MODULE 3: ENERGY

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Overview

In this section, we discuss the relationship between food and energy in the context of a changing climate and increasing competition for natural resources. With a global agri-food system almost entirely dependent upon fossil fuels and with modern bioenergy increasingly turned to as an alternative to these, this relationship is becoming ever stronger and more complex. Sound management of energy for and from agriculture and food could make a crucial contribution to a transition to climate-smart agriculture and to the achievement of food, climate and energy security if existing examples of energy-smart food systems can be scaled up significantly and adequate assessment of the effects of energy-based interventions in agri-food systems on sustainable development goals are conducted and used to inform policy and practice.

Key Messages

- In light of increasing and volatile fossil fuel prices, the huge dependence of agri-food systems on fossil fuels represents a major threat to food security and climate change.
- This challenge can be tackled through the up-scaling of “energy-smart food” systems, which increase energy efficiency, use and production of renewable energy and access to modern energy services in agri-food systems.
- Generally speaking, energy-smart food systems will also be climate-smart and many of the solutions at the level of technologies and practices, policies, institutions and financing are common to energy-smart food and climate-smart agriculture.
- Even though more energy is generally used in post-harvest stages of the food supply chain whereas most GHG emissions occur in the primary production phase, there is greater synergy between energy-smart and climate-smart agricultural practices than may at first seem the case, in the form of resource-efficient farming practices that reduce pressure on land-use change, embedded emissions in agricultural inputs and reliance on fossil fuels and enhance productivity and resilience of agroecosystems.
- However, it must be recognized that each case requires careful analysis, on a lifecycle basis and including indirect effects, to assess synergies and trade-offs between identified energy, climate, food and water security and other sustainable development goals.
- In developing countries, increased access to (and use of) modern energy services is often required in agri-food systems in order to improve productivity, income and economic and social development. However, such an increase in energy consumption, even if based initially on fossil fuels, may result in lower absolute GHG emissions (e.g. due to reduced deforestation as a result of demand for traditional wood fuels, short-term profitable activities such as logging and charcoal production, or agricultural expansion) and is likely to reduce emissions per unit of food production or per unit of GDP. The effect of increased energy access on climate change mitigation should be assessed taking into account the stage and model of development of a country or community: it
should not be assumed that there is always an energy access-climate change mitigation trade-off.

- Some success stories of energy-smart food solutions include:
  - on-farm production of biogas from manure and sale of this biogas to local households, improving their access to cooked meals;
  - generation of electricity from crop residues and partial export of this electricity to the national grid, diversifying and increasing on-farm income and contributing to a cleaner and more secure national energy matrix;
  - introduction of trees or perennials (such as pigeon peas) in farms to produce wood for on-farm energy purposes, whilst also providing multiple benefits for the farm, including improving soil carbon sequestration and nutrient fixing, reducing the need for synthetic fertilizer application;
  - solar-powered water pumps that provide irrigation and improved yields without use of expensive and polluting fossil fuels; and
  - use of energy-efficient continuous flow grain dryers that reduce post-harvest crop losses and hence increase farmer income in a sustainable manner.
3.1. INTRODUCTION – ENERGY AND THE AGRI-FOOD SYSTEM

Global primary energy demand will increase by a third between 2010 and 2035, and today’s developing countries will account for a vast majority of this increase (IEA 2011a). Fossil fuels are expected to remain the bulk of the primary energy mix, while renewable energy is on the rise and will continue to be so in the future.

Crude oil prices fluctuated around a generally steadily increasing trend from USD 28 per barrel to USD 120 over the last decade, with one dramatic price spike around 2008. Conversely, the costs of renewable energy have been recently declining. This trend will continue in the coming decades, making renewable energy more and more competitive.

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

Agriculture and energy have always been closely interlinked but the nature of the linkages has changed and their strength has increased over time. Agriculture, including forestry, has always been a source of energy (through bioenergy), whilst 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. sale of biogas produced on-farm to local households, or generation of electricity from residues used partly to feed the national grid).

These two-way linkages between energy and agriculture, i.e. energy FOR and FROM the agrifood sector, are illustrated in Figure 3.1.
Figure 3.1: Energy FOR and FROM the Agrifood System

Based on FAO’s current work on “Energy-Smart Food for People and Climate” (ESF) (see FAO, 2011a and b), the food sector\(^1\) currently accounts for around 30 percent of the world’s total end-use energy consumption\(^2\), and more than 70 percent of that energy is used beyond the farm gate (Fig E2). High-GDP countries 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 3.2. Indicative shares of final energy consumption for the food sector for high- and low-GDP countries

Linkages on the input side have strengthened as agriculture became increasingly reliant on chemical fertilizers, irrigation and machinery for example. Post-harvest activities such as food storage, processing and distribution, too, are energy intensive. Higher and volatile energy costs, therefore, have a direct impact on agricultural production costs and food prices. The increased use of energy by agriculture has significantly contributed to feeding the world over the last decades. 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 grew by 80-100%, but the energy harvested in edible crops expanded six fold. This greater productivity was made possible by
an 85-fold increase in energy input per hectare (Smil, 2008). But this occurred in an area of cheap oil and few climate change concerns. Times have changed. Prices for nitrogen fertilizers and other fossil fuel-dependent inputs are closely related to the crude oil price. Therefore, rising and volatile oil prices translate into higher and fluctuating food production costs and farmers, in particular smallholders, are the first ones to be hit. As a result, the prevalence of agrifood systems highly dependent upon fossil fuels poses serious development challenges – which in turn could hamper food security in the foreseeable future.

Food losses occur at all stages of the supply chain and about one-third of the 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).

The previous sections show that one of the greatest challenges the world now faces is to develop global food systems that emit fewer GHG emissions, enjoy a secure energy supply and are resilient to fluctuating energy prices while at the same time supporting food security and sustainable development. This requires energy-smart food (ESF) for people and climate. Energy-smart food systems:

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

Amongst the types of renewable energy to be used to achieve ESF measures 2 and 3, bioenergy has a special role to play in relation to food security because (i) biomass is currently, and for the foreseeable future, the most important source of renewable energy, primarily for cooking and heating, but it is often used in unsustainable ways, (ii) biomass is present almost everywhere (iii) agri-food systems can use but also produce bioenergy, for instance through integrated food-energy systems, but (iv) implementing bioenergy in the right way is more complex than other types of renewable energy because, if not well managed, bioenergy development may harm food security and the environment. This is further discussed in Box E3.

### 3.2. ENERGY-SMART FOOD (ESF) IN THE CSA CONTEXT

The energy sector is the largest contributor to climate change, as it produces nearly 60 percent of CO₂ emissions (FAO 2011a). The agri-food sector itself contributes over approximately 20 percent of total GHGs emissions, most of it from methane and nitrous oxide (Fig. E3). Globally, primary farm and fishery production³ accounts for around one fifth

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³ Primary production here includes cropping, pastoral and intensive livestock, aquaculture and fishing.
of the total energy demand for food, but produces two thirds of the GHGs (FAO, 2011 a).

Figure 3.3. Shares of GHG emissions along the food supply chain with breakdown by energy consumption (by phase) and GHG emissions (by phase and by gas).

It is important to point out that these facts and figures concern the agri-food chain from “farm” to “fork” and do not account for emissions related to land-use changes, international trade (transport) or food waste; whereas GHG figures related to agriculture usually concern only behind the farm gate stages (excluding fuel combustion and sewage waste) and often also include land-use change impacts.

In the following three sub-sections, we explore the potential for energy-smart agri-food systems to also be ‘climate-smart’, examining each dimension of CSA in turn.

3.2a. CSA objective: sustainable increases in productivity and income

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

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4 Often LULUCF emissions (assumed) due to agricultural expansion are lumped together with Agriculture sector emissions, which, at least in national GHG inventories prepared for reporting under the UNFCCC, do not include important pre-farm gate sources of emissions such as fertiliser production (Industrial Processes and Energy sectors), on-farm fuel combustion (Energy Sector) or sewage waste (Waste sector), in a statement that agriculture is responsible for about 30% of emissions. But if we consider the whole agrifood chain, one has to add other sources of emissions 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.
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- Methods used to save fossil fuel-dependent inputs that also lower productivity, such as just 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 (MJ per kg of product), especially when they result in increased yields. Conversely, low-input systems can have relatively high energy intensities when lower yields result;
- In promoting “Energy-Smart Food”, balance needs to be sometimes found between improving access to energy sources and increasing the efficiency of available energy and the proportion of renewable energy, based on local conditions and the economic trade-off between these options. As regards energy efficiency, Box E1 illustrates this trade-off in the case of the deployment of machinery systems for small farms in Bangladesh.

**Box 3.1. Low-cost machinery systems for small farms in Bangladesh**

The introduction in Bangladesh of small, mobile, diesel engines that are demountable and can be used for a range of applications, including powering small boats, tractors or trucks, generating electricity, operating processing equipment and water pumps, has increased food production (Steele, 2011). 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 compared with more sophisticated and more fuel-efficient machinery manufactured in India. The introduction of inexpensive Chinese technology led to the ‘agro-tractorization’ 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 almost five times: from 0.24 KW/Ha in 1960, to 0.61 KW/Ha at the end of the ‘90s, to 1.17 KW/Ha in 2007 (Islam, 2008). The available power gradually increased from 0.24 kW/ha in 1960, increased moderately until the ‘80s and then 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 in workshops. Farm machinery, such as, weeder, threshers, winnowers and centrifugal pumps are developed and manufactured locally with locally available materials (APCAEM-ESCAP 2010).
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Figure XX. Cereals and vegetables yield increases in Bangladesh from 2000 to 2010 (FAOSTAT)

In the early 1970s, when Bangladesh was characterised as a “basket case” by some international development specialists, no one was forecasting that Bangladesh would, in 2010, have one of the most mechanised agricultural economies in South Asia (Islam 2009). 80% of primary tillage operations are mechanised today, performed mainly by 300,000 small 2WTs and a few (3,000) 4WTs. There is a highly developed market for tractor services, pumpset services, threshing and other services derived from the use of small engines (Biggs and Justice, 2011).

The figures above mean that from 2000 to 2007 external energy subsidies in agriculture increased by 60-70% for cereals and vegetables (per kg of product), but also yields (per unit of cultivated area) increased by 20-25%, making mechanized agriculture more profitable, and freeing farmers 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. This has led to the present numbers of over one million small horsepower diesel irrigation pumpsets and nearly 400,000 diesel 2WTs. In Bangladesh the import value of soil machinery is consistently higher and increasing compared to agricultural machinery such as, harvesters and threshers, milking and dairy machinery, agricultural tractors and other agricultural machinery and equipment. In 2007 Bangladesh started exporting some agricultural machinery, but mostly are 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 (Source: Biggs and Justice, 2011).

Affordability and cultural issues are essential in the deployment of new or improved energy technologies. The dissemination of improved designs of domestic stoves, which account for a major part of energy consumption of food chains especially in developing countries,
continues, succeeding 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 the demand for traditional fuelwood by half (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 cooking in the heat of the day with a solar oven.

3.2b. CSA objective: strengthened resilience to climate change and variability

Due to climate change some farming practices may become less reliable as sources of income and therefore diversification to on-farm energy generation could be a coping strategy. On the other hand, by improving access to modern energy services and increasing energy diversity, ESF increases energy security in light of high and volatile fossil fuel prices. This is not climate change adaptation, but does relate to resilience, which is the broader term used in the CSA definition. Reliance on local energy sources does not automatically enhance resilience to climate change; it depends on their climate resilience (see Table E3 below). Therefore it is the income effect and the increased energy diversity that increase resilience in the face of, if not to, climate change. The use of biogas cookstoves illustrates both types of adaptation effects. While ensuring self reliance in household energy, biogas cookstoves, and their liquid fertiliser by-product, can lead to important reductions in costs related to the purchase of woodfuel and chemical fertiliser, and also save time in gathering firewood.

While renewable energy plays a key role in future low-carbon plans aimed at limiting global warming, its dependence on climate conditions makes it also susceptible to climate change, and this applies also to “Energy-Smart Food” systems. Examples include crop response to climate change regarding biofuel, water availability and seasonality for hydropower, atmospheric features for wind and solar energy, and variations in needs for energy for heating and cooling. As these impacts will increase in a significant way, the energy sector will have to adapt to them. Therefore, for energy use in the agri-food system to be “climate-smart”, the energy supply needs to be “climate-proofed” to the extent possible through some of the measures shown in Table E3, which presents examples of adaptation measures to reduce climate change-related losses and risks in the energy sector. Interestingly, similarly to energy efficiency measures, several of these measures are similar to those promoted for climate change adaptation in agriculture, hence to CSA. Furthermore, while the table shows adaptation measures for individual energy classes, one should also note that a diverse energy portfolio could be a means for reducing climate risk to energy supply (even better one that hedges identified national or local climate risks to energy supply).
The World Bank ESMAP Programme has developed a web tool called HEAT (Hands-on Energy Adaptation Toolkit – see http://esmap.org/esmap/node/312) to assess the vulnerability of energy, to climate change, amongst other factors.
<table>
<thead>
<tr>
<th>ENERGY SYSTEM</th>
<th>TECHNOLOGICAL</th>
<th>BEHAVIORAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MINED RESOURCES</strong>&lt;br&gt;(inc. oil and gas, thermal power, nuclear power)</td>
<td>“Hard” (structural) Improve robustness of installations to withstand storms (offshore), and fl flooding/drought (inland)</td>
<td>“Soft” (technology and design) 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</td>
</tr>
<tr>
<td>HYDROPOWER</td>
<td>Supply Build de-silting gates Increase dam height Construct small dams in the upper basins Adapt capacity to flow regime (if increased)</td>
<td>Changes in water reserves and reservoir management Regional integration through transmission connections</td>
</tr>
<tr>
<td>WIND</td>
<td>Improve design of turbines to withstand higher wind speeds</td>
<td>(Re)locate based on expected changes in wind-speeds (Re)locate based on anticipated sea level rise and changes in river flooding</td>
</tr>
<tr>
<td>SOLAR</td>
<td>Improve design of panels to withstand storm or reduced loss of efficiency due to higher temperatures.</td>
<td>(Re)locate based on expected changes in cloud cover</td>
</tr>
<tr>
<td>BIOMASS</td>
<td>DEMAND</td>
<td>TRANSMISSION AND DISTRIBUTION</td>
</tr>
<tr>
<td>---------</td>
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<td>-----------------------------</td>
</tr>
<tr>
<td>Build dikes</td>
<td>Invest in high-efficiency infrastructures and equipment</td>
<td>Improve robustness of pipelines and other transmission and distribution infrastructure</td>
</tr>
<tr>
<td>Improve drainage</td>
<td>Invest in decentralized power generation such as rooftop PV generators or household geothermal units</td>
<td>Burying or cable re-rating of the power grid</td>
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<tr>
<td>Expand/improve irrigation systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve robustness of energy plants to withstand storms and flooding</td>
<td>Efficient use of energy through good operating practice</td>
<td>Emergency planning</td>
</tr>
<tr>
<td>Introduce new crops with higher heat and water stress tolerance</td>
<td>Early warning systems (temperature and rainfall)</td>
<td>Regular inspection of vulnerable infrastructure such as wooden utility poles</td>
</tr>
<tr>
<td>Substitute fuel sources</td>
<td>Support for emergency harvesting of biomass</td>
<td></td>
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<tr>
<td>(Re)locate based in areas with lower risk of flooding/storms</td>
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</table>

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**CLIMATE SMART Agriculture**
3.2c. CSA objective: contribution to climate change mitigation

Based on the facts and figures presented above, one could think that ESF is not very important for CSA since most agricultural emissions are from primary production whereas most energy use in the agri-food sector is not from primary production. This is true regarding the direct energy used in the agrifood chain. However, there are further links that make ESF more important for CSA than one would first think from these facts and figures, many of which become more apparent when looking at the mitigation potential rather than current GHG emissions and energy consumption. Clearly reducing energy use in the chain will reduce CO\(_2\) emissions. Fig E2 shows that, globally, these are not the major part of GHG emissions from the agri-food chain. However:

- The situation differs between high and low GDP countries. In the former case, the post harvest stages contribute most to GHG emissions in the shape of CO\(_2\); whereas in low GDP countries, most contributions happen behind the farm gate, in the shape of methane and nitrous dioxide;
- There is to some extent a correlation between N\(_2\)O emissions from fertiliser application and energy use (and hence CO\(_2\) emissions) in the production of fertiliser. In other words, precision agriculture, including regarding fertiliser use, will reduce CO\(_2\) and N\(_2\)O emissions as well as reducing fossil energy consumption. Furthermore, methane emissions can be reduced by using manure for biogas, which may also improve energy access or reduce fossil energy use on farm. Also, growing trees on farms for energy purposes can sequester carbon as well as displace fossil fuels. On the other hand, if increasing energy efficiency of agricultural production also increases profits, this could in some cases lead to agricultural expansion that could in turn result in higher GHG emissions (even per unit of production) due to land-use change. These provide further

**Box 3.2: Examples on the importance of energy-related GHGs beyond the farm gate in high GDP countries**

As shown in Figure E3, the energy component associated with carbon dioxide emission is mostly relevant in post-harvest operations of the agri-food chain, and makes the bulk of emissions in high-GDP countries. For instance, a recent UK study has shown that around 52% of the emissions take place in the post-farm stages of UK food production, see Figure i (DEFRA, 2011). Similar figures can be observed for the US with around 54% of GHG emitted after the farm-gate (see Figure ii).

Of course these results depend on a number of factors, including the definition of the boundaries of the food system. The inclusion of dishwashing or of international food trade could change significantly the overall picture. For example if food net trade has to be included in the UK food system, this would be responsible for around 24% of total emissions of the food chain, bringing down the relative proportion of emissions attributable to farming to just 32% (FAO elaboration based on UK DEFRA 2010 – 2007 data).
links between ESF and CSA beyond the obvious fossil fuel-CO$_2$ reduction one.

Efforts to achieve food and energy security in a smart way will be low carbon, either directly, through increased use of renewable energy in the agri-food sector, or indirectly through the energy efficiency measures presented in Table E1. It is worth pointing out that many energy-efficiency measures, in particular behind the farm gate, concern highly resource efficient farming practices that are part and parcel of climate-smart agriculture. Implementing those would therefore be a win-win solution from both a CSA and ESF point of view.

**Table 3.1:** Examples of energy efficiency improvements through direct or indirect technical and social interventions along the food chain
Box 3.3: Can biofuels contribute to CSA?

Global liquid biofuel production has increased more than five-fold since 2000, and is projected to increase a further 50 percent by 2020 (and even more by 2050).

Policies have played a critical role in shaping the rapid increase in liquid biofuel production, principally for transport, over the past 5-6 years. Policy support for biofuels has been motivated by interest in increasing energy security, reducing greenhouse gas emissions, rural development and increasing farmers’ incomes. After the rapid introduction of new and expanded support measures, we now have a better evidence base with which to review impacts and reflect on how policies might be adjusted to address changing goals and concerns.

As regards more specific 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 – hence to sustainable increases in productivity and income. A recent study on small-scale bioenergy initiatives (FAO, 2009) shows that, on a small-scale, this can be achieved with minimum sustainability risks.

- The above features mean that biofuels, especially on a small-scale, can strengthen resilience to climate change and variability, though they may also bring their own climate risks through creating a link between energy security and crop yields, particularly where there is little feedstock diversity.

<table>
<thead>
<tr>
<th>Behind farm gate</th>
<th>Directly</th>
<th>Indirectly</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Adopting and maintaining fuel efficient engines.</td>
<td>– Less input-demanding crop varieties and animal breeds.</td>
<td></td>
</tr>
<tr>
<td>– Precise water applications.</td>
<td>– Reducing soil erosion.</td>
<td></td>
</tr>
<tr>
<td>– Precision farming for fertilizers.</td>
<td>– Reducing water demand and losses.</td>
<td></td>
</tr>
<tr>
<td>– Adopting no-till practices.</td>
<td>– Use of bio-fertilizer</td>
<td></td>
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<tr>
<td>– Controlled building environments.</td>
<td>– Efficient machinery manufacture.</td>
<td></td>
</tr>
<tr>
<td>– Propeller designs of fishing vessels.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Beyond farm gate</th>
<th>Directly</th>
<th>Indirectly</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Truck design and operation.</td>
<td>– Improving road infrastructure.</td>
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<tr>
<td>– Variable speed electric motors.</td>
<td>– Urban planning to reduce distances travelled to distribute and buy food.</td>
<td></td>
</tr>
<tr>
<td>– Better lighting and heat processes.</td>
<td>– Reducing food losses at all stages.</td>
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</tr>
<tr>
<td>– Insulation of cool stores.</td>
<td>– Changing diets away from animal products.</td>
<td></td>
</tr>
<tr>
<td>– Minimizing packaging of food.</td>
<td>– Lowering obesity levels.</td>
<td></td>
</tr>
<tr>
<td>– Improve efficiency of cooking devices and space heating.</td>
<td>– Labeling of food products.</td>
<td></td>
</tr>
</tbody>
</table>
The impacts on GHG emissions and carbon sequestration are more complex and debated. Bioenergy is often considered to be CO₂ neutral because the generation of biomass by photosynthesis absorbs the same amount of CO₂ as is released by burning the biomass. However, this fails to consider the linkage between the carbon cycle and other cycles, including nitrogen, phosphorus, and water. These elements are also required for photosynthesis. This means that they are consumed whenever biomass is produced, and as a result, soil nutrients are consumed and need to be supplemented. These additions, for instance in the shape of fertilizer application, can result in GHG emissions (e.g., nitrous oxide). Therefore, a full life cycle assessment has to be carried out, which includes agricultural production and processing as well as land-use changes (both direct and indirect).

Some good practices can improve the performance of biofuels in terms of climate change mitigation. These include:

- Agroecological zoning, to avoid biofuel development in high carbon areas (e.g., primary forests, peat land) and promote it only in areas of high land suitability;
- Use of residues for biofuel production, so long as it does not affect their use for soil management or as animal feed;
- Conservation agriculture as this is usually low carbon and even sometimes lead to its sequestration.

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

- an in-depth understanding of the situation and of 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/producers in order to reduce risks and increase opportunities; and appropriate policy instruments to promote these good practices; and
- proper impact monitoring and evaluation and policy response mechanisms.

In order 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’ – summarized here [http://www.fao.org/bioenergy/28392-0a61de8f511d0a4d08b2137bc929214a7.pdf](http://www.fao.org/bioenergy/28392-0a61de8f511d0a4d08b2137bc929214a7.pdf).

### 3.2d. Synergies and trade-offs between energy-smart food and climate-smart agriculture

The above discussion means that climate benefits can and would often accrue through the achievement of energy-smart food systems as there are numerous synergies between these two objectives. However, combining CSA and ESF objectives might also require some trade-offs. Table E2 presents examples of such potential synergies and trade-offs between ESF and CSA objectives. It should be noted this table presents a very broad picture and should be considered as a first approximation aimed to summarize possible linkages between ESF and...
CSA. Indeed these linkages are often quite complex and context specific, and this table actually also shows that more research is needed on this topic.

Table E2: Examples of possible synergies (in italic green) and trade-offs (in bold red) between Energy Smart Food (ESF) and Climate

<table>
<thead>
<tr>
<th>Smart Agriculture (CSA) objectives</th>
<th>Sustainable increases in productivity &amp; income (SPI)</th>
<th>Strengthened resilience to climate change &amp; variability (CCA)</th>
<th>Reduced agriculture’s contribution to climate change (CCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increased energy efficiency (EE)</strong></td>
<td>![Checkmark] 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</td>
<td>![Checkmark] 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 EE through its impacts on productivity.</td>
<td>![Checkmark] 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 CO2 emissions from LUC 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.</td>
</tr>
<tr>
<td><strong>Increased production and use of renewable energy in agri-food systems (RE), including through integrated food-energy systems (IFES)</strong></td>
<td>![Question Mark] 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 be result in more expensive energy inputs (i.e. fossil fuel might be cheaper than renewable energy) . Specific: Practices such as conversion of agricultural waste to bioenergy, biohydrogen, biofuels.</td>
<td>![Question Mark] General: RE 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.</td>
<td>![Question Mark] 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 agricultural 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.</td>
</tr>
</tbody>
</table>


6 Of course IFES can be used to increase access to modern energy services (the third pillar of ESF) as well as to increase production and use of renewable energy in agri-food systems (the second pillar) (Bogdanski et al., 2010, Bogdanski, 2012).
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 whilst also providing energy.

Excessive use of agricultural and forestry residues for bioenergy can compete with their role in improving soil organic matter and hence damage productivity.

Biofuel production could lead to increased pressure on water resources, reduced agrobiodiversity (where monoculture used) and introduction of invasive species.

The degree to which new energy services are climate resilient depends on the energy source (see table E3 below).

Specific:
Excessive use of agricultural and forestry residues for bioenergy can compete with their role in improving soil management, which could decrease resilience to extreme weather events.

Indirect effects of biofuel demand such as indirect land-use change and price-induced intensification can lead to net GHG increases.

### Increased access to modern energy services (EA)

**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 SIPI (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, taking into account.

 More affordable energy services may be less energy efficient (e.g. efficient versus less efficient but cheaper tractors).

**General:**
EA 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:**
EA will generally lead to increased energy consumption. This will often lead to increased GHG emissions (though 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 resultant reduction in deforestation and forest degradation could lead to reduced GHG emissions.

EA 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 EE vs CCM).

**Specific:**
Bioenergy technologies that retain more nutrients (e.g. anaerobic digestion) versus those that retain less nutrients (e.g. gasification and combustion).

### Legend:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑</td>
<td>Synergy between ESF and CSA objectives</td>
</tr>
<tr>
<td>❓</td>
<td>Synergy between ESF and CSA objectives with some significant caveats</td>
</tr>
<tr>
<td>❖</td>
<td>No clear trend</td>
</tr>
</tbody>
</table>

Legend:

☑️ = Synergy between ESF and CSA objectives

❓ = Synergy between ESF and CSA objectives with some significant caveats

❖ = No clear trend
3.3. MOVING FORWARD – POSSIBLE ENERGY SOLUTIONS FOR CSA

FAO projections to 2030 show an important expected shift in cultivation practices in developing countries. The proportion of land cultivated by hand and animal will decrease and this offers the opportunity for increased productivity and reduced drudgery for farmers, but expensive machinery and equipment are often not available to poor people. Innovative business and community models are required to ensure smallholder farmers are able to access improved technologies, through rental schemes or cooperatives for example. This shift to mechanized farm systems is likely to reduce the labour requirements of cultivating land and result in fewer employment opportunities in rural areas. Well-designed policies and programmes are required to encourage alternative opportunities along the agricultural value chain and with other rural livelihoods during this shift.

3.3a. Technologies for ESF and CSA

A mix of appropriate technologies, equipments and facilities to be located in the settlements is needed to gradually shift towards energy-smart food systems, depending on the natural site conditions, infrastructure and available skills in the region. These technologies could 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, for energy production; stirling motors, water pumps (solar, wind or bioenergy operated), RE powered vehicles, monitoring systems, ICT, cooking stoves, equipment for water supply, distribution and purification and (food) processing facilities, for energy use. These technologies help to add value close to the source of raw materials. They can even be combined on the same farm in integrated food-energy systems as shown in Figure 3.4.

Figure 3.4. Example of integrated RE approach for farming systems
It is difficult, with currently available data, to identify general ESF “hot-spots” and intervention priorities as different food chains can undergo very different processes and require different forms of energy inputs. In particular more research is required on relationships between energy use and yields and production costs in various agricultural systems and settings.

Field efficiencies can be up to 90% in tilling and cultivating, 65-70% in fertilizing and grain harvesting but this depends very much on yields and plot size. Fuel consumption is typically (in MJ/ha) 600-1200 for mouldboard ploughing, 200-4900 for diskimg, 80-160 for planting, 150-300 for ammonia application, 100-200 for cultivating and 250-500 for grain harvesting (Smil, 2008).

Farming systems that have typically low energy needs and can benefit from extensive fields for farming and grazing like in Australia or New Zealand can require as low as 2-3 GJ/ha, while input intensive agricultures in the Netherlands or Israel can go up to 70-80 GJ/ha (Smil, 2008).

On a per calorie of food output basis, China has more energy-intensive agriculture today than US or EU (high cropping ratio, extensive irrigation, intensive fertilization). In post 1978 farming reforms China nitrogen (half inorganic fertilizers) has provided about 60% of the nutrient in cropping and over 80% of protein has been derived from crops. Such a sector is highly dependent on fossil fuels, but at the same time could feed about 8.5 people per hectare, and up to 15 people in populous provinces. This was also thanks to a national diet with little animal proteins.

Losses in nitrogen fertilizer are usually above 50% and sometimes amount to 60-70% of applied nutrients (Cassman et al, 2002). In many areas, reducing the level of fertilizer application only to that of optimal growth efficiency would improve significantly the energy balance of food production, while contributing to conservation of the environment and translating into a cost saving for farmers. (In some areas, such as in Africa, however, reaching optimal energy efficiency may require additional fertilizer application to increase yields.) Reducing soil erosion would be another important way to reduce fertilizer losses.

While water efficiency is becoming a priority in irrigation, this might actually require more energy, such as in the case of drip irrigation as it requires pressurized water. A lot of the energy needed for irrigation often goes into pumping operations. Extending irrigation in remote areas requires appropriate energy solutions such as solar powered pumps which can save hours of labor daily in rural off-grid areas. Irrigation efficiency may be as high as 95%; but good field practices should average around 65-75 %, while furrow irrigation can only achieve 30-40 %. In Asia, irrigation efficiency could be potentially doubled (Smil, 2008).

Liquid fuels are usually needed for operations related to soil preparation and the amount of energy needed is also 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, ploughing in particular. That is why reduced tillage cropping systems, particularly no-till systems, have become particularly attractive in times of high energy costs. Practices such as no till have a potential for significant overall saving of energy, sometimes up to 40-50% (Doets et al, 2000, SCCA, 2012) – see example in Table E3.

This is primarily due to the reduction of external inputs; as these are usually energy intensive.

Table 3.3. Total energy inputs per crop per hectare for conventional (regular) agriculture (RA) and conservation agriculture (CA) for the complete micro-catchment of Lajeado São José (Brazil)⁷ (source: Doets et al, 2000)

<table>
<thead>
<tr>
<th></th>
<th>RA</th>
<th>CA</th>
<th>System¹</th>
<th>Percentage²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize</td>
<td>Soya</td>
<td>Beans</td>
<td>Wheat</td>
</tr>
<tr>
<td></td>
<td>1514</td>
<td>1018</td>
<td>254</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>525</td>
<td>693</td>
<td>227</td>
<td>604</td>
</tr>
<tr>
<td></td>
<td>1625</td>
<td>2167</td>
<td>1673</td>
<td>1450</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>28</td>
<td>71</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3664</td>
<td>3906</td>
<td>2226</td>
<td>2054</td>
</tr>
<tr>
<td></td>
<td>2962</td>
<td>1416</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 = differences for CA compared to RA regarding all crops combined
2 = sum of energy inputs for herbicide, machinery and fuel
3 = sum of energy inputs per average hectare

A number of technological solutions exist to minimize energy use. They include minimizing the rolling resistance and slippage of the combine harvesters, for example improving tractor tyres. Energy conservation in greenhouses⁸, animal houses and agricultural buildings is also a major field of intervention. This can be achieved through the larger deployment of heat pumps (mostly of mechanical compression type, driven by electric motors) and heat recovery systems. They 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 tremendously increase energy efficiency in all operations that require heat. Pipe heating, heated floors, infrared heating, air heating are all technological solutions that can be considered, however a proper construction and insulation and correct ventilation of building and greenhouses is usually one of the most economic energy efficiency interventions.

Beyond the farm gate, for all activities that in the IPCC GHG accounting system are not included under agriculture but under the industrial processes or energy sectors (part of the agri-food chain though), a best and worst assumption of energy intensity per unit of produce can be made, leading to the results presented in Figure 3.5.

Figure 3.5. Global averages of energy intensities in the post-harvest stage of the food chain. Best and worst assumption (FAO, 2011a)

⁷ Mixed cropping system with the main crops cultivated being maize (Zea mays L.), soya (Glycine max (L.) Merr.), beans (Phaseolus L.) and wheat (Triticum aestivum L.).

⁸ Energy inputs are dwarfed by hydroponic cultivation in greenhouses for example, where energy consumption is determined above all by need for seasonal heating.
Important opportunities for reducing energy dependency can be identified in the drying, conditioning and storing of produce and in the improvement of efficiency of fuel consumption in field machinery. For grain drying, modern continuous flow dryers can be operated with much lower energy than conventional dryers, through the insulation of dryers, the recirculation of heat recovery of out-going air as well as with the help of improved instrumentation and automatic control. Combined (warm and cold air) dryers further reduce heat demand, but need a continuous and reliable electricity source for fans. Today also dielectric heating technology is available which can reduce significantly the energy needed for conditioning agricultural products. Typical rates of 600-750 kJ/kg of grain dried are needed to store products with a 14% moisture (LPG and electricity are the principal energizers). This rate goes up to 3-6 GJ/ha for corn (Smil, 2008).

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

Worldwide, the use of biomass for heat and power could save significant amounts of carbon provided that bioenergy is carbon neutral, and this is debatable (see Box E3). Co-firing of biomass with coal could save nearly 0.5 GtC per year at fairly modest costs (FAO, 2010). Savings in the traditional biomass and charcoal sectors could amount to another 0.5 GtC, although considerable effort would be required in this sector to overcome the higher investment cost, the complex socio-economic and cultural issues around traditional biomass.

By some estimates, up to 1 gigatonne of carbon (GtC) annually by 2030 (FAO, 2010)
use, and the transaction costs associated with providing the equipment and reliable biomass supply (FAO, 2010).

A transformation towards energy-smart ways of producing food is already happening along the agri-food chain in some instances.

Examples of progress towards energy-smart food production include:

- **Behind the farm gate:**
  - Significant improvement in energy efficiency through precision farming in industrial agriculture over the last 15 years, and conservation agriculture throughout the world;
  - Use of renewable energy on-farm, for instance through the increased use of solar pumps in irrigation systems and bioenergy-based integrated food-energy systems (Bogdanski, 2012) such as biogas in integrated crop-livestock systems, in particular in Asia, intercropping with perennials such as pigeon peas, for instance in Africa (Bogdanski & Roth, 2012) or more complex systems such as the Tosoly farm in Colombia, South America – see Box E.4. Another example concerns suspended solar panels in agro-photovoltaic systems, such as the one presented in Box E.5.

- **Beyond the farm gate:**
  - Use of renewable energy: In Sri Lanka, for example, woody biomass is being used to dry spices. This innovation has diversified income streams and 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).
  - Improvement of energy efficiency as regards food losses such as the UK “war on food waste” and “waste implementation programmes” (DEFRA 2003), and at preparation stage through the promotion of clean cooking stoves in many parts of the world.

10 [http://england.lovefoodhatewaste.com/content/save-time-money-0](http://england.lovefoodhatewaste.com/content/save-time-money-0)
Box 3.4. TOSOLY Integrated Food-Energy System (Colombia)

TOSOLY Farm is a highly integrated farm, aiming to produce food and energy for family consumption and for sale in a crop/livestock-based system. The cropping is based on sugar cane (feed for pigs, food and energy) and coffee and cocoa (food and energy), with multi-purpose trees. The 7 ha farm is situated in the Colombian foothills, north of Bogotá. The principal crop is sugar cane, presently occupying 1.5 ha. Tree crops include coffee, cocoa, and forage trees, forage plants and trees 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. 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 dual purpose cattle and goats. The juice is the energy feed for pigs and the source of “sweetener” for cooking for the farm family. 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, with the residual stems being another 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 progeny, kept for multi-purpose production of milk, meat and manure.

The pig unit has capacity for 40 growing-fattening pigs and five sows. Forty hens and six ducks are raised in foraging, semi-confinement systems for eggs and meat. Rabbit production is a new venture on the farm, applying the principles of 100 percent forage diets developed in Cambodia, Laos and Viet Nam.

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 recycled to the crops as fertilizer and a source of organic matter.

Most of the energy on the farm (approx. 100 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, which at the current price of electricity (US$0.20/kWh), would yield an annual return of US$7 600. The gasifier produces 4.4 tonnes of biochar yearly which is returned to the soil. Assuming that the 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.
Box 3.5. Suspended Agro-Photovoltaic farm in Italy

In 2011 an agro-voltaic plant was inaugurated in Mantua, Italy. “Agrovoltaic” technology identifies a production technique which uses and integrates in a new way existing technologies and it offers to farmers the possibility to continue to cultivate their lands producing at the same time clean energy. This solution allows farmers to partially shade the land permitting the cultivation of a wider range of crops.

It consists of a series of photovoltaic panels suspended at 5 meters above the ground, producing renewable electricity with a power capacity of 2.4 MW.

This project has been realized by REM (Revolution Energy Maker), a group of Italian entrepreneurs who operate at national and international level in the sector of electricity production. The plant is also equipped with a series of accessorizes which offer further possibility of use. These include, for example, a wireless system that allows users to change panels’ inclination, as well as to monitor ground temperature and relative humidity.

The plant makes use of recycled and non-pollutant technologies and materials, combining producers’ necessity of photovoltaic plants to develop renewable energy and farmers’ necessity of keeping their land cultivable and allowing land-owners to diversify their incomes, preserving and optimizing the use of the landscape.

This type of installation offers significant advantages for agriculture and the environment and it allows an automatic and programmed management of water distribution, irrigating sector by sector.

Such a system requires 4 to 5.5 hectares to produce a peak power of 1 MW installed and occupies at the most 2% of the land. Moreover, thanks to the omnidirectional dual-axis tracking of the photovoltaic panels, an “agrovoltaic” system increases the production of clean energy by 30%, compared with fixed panels.

The structure may integrate new automatic supporting systems for farming such as systems for watering, distribution of fertilizers and phytosanitary products and cultivation protection (anti-hail...
and shading nets, anti-frost systems). Each tracker may be equipped with a valve control system that would allow, an external source to give the command for spray irrigation, then the pumping and the daily biaxial

The examples of energy-smart food practices show that the transition it is already happening, even if at a slow pace. For it to have a large scale impact would require significant scaling-up.

3.3b. Policies and institutions for ESF and CSA

The promotion and scaling-up of energy-smart food requires innovative supportive policies and institutions. CSA policies and institutions that promote low carbon farming practices are relevant to energy smart food production because many of these practices are also good for energy efficiency and renewable energy. Particular attention should be paid to ensuring participatory processes, including adequate involvement of women, in decisions related to the deployment of modern energy service and, especially for bioenergy, ensuring secure land tenure. As regards policies specific to energy efficiency and renewable energy, some examples are summarised in Table E3.

Table 3.3. Examples of policy instruments to promote energy efficiency and renewable energy (FAO, 2011a)

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

Thailand provides an example of favourable renewable policy policies. Regulations were adopted in 2002 to simplify grid connection requirements for small electricity generators up to 1 MW (World Bank, 2011). This and other policies led to the development of integrated sugarcane and rice bio-refineries that produce food, ethanol, heat and electricity. In addition, organic residues were returned to the soil, increasing its 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 agricultural institutions that promote low-carbon agriculture also benefit energy-smart food. More specifically, examples related to institutional mechanisms that promote integrated food-energy systems concern division of labour and financial instruments. Examples of those include (FAO, 2011a):

- In parts of the UK, farmers produce wheat and a bioelectricity plant buys the straw, through a subsidiary company which collects the straw from farmers. 70% of the fuel needed to run the bioelectricity plant comes from the straw feedstock, the rest from another feedstock and natural gas. In this way farmers do what they are best at, i.e. producing wheat, leaving energy matters to other, more competent players (Bogdanski et al, 2010a).

- At the district model biogas farm in China, farmers cultivate other 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 in return get yearly dividends from any sales of pigs, cheap biogas and cheap liquid fertiliser from the district farm.

- In Bangladesh, two innovative business schemes are tapping into the private sector’s needs for biofertiliser 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. Mainly women participate in this programme. They receive funding to purchase a cow and a calf from an organic tea farm enterprise, the women then repay the loan from the sale of milk and dung back to the organic tea farm. In the second scheme, still in its pilot phase, households receive loans from the organic tea farm enterprise to pay for setting up a biogas system. The households repay the loan by selling dung and/or the slurry to the tea enterprise. Once the biogas installation has been completely paid for, the households have the option to continue selling the slurry and dung to the tea enterprise.

- ‘Fee for service’ schemes such as energy service companies (ESCO), leasing or concession arrangements schemes.

**3.3c. A multi-partner programme for scaling up ESF**

Shifting to more energy-smart food systems is clearly an important step toward 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 systems that are energy-smart, therefore contributing also to climate change mitigation and adaptation, and food security. But just because this shift will not be fully accomplished in the short term does not mean that we can afford to wait. 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 necessarily

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11 Fee-for-service (FFS) is a payment model where services are unbundled and paid for separately.
12 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, energy infrastructure outsourcing, power generation and energy supply, and risk management.
be gradual, through sustained efforts. Understanding and implementing energy-smart food systems is a complex multidisciplinary task that requires a multi-partner programme on “Energy-Smart Food for People and Climate”, which was launched in 2012. It aims to help countries promote ‘energy-smart” agri-food systems through the identification, planning and implementation of appropriate combined energy, water, food security and climate-smart solutions.
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REN 21 2011 Renewables 2011 – Global Status Report


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