half of which comes from inorganic fertilizers) has provided about 60 percent of the nutrients for crops. Over 80 percent of the country’s protein requirement are derived from crop production. Agriculture is highly dependent on fossil fuels, but has been able to feed about 8.5 people per hectare and up to 15 people per hectare in populous provinces. This result is also attributable to a national diet with relatively little animal proteins.

A number of technological solutions exist to optimize energy use. For example, in crop production, reducing the rolling resistance and slippage of tractors, combine harvesters or other motorized agricultural machinery (e.g. by improving tractor tires or optimizing tire pressure according to soil conditions) would improve energy efficiency of mechanized systems. Energy conservation in greenhouses, animal houses and agricultural buildings is another major area of intervention. Energy use can be minimized through a greater deployment of heat pumps (mostly of the mechanical compression type, which are driven by electric motors) and heat recovery systems, both of which can also be used for dehumidification 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 also technological options that can be considered. Some of the most economic energy-efficient interventions involve the proper construction, insulation and correct ventilation of buildings and greenhouses.

A best and worst assumption of energy intensity per unit of produce can be made for all activities in the agrifood chain. In the Intergovernmental Panel on Climate Change (IPCC) greenhouse gas accounting system, these activities are included under industrial processes or energy sectors, not under the crop and livestock sectors. These intensities are presented in Figure B9.6.

Figure B9.6. Best and worst assumption of energy intensities in the post-harvest stage of the food chain



Source: FAO, 2011a

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

Worldwide, the use of biomass for heat and power could save significant amounts of carbon: up to 1 gigatonne of carbon could be saved annually by 2030 (FAO, 2010). However, this bioenergy would have to be carbon-neutral, and there is debate as to whether this would be the case (see Box B9.1.). Co-firing of biomass with coal could save nearly 0.5 gigatonnes of carbon per year at fairly modest costs (FAO, 2010). Savings in the traditional biomass and charcoal sectors could amount to another 0.5 gigatonne of carbon. Considerable efforts would be required to obtain the higher investments required, address the complex socio-economic and cultural issues and cover the transaction costs associated with equipment and the reliable supply of biomass (FAO, 2010).

The transition to energy-smart food practices is already under way. However, the pace of change is slow. For these practices to have a large-scale impact, significant scaling up is required.

B9 - 5.2 Policies and institutions for energy-smart food and climate-smart agriculture

The promotion and scaling up of food practices that are both energy-smart and climate-smart require innovative supportive policies and institutions. Many climate-smart practices promote energy efficiency and renewable energy. For issues related to modern energy services, particular attention should be paid to ensuring participatory that gender-sensitive decision-making processes are followed. In the case of 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 summarized in Table B9.3.

Table B9.3. 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 agrifood chains - 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

Interventions promoting energy efficiency and/or energy-smart food production, which reduce carbon dioxide emissions through the increased use of renewable energy, can tap into many of the climate change financial mechanisms discussed in module C4 on financial instruments and investments. There are also financing sources especially targeted for renewable energy use, energy efficiency and increased energy access, including: innovative business models, such as energy service companies[vi]; 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 favour renewable energy. Regulations adopted in 2002 simplify the grid connection requirements for small electricity generators up to 1 megawatt (World Bank, 2011). These regulations and other policies led to the development of integrated sugarcane and rice biorefineries that produce food, ethanol, heat and electricity. Organic residues were also 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 megawatts (Chum *et al.*, 2011).

Implementing these types of 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 promoting integrated food-energy chains (FAO, 2011a). Examples of such mechanisms are listed below.

- In a wheat-producing area of the United Kingdom, a bioelectricity plant buys the farmers’ straw through a subsidiary company. Seventy percent of the fuel needed to run the bioelectricity plant comes from the straw feedstock; the rest from another type of feedstock and natural gas. In this system, farmers produce wheat and leave the energy matters to more competent players (Bogdanski *et al.*, 2010).
- At the district model biogas farm in China, farmers cultivate crops, can raise pigs but are notresponsible for producing the biogas. Instead, 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 from biogas. The farmers get in return yearly dividends from any sale of pigs, inexpensive biogas and 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 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'[vii] schemes are payment models where services are unbundled and paid for separately. These

include, for example, energy service companies. Leasing schemes or concession arrangements are other options for financing energy-smart food.

The need for cross-sectoral coordination is a requirement for successful bioenergy development. Box B9.3 provides an example from Sierra Leone.

Box B9.3 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. 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 it may represent an opportunity to attract much needed agricultural investment. 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 mechanisms, and sustainable resource management are key elements in the process.

Sierra Leone's Ministry of Energy and Water Resources 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 inter-ministerial working group, the Bioenergy and Food Security Working Group. The group's first activity was to identify the country’s main concerns and challenges for bioenergy development, and its immediate needs and longer-term requirements. One of the 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 issues of community inclusion in decision-making and conflict management. In the longer term, there is the need to identify the country’s potential for sustainable bioenergy development, fill in data and information gaps, and address long-term institutional requirements and training needs at both the policy and technical levels.

B9 - 5.3 A multipartner programme for scaling up energy-smart food

Shifting to more energy-smart food chains is an important step towards reaching the broader goals of climate-smart agriculture. Decision-makers need to adopt a long-term view to make the needed paradigm shift to food chains that are energy-smart, contribute to climate change mitigation and adaptation and strengthen 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 begin the transition to energy-smart food chains?”, but rather “How can we get started and make gradual but steady progress?” The shift towards energy-smart food chains will progress by degrees and can only be achieved through sustained efforts. Understanding and implementing energy-smart food chains is a complex multidisciplinary task that requires a multipartner programme (see chapter C2-1.1). Towards this end, the Energy-Smart Food for People and Climate Programme was launched in 2012, with the aim of helping countries promote energy-smart agrifood chains through the identification, planning and implementation of climate-smart measures that integrate efforts to achieve energy, water and food security.

Conclusions

This module has introduced the concept of energy-smart food systems and the important role they can play in transitioning to climate-smart agriculture. One of the module's key messages is that the dependence of agrifood chains 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 scaling up energy-smart food chains, which improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services. The case studies indicate how different technological solutions and integrated chains can be both energy- and climate-smart. Low-cost machinery, biofuels, integrated food-energy chains, modern technologies and new types of cross-sectoral collaboration are some of the examples of the interventions needed for making the shift to energy-smart food chains. In addition to synergies between energy-smart food and climate-smart agriculture objectives, there are also possible trade-offs that need to be recognized. The shift to the new approach, which must be initiated without delay, requires long-term vision and commitment, and multidisciplinary efforts.

Acknowledgements

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Reviewers: Josef Kienzle (FAO)

Notes: The module is an update of Module 5 Sound Management of Energy for Climate-Smart Agriculture in the Climate-Smart Agriculture Sourcebook (2013) written by Anne Bogdanski (FAO), Olivier Dubois (FAO), Alessandro Flammini (FAO) and Jonathan Reeves (FAO).

Acronyms

GDP	**Gross Domestic Product**

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