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Energy-Smart Food at FAO:

An Overview

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

CLIMATE CHANGE [ENERGY] TENURE

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CONTENTS

SCOPE OF PAPER

This paper presents FAO's work on energy in relation to specific components of the agrifood chain. It complements two recent publications, *Energy-Smart Food for People and Climate Issues Paper* and the policy brief, *Making the Case for Energy-Smart Food*.

These publications presented the findings of a 2011 study commissioned by FAO that examined the linkages between energy and agrifood systems and their implications for food security and climate. The study looked at energy uses along the entire agrifood chain from field to plate and the potential of agrifood systems to produce energy. Findings confirmed that agrifood systems use a large share of the global energy supply, rely heavily on fossil fuels to meet production targets and contribute to greenhouse gas emissions. The study concluded that agrifood systems will have to become 'energy-smart' to meet future food and energy challenges, and recommended establishing a major long-term multi-partner programme on energy-smart food systems based on three pillars (i) improving energy efficiency in agrifood systems, (ii) increasing the use of renewable energy in these systems and (iii) improving access to modern energy services through integrated food and energy production.

In response to these recommendations, FAO has launched the multi-partner Energy-smart Food for People and Climate (ESF) Programme. This paper illustrates how FAO's longstanding work in the area of energy and agrifood systems contributes towards the ESF Programme's objectives.

The paper is divided into three parts. Part one summarizes the findings and recommendations from the *Energy-smart Food for People and Climate Issues Paper.* It also gives a general overview of the ESF Programme and necessary background information about the role that energy plays in food security, how the agrifood chain can help improve energy security and how changes in the agrifood system can reduce the impact of climate change. The second part of the paper describes FAO's work in various components of the agrifood chain, looks at the energy dimension for each of these components and highlights how this work contributes to the ESF Programme. This part is divided into thematic sections that look at the energy links in relation to cropping, fishing, livestock and forestry production. The section also looks at the energy issues in food processing and post-harvest operations. The bioenergy section presents an overview of FAO's work on sustainable bioenergy and the technical and policy assistance FAO is providing in this area to countries. The economic and gender dimensions of energy in relation to FAO's work are also considered. The final section puts into context the relationship between energy-smart food systems and climate-smart agriculture. The third part of the paper emphasizes the need to build partnerships to effectively address the linkages between energy security, food security, climate change and water.

KEY MESSAGES

Making a gradual shift to energy energy-efficient agrifood systems that make greater use of renewable energy technologies and better integrate food and energy production, may be the most viable solution for simultaneously reducing agrifood systems' dependency on fossil fuels and building their resilience against higher energy prices. This shift to energy-smart agrifood systems can also improve productivity in the food sector, reduce energy-poverty in rural areas and contribute to achieving goals related to national food security, climate change and sustainable development.

FAO has launched the Energy-Smart Food for People and Climate (ESF) Programme, a multi-partner initiative, to assist member countries make the shift to energy-smart agrifood systems. The Programme focuses on three thematic areas:

- energy efficiency,
- energy diversification through renewable energy
- energy access and food security through integrated food and energy production.

FAO has been working on aspects of energy in the agrifood sector for many years. The Organization's experience and ongoing work in this area are an integral part of the ESF Programme.

The ESF Programme follows an interdisciplinary 'nexus' approach to ensure that food, energy, water and climate issues are jointly addressed, trade-offs considered and appropriate safeguards are put in place.

While FAO and other organizations have been working on components of the ESF Programme for some time, scaling up the Programme will require more collaborative learning and action among other UN agencies, multilateral organizations, donors, policy-makers, civil society and the private sector. Building partnerships is critical for the ESF Programme's success.

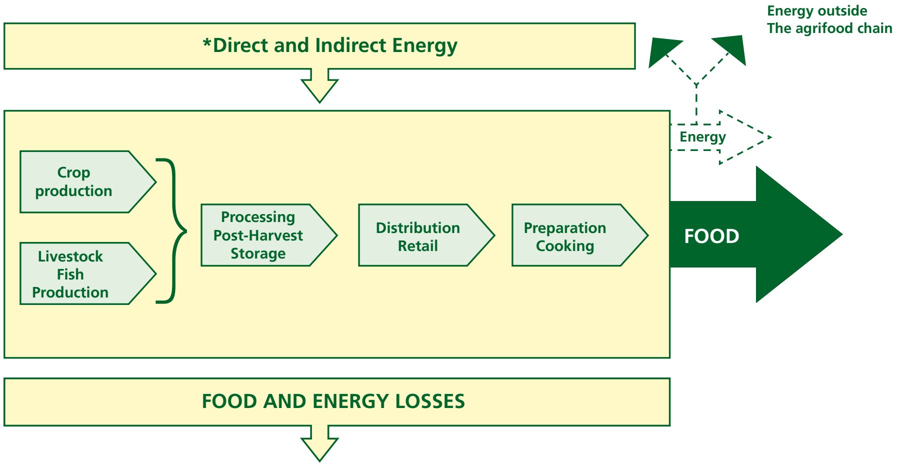
CHAPTER 1

AT A GLANCE: THE ROLE OF ENERGY IN FOOD SECURITY AND CLIMATE

How energy affects food security

Energy is needed in all steps along the agrifood chain: in the production of crops, fish, livestock and forestry products; in post-harvest operations; in food storage and processing; in food transport and distribution; and in food preparation. The direct and indirect energy used in the agrifood chain are described in Figure 1. Direct energy includes electricity, mechanical power, solid, liquid and gaseous fuels. Indirect energy, on the other hand, refers to the energy required to manufacture inputs such as machinery, farm equipment, fertilizers and pesticides. The type of energy we use in the agrifood chain and how we use it will in large part determine whether our food systems will be able to meet future food security goals and support broader development objectives in an environmentally sustainable manner. As shown in Figure 1, agrifood systems not only require energy, they can also produce energy. For this reason, agrifood systems have a unique role to play in alleviating 'energy poverty'.

Figure 1: Energy FOR and FROM the agrifood chain



Over the last several decades, the availability of cheap fossil fuels has made a significant contribution to feeding the world. The 'green revolution' of the 1960s and 1970s addressed food shortages, not only through improved plant breeding, but also by tripling the application of inorganic fertilizers, expanding the land area under irrigation and increasing the use of fossil fuels for farm mechanization, food processing and transport (FAO, 2011a). However, cheap energy sources appear to be becoming progressively scarcer and energy markets more volatile, and this has triggered higher energy prices. Our ability to reach food productivity targets may be limited in the future by a lack of inexpensive fossil fuels. This has serious implications both for countries that benefited from the initial green revolution and for those countries that are looking to modernize their agrifood systems along similar lines. Modernizing food and agriculture systems by increasing the use of fossil fuels as was done in the past may no longer be an affordable option. We need to rethink the role of energy when considering our options for improving food systems.

KEY FACTS

- Globally, the agrifood chain consumes 30 percent of the world's available energy – with more than 70 percent consumed beyond the farm gate.
- The agrifood chain produces about 20 percent of the world's greenhouse gas emissions.
- More than one-third of the food we produce is lost or wasted, and with it about 38 percent of the energy consumed in the agrifood chain.

Source FAO 2011a.

Historical trends indicate an evident link between food prices and energy prices (FAO, 2011a). Between 2007 and 2008, world oil prices dramatically increased, reaching close to US$ 150 per barrel at its highest peak (Chantret and Gohin, 2009). According to FAO, the higher fuel costs increased the cost of producing and transporting agricultural commodities (FAO, 2008f). Recent studies have further established that energy was one of the key drivers that caused food prices to surge to their highest levels in nearly 50 years (Headey and Fan, 2010; FAO, 2008f). FAO's *The State of Food Insecurity in the World 2008*, noted that higher food prices affected food access, which drove millions of people into food insecurity, worsened conditions for many who were already food insecure and threatened long-term global food security (FAO, 2008a). According to the report, in 2007, seventy-five million more people were added to the total number of undernourished relative to 2003-05 (FAO, 2008a). A food sector that is less dependent on fossil fuels could help stabilize food prices for consumers and reduce financial risks for food producers and others involved in the food supply chain.

Energy security is important to food security

Improving energy access to impoverished communities is essential if the poverty reduction targets set out in the Millennium Development Goals (MDGs) are to be met. Almost 3 billion people have limited access to modern energy services for heating and cooking, and 1.4 billion have zero or limited access to electricity (UNDP/WHO, 2009). Without access to electricity and sustainable energy sources, communities have little chance to achieve food security and no opportunities for securing productive livelihoods that can lift them out of poverty.[1]

1 Energy services include lighting, heating for cooking and space heating, power for transport, water pumping, grinding and numerous other services that fuels, electricity, and mechanical power make possible.

KEY FACTS

- Developed countries use about 35 gigajoules per person a year for food and agriculture (nearly half in processing and distribution).
- Developing countries use only 8 gigajoules per person per year (nearly half for cooking)

Source FAO 2011a.

Today there is a large gap between energy demand and access, and demand will certainly increase as countries develop. Average per capita energy use in low-income countries is a third of that of middle-income countries, which is in turn almost a fifth of per capita energy demand in high-income countries.[2] According to a United Nations Development Programme (UNDP) report on the role of energy in reducing poverty, no country in modern times has substantially reduced poverty without a massive increase in its use of commercial energy and/or a shift to more efficient energy sources that provide higher quality energy services (UNDP, 2005). From a household perspective, access to modern energy services is still extremely problematic in many developing countries. The International Energy Agency (IEA) estimates that a fifth of the world's population lacks access to electricity, and that two-fifths rely on traditional biomass for cooking (IEA, 2011). The use of traditional biomass in open fires or with simple cooking stoves is not only less efficient and more polluting than modern energy options, but it is also unreliable, not easily controllable and subject to various supply constraints. The poor in developing countries pay much more in terms of health impacts, collection time and energy quality for the equivalent level of energy services as do their counterparts in the developed world (Johnson and Lambe, 2009).

From a rural development perspective, access to energy is fundamental for the provision of goods and services that can improve agricultural productivity and bring new opportunities for generating income (Practical Action, 2009). Increasing energy services in rural areas has the potential to spur agricultural development by increasing productivity, for example through irrigation, and improving crop processing and storage. It could also strengthen the development of non-farm commercial activities, including micro-enterprises, and create opportunities for other livelihood activities beyond daylight hours (DFID, 2002). Energy development, especially renewable energy, also has the potential to create green jobs in rural communities, in areas such as fuel crop cultivation and the provision and maintenance of energy services. This will have indirect impacts on agricultural productivity and risk management due to increased household incomes and diversification out of agriculture.

2 Average per capita energy use in low income countries is 423 kilo tonnes of oil equivalent (ktoe)/capita, 1242 ktoe/capita in middle income countries and 5321 ktoe/capita in high income countries (World Bank, 2010).

Renewable energies such as bioenergy, solar, wind, hydro and geothermal can be used in agrifood systems as a substitute for fossil fuels to generate heat or electricity for use on farms or in aquaculture operations. If excess energy is produced, it can be exported off the property to earn additional revenue for the owners. Such activities can bring benefits for farmers, landowners, small industries and rural communities.

FAO projections indicate that by 2050 a 70 percent increase in food production over 2005-2007 levels will be necessary to meet the expanding demand for food. This is equivalent to the additional production of around 1 000 tonnes of cereals and around 200 tonnes of meat and fish. These production gains are largely expected to come from increases in productivity of crops, livestock and fisheries (FAO, 2009a). Furthermore, as populations expand and economies grow, the global demand for energy and water is also expected to increase by 40 percent (IEA, 2010, WEF, 2011).

If the world is to fulfill its commitments to halving hunger and poverty by 2015 and helping low-income countries meet their basic energy needs by 2030, these food, water and energy challenges must be overcome. It is clear that in our efforts to build a world without hunger, we will need more energy. FAO's *Energy-Smart Food for People Issues Paper* (FAO 2011a) provides a comprehensive analysis of the energy status of the food sector from the perspective of demand and supply. It examines in detail energy uses in each of the agrifood chain components and identifies opportunities for implementing energy-smart approaches. The issue paper concludes that higher costs of oil and natural gas, insecurity regarding the limited reserves of these non-renewable resources and the global consensus on the need to reduce greenhouse gas emissions, could hamper global efforts to meet the growing demand for food, unless the agrifood chain is decoupled from fossil fuel use.

Energy, agrifood systems and climate change

Primary food production and the food supply chain, including landfill gas produced from food wastes, contribute approximately 22 percent of total annual greenhouse gas emissions (FAO, 2011a). An additional 15 percent of greenhouse emissions results from land use changes, particularly changes linked to deforestation brought about by the expansion of agricultural land (IPCC, 2007). Energy-related carbon dioxide emissions along the agrifood chain are produced from the combustion of fossil fuels to run machinery, generate heat and electricity for food storage and processing, and from the use of petroleum fuels for food transport and distribution (FAO, 2011a). Energy is essential for food security and development, but current food production and energy use patterns are unsustainable if climate change targets are to be met.

ENERGY-SMART FOOD FOR PEOPLE AND CLIMATE (ESF) PROGRAMME

In keeping with the 2011 study's recommendations for a major long-term multi-partner programme on energy-smart food systems, FAO's ESF Programme focuses on three thematic areas:

- energy efficiency,
- energy diversification through renewable energy and
- energy access and food security through integrated food - energy production.

The ESF Programme aims to help countries promote energy-smart agrifood systems through the identification, planning and implementation of appropriate energy, food security and climate-smart strategies that spur agricultural growth and rural development.

KEY QUESTIONS ADDRESSED BY THE ESF PROGRAMME

- How should countries carry out the energy analysis of the agrifood chain?
- How much energy is currently used and produced by the agrifood chain?
- How and to what extent can an energy-smart food system contribute to energy access for the poor?
- How much room for improvement is there through improving efficiency gains, reducing loss and waste reduction and diversifying energy sources?
- What proven and implementable energy-smart alternatives exist?
- What energy-smart food systems are applicable in a given country context and how do they vary by scale?

The ESF Programme is currently raising awareness about the dependency of global agrifood systems on fossil fuels, the implications this dependency has for food security and climate and the potential for agrifood systems to alleviate this problem by becoming a source of renewable energy. The Programme is also generating information to fill knowledge gaps.

This paper is the result of an internal stock-taking exercise to determine the current extent of FAO activities related to energy and identify the in-house, knowledge, capacities and expertise that support specific aspects of the ESF Programme. Forthcoming publications include a global case study on the practical implementation of energy-smart practices in relation to the three thematic areas of the ESF Programme. The Programme is also working on defining an assessment framework to characterize the amount of energy used at different stages of the agrifood chain and determine the potential of the agrifood chain to produce energy. Another major ongoing activity is outreach to potential partners to establish a collaborative framework for gathering knowledge and mobilizing actions to address the energy-food security-water-climate nexus.

CHAPTER 2 ENERGY-SMART FOOD: THE WORK AT FAO

The ESF Programme follows a multidisciplinary approach that brings together different FAO departments to address issues related to energy in the agrifood sector in a systematic and integrated manner. Energy is a subject that touches on a number of aspects of FAO's work, so it is not surprising that many of the Organization's activities are already directly or indirectly connected with the EFS Programme's three thematic areas. The following sections present an overview of the current work FAO is undertaking to address energy-related issues in cropping, fishing and livestock production systems, as well as in processing and post-harvest operations

2.1 CROP PRODUCTION

Increases in crop productivity achieved between the 1960s and 1980s are attributable to advances in sciences and the significant use of fossil fuel-powered farm equipment and machinery, intensive tillage, irrigation and chemical inputs (FAO, 1996, Rayner, et.al, 2011). Modern mechanization, particularly in developed countries, has helped enhance productivity and production with the lowest cost (Verma, 2008; FAO, 2011a). In most developing countries, particularly in Asia and Latin America, modern mechanization has also successfully enhanced agricultural productivity (FAO, 2008b). The use of mineral fertilizers has also been instrumental in this regard, with at least one-third of crop yield increases attributable to the application of mineral fertilizers (FAO, 2012c). In addition, irrigated agriculture contributes 40 percent of the world's food production (FAO, 2011d). As has been mentioned earlier, production intensification through use of fossil fuel-based inputs was made possible largely due to the availability of cheap oil (FAO, 2011a). However, there is significant uncertainty concerning the price and availability of energy needed to power farm operations and produce key inputs, principally fertilizers. Moreover, it is widely recognized that the gains in crop production and productivity were often accompanied by negative effects on agriculture's natural resource base. This jeopardizes future productive potential and reduces productivity of inputs (FAO, 2011c).

2.1.1 Cultivation[1]

Recognizing that a paradigm shift to the sustainable intensification of agricultural crop production is required to ensure future global food security, FAO has established

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1 This section is largely based on information from *Save and Grow: A policymaker's guide to the sustainable intensification of smallholder crop production.*

the Programme on Sustainable Crop Production Intensification (SCPI). The Programme aims to find intensification solutions through an ecosystem approach, drawing on nature's contribution to crop growth with appropriate external inputs applied at the right time and in the right amount. This approach relies less on fossil fuel-based inputs, which reduces producers' fuel costs and makes production more resilient to fluctuations in energy prices. FAO's Agricultural Plant Production and Protection Division is leading the SCPI Programme's implementation by bringing together the division's expertise in integrated pest management, soils, ecosystem production-based approaches, fertilizers, crops and conservation agriculture to define farming practices that enhance yields in a sustainable manner. Farming systems for sustainable crop production intensification are based on three technical principles: 1) simultaneous achievement of increased agricultural productivity and enhancement of natural capital and ecosystem services; 2) higher rates of efficiency in the use of key inputs, including water, nutrients, pesticides, energy, land and labour; and 3) the use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses (FAO, 2011c). FAO's SCPI Programme works with Member States to avoid mechanical tillage; promote the judicious use of organic and inorganic fertilizer; incorporate integrated management of pests, diseases and weeds to reduce the need for pesticides; and encourage efficient water management. All of these practices contribute to reducing the use of fossil fuels.

CONSERVATION AGRICULTURE BOOSTS PRODUCTION AND SAVES FUEL IN THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA

The Democratic People's Republic of Korea asked FAO to provide technical assistance in the introduction of conservation agriculture to address the problems in agricultural production. Soil tillage was eliminated, permanent soil cover was introduced and crop rotations were implemented to improve soil conditions. This led to a reduction in fertilizer requirements and significant fuel savings. The economics of conservation agriculture and the traditional tillage system for Korea were compared by measuring the fuel consumption per ha and season on the three farms between 2003 and 2005. Conservation agriculture practices allowed input savings of 30 to 50 percent. An average of 15.5 kg fuel per ha was saved by following the conservation agriculture system.
http://www.fao.org/ag/ca/doc/WorkPaperKorea.pdf

Lower energy consumption through sustainable intensification

Building resilience to fluctuations in energy prices demands a careful evaluation of farming practices. Soil tillage for land preparation is the single most energy-consuming operation in a cropping cycle. Reducing mechanical tillage can lower fossil fuel consumption and save costs and labour (FAO, 2000a). For many years FAO has promoted conservation agriculture, which promotes zero tillage as a way of making agriculture both sustainable and profitable. The results from a study carried out from 1998 to 2003 on CA at the smallholder level in Paraguay indicated that crop yields improved, while fertilizer, herbicide and fuel inputs were reduced. Lower production costs from reduced quantities of fossil fuel-based inputs and higher crop yields has lead to higher incomes with positive impacts on smallholder farmer livelihoods. To date, FAO has generated a considerable body of knowledge on reference material for extensionists, professors, agronomy students, technicians in general, and farmers to illustrate the benefits of conservation agriculture and to facilitate the adoption of no-tillage cultivation, the use of green manures and the practice of crop rotation in small farms.

Fertilizer use

Since 1960, fertilizer consumption in developing countries has increased more or less continuously, and today accounts for about 60 percent of the world total, a trend which is continuing (IFA/UNEP, 2000). Inefficiencies in fertilizer use lead to substantial economic losses and present environmental risks. In China, the nitrogen uptake efficiency is only about 26-28 percent for rice, wheat and maize, and less than 20 percent for vegetable crops. Increasing uptake efficiency is a question of how fertilizer is managed, including the method and timing of applications (FAO, 2011c). The SCPI Programme promotes efficiency in the use of mineral fertilizer together with the use of organic fertilizers and legumes in crop rotations. For smallholder farmers in many developing countries, it can be a real challenge to obtain chemical fertilizers. Furthermore, farmers using chemical fertilizers in both developed and developing countries are vulnerable to fluctuations in energy prices that push chemical fertilizer prices upward making them unaffordable. Using organic fertilizer, such as livestock manure or organic plant material, can help farmers better cope with changing energy costs and reduce fossil fuel consumption.

IMPROVING RURAL LIVELIHOODS

With extreme weather conditions and low agricultural productivity, the Altiplano in Bolivia is one of the poorest areas in the country. FAO in collaboration with AgroClim implemented biogas digestor systems to produce organic fertilizer to be used in farms and help improve productivity. The biogas systems were also set up to use methane for household cooking and lighting. This has brought important socio-economic benefits beyond increased crop productivity. The use of biogas has also improved women's livelihoods by relieving them of the chore of collecting fuelwood, improving household air quality, improving the quality of cooked foods and allowing children to study at night.

http://www.rlc.fao.org/uploads/media/07_InformeGirasTecnicas__2_.pdf

Pesticides

Pesticide use grew by a factor of 32 between 1950 and 1986. Developing countries now account for a quarter of the world's pesticide use (University of Michigan, 2012). The need for insecticides and fungicides can be reduced through greater use of pest control methods based on the principals of Integrated Pest Management (IPM) (FAO, 2011b). FAO's work promotes IPM to encourage the use of natural pest control mechanisms to reduce the overall use of chemical pesticides and associated 'embodied' fossil fuel. Replacing herbicides by integrated weed management practices has also been successfully introduced in smallholder systems. Crop production activities at FAO build on IPM using the Farmer Field School (FFS) approach to train hundreds of thousands of smallholder farmers in developing countries. This approach has led to the training of millions of farmers in IPM methods, and thousands have now become trainers themselves.

CONSERVATION AGRICULTURE IN THE UNITED REPUBLIC OF TANZANIA

Since conservation agriculture was introduced in 2005 in the United Republic of Tanzania's Kataru district, farmers have stopped ploughing and hoeing and are growing mixed crops of direct-seeded maize, hyacinth bean and pigeon pea. This system produces good surface mulch, so that weed management can be done by hand without need for herbicides. Every few years, fields are rotated into wheat. The overall results have been positive, with average per hectare maize yields increasing from 1 tonne to 6 tonnes. This dramatic yield increase was achieved without agrochemicals and using livestock manure as a soil amendment and fertilizer.

http://www.fao.org/ag/ca/doc/Tanzania_casestudy.pdf

2.1.2 On-farm power

The term 'mechanization' is often misconstrued to mean modern mechanization based on fossil fuel-driven agricultural equipment and machinery (FFTC, 2005). However, mechanization in the wider context refers to the use of all farm equipment, ranging from traditional hand-held tools, to animal traction, to modern machinery powered by fossil fuel. All of these are important inputs to agricultural systems. Mechanization of farming has allowed an increase in the area that can be planted and has contributed increased yields, mainly due to the precision and timing with which the crop husbandry tasks can be accomplished (Singh, 2001). Most farmers in developing countries spend more per year on farm power inputs than on fertilizer, seeds or agrochemicals (FAO, 2012a). Mechanization interventions that enhance productivity to meet the growing demand for food and ensure the economic resilience for farmers must also contribute to the environmental sustainability of the production systems. FAO is striving to assist member countries in finding mechanization solutions that can offer farmers the right choice of technology at the right price to increase agricultural productivity sustainably, reduce post-harvest losses and safeguard food security. FAO's Agricultural Machinery and Infrastructure Unit in the Rural Infrastructure and Agro-Industries Division assists farms and agribusinesses in designing appropriate agricultural mechanization operations to improve the efficiency, effectiveness, competitiveness, and profitability of agricultural and food enterprises.

Sustainable Agricultural Mechanization Strategies

FAO encourages and supports member countries in designing sustainable agricultural mechanization strategies that are aligned with the country's particular situation, based on farmers' needs and consider the institutional arrangements and the availability of services to meet these needs. Such considerations are fundamental for identifying the most appropriate machinery and power source for a given situation. The choice will depend on the work to be done and the relative desirability, affordability, availability and technical efficiency of the options. Energy availability, accessibility and energy efficiency parameters are taken into account in FAO assessments. Lack of knowledge and skills in the efficient use, proper maintenance and repair of machinery is another area that affects energy efficiency and fuel consumption (FAO, 2011a). Choosing the right size of equipment based on the desired type of operation and land size is also important. For example, using a large tractor for light loads is inefficient because extra horsepower is used to move the larger tractor. On the other hand, using a smaller tractor to perform operations that require more horsepower can overload the tractor. FAO provides guidance on agricultural technologies and appropriate mechanization pathways that can lead to improved energy efficiency in crop production. FAO also supports capacity building to improve efficiency and reduce maintenance costs by integrating agricultural mechanization into the overall concept of a sustainable intensification of crop production.

Farm power and mechanization for small farms in sub-Saharan Africa provides an overview of options for farm power and technologies that could be suitable for small and medium-sized farmers. The manual also lays out the importance of the farming systems and the economic context within which the mechanization takes place. Special emphasis is given to the financial implications of farm power and the environmental impact of mechanization.
ftp://ftp.fao.org/docrep/fao/009/a0651e/a0651e00.pdf

Adequate mechanization for conservation agriculture

A key focal area in the SCPI Programme, particularly in relation to conservation agriculture, is the identification of appropriate mechanization that can improve energy efficiency in crop production (FAO, 2011c). According to the publication, ***Conservation Agriculture in Developing Countries: the Role of Mechanization***, adopting conservation agriculture represents a fundamental change in soil systems management and the design and management of the cropping system. These changes in turn lead to adjustments in the required field operations and the related mechanization. Designing new and appropriate farm implements is critical for the success and scaling up of conservation agriculture. Realizing conservation agriculture's full potential will require the development of a new set of mechanical technologies and changes in farm power requirements. For example, under a conservation agriculture system, small farmers using single axle tractors, who would normally have to hire a four-wheel tractor to till their fields, can continue to farm without making any changes. This can decrease overall power requirements by 50 percent.

2.1.3 Water

Irrigation has been a major driver behind the green revolution and continues to plays a key role in food production systems (Comprehensive Assessment, 2007). Globally, some 300 million hectares of farmland, representing 20 percent of the world's cultivated land is irrigated. Irrigated agriculture, which accounts for 70 percent of all freshwater withdrawals, contributes 40 percent of the world's food production (FAO, 2011d). Unreliable water supplies have a significant impact on the productivity of on-farm irrigation systems. A global estimate is that 40 percent or more of the water withdrawn for irrigation is 'lost' through conveyance leakage, deep percolation or surface run-off (FAO, 2011d). Many of these 'losses' are in fact recovered through tubewells and shallow lift pumping from drainage channels. Even if water is supplied under gravity, realizing the actual benefits of water distribution and storage within irrigation schemes involves an increase in energy intensity per hectare of cropped land

Water management in agriculture faces a number of challenges that will affect the availability and reliability of future water resources (FAO, 2011d). Improving water use efficiency is paramount. Energy consumption in irrigated agriculture results primarily from water pumping requirements. Estimates suggest that by the end of the 20th Century, as much as 20 percent of energy worldwide was used by pumps of various types (Hydraulic Institute, Europump, and the U.S. Department of Energy, 2004). This high energy use highlighted the need to improve the efficiency of the pumps and pump motors. While there is no breakdown of what percentage was used to pump groundwater, it is possible that it was one or two percent, and almost certain that at least 75 percent of this usage was for pumping groundwater for irrigation (Jones, 2012).

Reliable energy supply and irrigation

Consistency of energy supply is an important aspect in groundwater irrigation systems. For example, in India, the unreliability of the electricity supply influences farmers in their selection of groundwater pumping equipment and abstraction routines. Oversized pumps are used to maximize abstraction during the periods when electricity is available and to minimize motor burnout due to supply fluctuations (S. Padmanaban & A. Sarkar, 2005). A frequently given reason for the over-application of irrigation water is that farmers install automatic pump switches to ensure they pump water whenever the irregular electricity supply is working. This can lead to excessive groundwater abstraction (Shah, et. al, 2008).

However, more efficient water-use irrigation systems may consume more energy. For example, pressurized irrigation systems, such as drip irrigation, conserve water but require energy to pressurize the system (Dale, et. al, 2008). Therefore, tradeoffs need to be carefully assessed and decisions made based on local conditions.

Small-Scale Pumped Irrigation: Energy and Costs helps users to reduce the costs involved in small-scale pumped irrigation schemes. Too often, schemes are designed and constructed with only the immediate costs of construction, buying and installing equipment in mind. Little or no attention is given to operating costs. As a result, some schemes may be inexpensive to install but costly to run. The manual describes ways of designing irrigation schemes and selecting equipment that take into account both investment and operating costs with particular emphasis on the significance of energy costs.
ftp://ftp.fao.org/agl/aglw/fwm/SmallScalePumpedIrrigation.pdf

Efficiency of irrigation systems

The implementation of effective solutions for saving energy and water requires an understanding of the relationship between water application and energy use, and the trade-offs of using one particular irrigation method over another. The Water Programme at FAO maintains a strong technical expertise in water management, with special focus on agricultural productivity, poverty alleviation and environmental sustainability. It offers technical assistance to Members States in a variety of areas, including the design and implementation of on-farm irrigation systems; the identification and adaptation of irrigation techniques; the development of water resources through small-scale irrigation and appropriate water control technologies; and best practices for sustainable water use, conservation (including dryland management) and water harvesting.

EFFICIENT IRRIGATION SAVES ENERGY IN INDIA

A survey of installed pumps under the Bangalore Electricity Supply Company (BESCOM) pilot project in Doddaballapur Taluk District in India showed that over 90 percent of the functioning pumps sets were less than 30 percent efficient. The replacement of pumps with correctly-sized efficient pumps and conversion of at least 0.4 ha of flood irrigated fields to drip irrigation in the project showed that overall efficiency improvements of 70 percent in terms of energy and a 60 percent reduction in water usage could be achieved (Jones, 2012).

Agriculture is in constant evolution, and irrigation needs to adapt to new, more stringent requirements. The supply of water within large irrigated systems needs to become much more reliable and flexible. To respond to this need, FAO has developed a multi-language training package for modernization and rehabilitation of large-scale irrigation schemes. The Mapping Systems and Services for Canal Operation Techniques (MASSCOTE) approach has been applied in 20 countries. MASSCOTE is a step-by-step methodology for evaluating and analysing different components of an irrigation system and developing a modernization plan. The plan consists of physical, institutional and managerial improvements in different components to improve water delivery service and the cost effectiveness of operations and management. One step in the MASSCOTE approach is the mapping of energy balances to assess energy performance. This is done by looking at, among other things, a combination of efficiencies in the pump and motor system.

IRRIGATION AND ENERGY IN SYRIA

FAO's work to modernize the Mounshaat-Al-Asad irrigation scheme in Syria using the MASCOTTE approach found that energy spent at the head station accounts for approximately 80 percent of the overall operational and maintenance costs. The efficiency of the pumping station can be improved including water saving from improvements in the distribution network, which brings high savings on electricity. For example, a 10 percent savings in water used equals as much as the staff budget allocated to the canal.
http://www.fao.org/nr/water/docs/masscote/applications/MASSCOTE_Mounshaat_2OCT09.pdf

Water and energy production

Water is used to generate hydroelectricity and grow feedstock for the production of biofuels. Water for energy currently amounts to about eight percent of global water withdrawal (FAO/UN-WIDER, 2011). The recent surge in liquid biofuel production has been driven by a number of factors, including, national goals for achieving energy autonomy, concerns over the impacts of greenhouse gas emissions and high fossil fuel prices. The growth in the biofuel sector has increased the links between food and energy production and raised questions about its impacts on natural resources, including land and water. Biofuels are generated from agricultural feedstock, which is typically a water-intensive sector. Globally, biofuels currently account for about 1 percent of all

ASSESSING THE IMPACT OF BIOFUEL PRODUCTION ON WATER IN PERU

In the semi-arid coastal region of Peru, more than 100 000 hectares of non-cultivated land has been targeted for biofuel crop production. This region also contains Peru's largest cities and its largest commercially irrigated agricultural areas. In the Chira valley, the development of 23 976 hectares of sugar cane for ethanol production will require new irrigation systems. To assess the implications of this development, FAO's BEFS Project undertook a water analysis using the Water Evaluation and Planning System (WEAP). Results show that under current conditions, there is not enough water available to support the cultivation of the additional sugar cane projected for the Chira valley. The current supply of water would only be enough to support an additional 10 000 hectares of sugar cane.
http://www.fao.org/docrep/013/i1968e/i1968e.pdf

water used by crops. However biofuel production is projected to increase substantially. Consequently, switching from fossil fuels to biofuels is expected to increase significantly a country's overall water use. If irrigated production schemes for biofuel feedstock are pursued, this can have important implications for local water availability and food security. Production of feedstock through irrigated agriculture requires an assessment on the impact of biofuel production on water.

In the framework of the Bioenergy and Food Security Project (BEFS) and the Environmental Impact Analysis Programme (BIAS) (further explained in the Bioenergy section 1.6), FAO studies the potential impact of biofuel production on water resources and water quality to help countries develop fair and sustainable bioenergy production policies.

2.2 FISHERIES

Globally, fish provides about 16 percent of animal protein and 6.1 percent of all protein consumed by people. Annual per capita consumption has grown from 11.5 kg in the 1960s to about 17.1 kg in 2008 (FAO, 2011e). Capture fishing has traditionally been the primary source of supply, but it is facing resource and yield limits. Aquaculture has significantly increased over the last two decades. It now contributes some 46 percent of food fish supply and is set for further expansion (FAO, 2011e).

Fish consumption varies across regions and countries. This variety reflects the different levels of availability of fish and other foods, as well as diverse food traditions, demand, income levels and prices. Developed countries have generally higher consumption levels and have increasingly looked to imports to satisfy demand. In developing regions, changes in consumption have been more variable. For example, in sub-Saharan Africa, consumption has been relatively low and, in some cases, is declining. However, broad projections suggest that global per capita consumption will rise (FAO 2011e).

In both capture fisheries and aquaculture, a wide variety of technologies, from artisanal to highly-industrial, are involved in production and supply. These different technologies, which encompass vessels, equipment and culture systems, use a range of different types of energy and in varying amounts (FAO, 2011a). Because of increased mechanization of fishing vessels and increased numbers of fishers, the intensification of aquaculture, and growth in processing, transport and retail distribution, fossil fuels have played an increasingly important role in fisheries production. The economic viability of the sector has become closely linked to fuel and energy prices and their indirect impacts on key inputs, such as aquaculture fertilizers and feeds (FAO, 2011a) . Most current production methods originated when resources were abundant, energy costs were dramatically lower and less attention was paid to operating efficiency and ecosystem impacts. The new realities of high energy prices and greater environmental awareness present major challenges for the future viability of the sector. This may be especially true in developing countries where access to and promotion of energy efficient technologies has been limited (FAO, 2011e, Suuronen et. al, 2012)). Future production will be increasingly constrained by the cost of fuel and energy supplies. The expansion of aquaculture will need to make efficient use of embodied energy in feeds and to use energy efficiently in production systems. The fishing industry will need to become energy-smart along the entire food chain to cope with the volatility and rising trends of fuel and energy prices (FAO, 2011a) and to ensure food availability at accessible prices.

FAO's Fisheries and Aquaculture Department supports and promotes responsible and sustainable development in capture fisheries and aquaculture, in post-harvest processes and in distribution, markets and trade. It does this by generating knowledge and information, providing a global neutral forum for negotiations on key issues, and offering technical assistance at national and regional levels. The importance of energy issues in fisheries has long been recognized. The Department developed the first standardized surveys of fishing fleet fuel use in the 1980s (FAO, 1986). The associated methodologies for fuel use and costs have also been important in estimating the scale of global subsidies in capture fishing and for making the case for strategic reforms (WB/FAO 2009). Energy and fuel use has continued to be an important technical theme. FAO is developing a wider review on global use and possible reduction strategies (FAO, forthcoming) and technical guidelines on practical means of reducing fuel use in fishing vessels (FAO, 2012b). The Department has also incorporated energy issues in their activities on climate change adaptation and mitigation. A review of these activities identified key mitigation routes for the sector in energy consumption, through fuel and raw material use. As with other food sectors, the sound management of distribution, packaging and other supply chain components was also recognized as contributing significantly to decreasing the sector's carbon footprint (FAO, 2009c).

Capture fishing

Many forms of capture fishing have become highly energy-intensive, with fuel costs typically representing 30-50 percent of operating costs. The global fishing fleet is made up of about 4.3 million vessels, about 60 percent of which are powered by internal combustion engines (FAO, 2011e). With no practical energy alternative in sight in the short or medium term, FAO's work has focused on generating knowledge and information on energy efficiency in conventional fishing. This includes identifying practical and technical areas affecting energy efficiency and options to address them. Recent FAO activities include a review of key capture technologies and the identification of gaps, constraints and opportunities in the development of 'Low Impact and Fuel Efficient' (LIFE) fishing. The review also looked at the transfer and adaptation of technologies from fisheries that have demonstrated commercial potential for similar species. Review findings also include examples of potential energy saving techniques and operational adaptations to reduce fuel consumption and the environmental impacts of demersal trawling (Suuronen et. al, 2012). The options for fuel and energy reduction vary widely depending on the fleet, fishing

> ***Fuel and financial savings for operators of small fishing vessels*** provides guidelines on operational and technical measures to assist fishery owners and operators of small-scale fishing vessels in improving and maintaining the energy efficiency of their vessels. It addresses fuel saving measures for existing boats without incurring major costs and gives information on the design of a fuel-efficient boats and options concerning the use of sail.
> ftp://ftp.fao.org/docrep/fao/007/x0487e/x0487e00.pdf

techniques, management and market conditions. In many cases, there is the potential to reduce fuel use per capture output. However, the means for tapping this potential, perhaps through incentives and support for small-scale fishing fleets, still need to be addressed.

Aquaculture

The use of fuel and energy in aquaculture is more indirect than in capture fisheries. Aquaculture production systems are diverse, ranging from low-intensity subsistence operations to high-intensity industrial models. The rapid growth of aquaculture production has been accomplished in part through intensification. Global feed production for farmed fish and crustaceans is estimated at about 6 million tonnes (FAO/GLOBEFISH, 2007). Along with the energy costs of capturing the feedstocks, the production of fish meal and fish oil requires significant amounts of energy for cooking, drying and evaporation. Energy consumption in fish meal production is estimated at 32 kilowatt-hours (kWh) plus 32 litres of fuel oil per tonne of raw materials processed (UNDP, 1999). Substantial parts of the aquaculture sector are now reducing their dependence on fishmeal and oil, but the energy required to produce terrestrially sourced raw materials is also significant. Water exchange and treatment, boats, vehicles and handling systems create additional energy demands in aquaculture. However, these demands are usually less important than feeds and fertilizers. Growth in the aquaculture sector will depend on improving

> FAO has released many publications dealing with aquaculture feed supply and production. Although energy issues are not specifically detailed, they help improve feed production, which has implications for energy use. Below are two examples:
> ***Farm-made aquafeeds: the use of farm-made feeds in Asia*** presents a review of 11 countries and five technical papers and additional working papers on farm feed preparation and feeding strategies. http://www.fao.org/DOCREP/003/V4430E/V4430E00.HTM
> ***Use of Fishmeal and Fish Oil in Aquafeeds: Further Thoughts on the Fishmeal Trap*** assesses the use of fishmeal and fish oil in aquafeeds in the context of the currently static supplies of marine resources.
> http://www.fao.org/docrep/005/y3781e/y3781e00.htm

feeding efficiency and increasing land or water-based productivity. Information on energy options and strategies for feeding and practical advice for producers will be important in supporting the aquaculture sector and ensuring that it provides sustainable benefits for producers and consumers.

Fisheries, energy and climate

At the twenty-ninth session of the Committee on Fisheries (COFI) in 2010, FAO reported that net greenhouse gas contributions of fisheries, aquaculture and their supply chains were poorly studied. The paucity of data on greenhouse gas emissions across fisheries and aquaculture supply chains severely hampers the development of strategies to address energy use. FAO also reported that the transition to energy-efficient and low carbon foot print aquatic food production systems would depend on a number of factors including: the development of standardized methodologies for energy and emissions calculations throughout the food chain; the collection of data using these methodologies; and the development of policy and technologies associated with energy use and greenhouse gas emission reductions. COFI recommended that FAO should provide its Members with information on possible fishing industry contributions to climate change, and on ways to reduce the sector's reliance on, and consumption of, fossil fuels, respecting the principles embodied within the United Nations Framework Convention on Climate Change (UNFCCC). FAO's Fisheries and Aquaculture Programme focuses on energy conservation and reducing potential impact of climate change along fisheries and aquaculture supply chains. FAO works closely with industry practitioners to identify practical and reliable ways of measuring the impacts and the effects of changing practices in the sector. The objective is to develop a comprehensive framework and a global approach for defining resource use, comparative production efficiency, and greenhouse gas climate change interactions.

INTERNATIONAL COOPERATION ON FISHERIES AND CLIMATE CHANGE

With financial support from the government of Norway, FAO, in collaboration with Seafish, researchers at SINTEF and Dalhousie University, is investigating methods for understanding and enabling the mitigation of greenhouse gas emissions in fisheries and aquaculture production systems and supply chains. In 2011, a workshop was carried out in to develop practical performance metrics in greenhouse gas assessment methodologies for policy guidance, industry and producer use, consumer information and purchase choices. This is to be followed up with a further workshop on practical approaches for greenhouse gas mitigation.

2.3 LIVESTOCK

Globally, livestock products account for around 13 percent of calories consumed and provide 25 percent of dietary protein. Meat consumption is projected to rise by nearly

73 percent by 2050 and dairy consumption will grow 58 percent (FAO, 2009d). In many developing countries, rapid income growth, urbanization and population growth are driving the demand for meat and other animal products. Over the past 40 years, global production of animal products has grown steadily, largely as a result of expansion of industrialized production systems (FAO, 2011f).

Cheap inputs, including feed grain and fuels, have played an important role in this growth. Declining grain prices have contributed to their increased use as feed, and lower transportation costs have facilitated the movement of feed and livestock products (FAO, 2011f). However, recent increases in feed and fuel prices may signal the end of the era of cheap inputs. This will have profound implications on how the livestock sector will develop to meet future demands. The continuation of fossil-fuel driven animal-rearing operations is hard to imagine. Meeting future demands may be better accomplished by exploring ways to improve efficiency along the animal chain.

Animal feed

Fossil fuels are required to produce, process, store, transport and distribute animal feeds. The type of production system and species influence the energy intensity of livestock production. Animals in intensive systems or landless systems are given concentrated feed that includes cereals, soya and fishmeal. These systems produce 45 percent of the world's meat, mainly from poultry and pigs, and 61 percent of the world's eggs (FAO, 2009d). In these systems, animal feed constitutes a significant component of the total energy input. In small-scale livestock systems, particularly in developing countries, one of the basic reasons for poor performance is the seasonal inadequacy of feed, both in quantity and quality (FAO, 2007). FAO is addressing this issue through a better understanding of the nutritional principles underlying the utilization of agro-industrial by-products as livestock feed and by assisting smallholders in improving the nutritional quality of animal feed using local resources.

FAO assists countries in generating new data and information, for example through the establishment of national feed inventories, and by mapping feeding systems and feeding baskets to foster formulation of sound policies and guidelines for efficient livestock-sector planning. This information also helps the feed industry to obtain feed ingredients efficiently from local sources, which reduces their carbon footprint and enhances profitability. The Organization also strengthens quality control system in feed analysis laboratories (FAO, 2011g) to generate reliable data required for making balanced and safe diets. FAO makes the feed composition data and information on safe use of feed ingredients available to countries through a user-friendly database, AFRIS - Animal Feed Resources Information System (AFRIS, 2012).

FAO is engaged in a number of other activities related animal feed that have implications for energy use. In cooperation with the International Atomic Energy Agency,

THE IMPORTANCE OF A BALANCED DIET

The shift from an unbalanced diet to a balanced diet on smallholder farms means that less feed is required per unit of animal product and increases feed use efficiency by 30 to 40 percent. More balanced diets also decrease methane production from large ruminants by approximately 15 percent and increase the yield from animals. These measures also reduce the wastage of feeds and other resources.

FAO has carried out work to develop a number of feed supplementation packages that use feed resources available on-farm and by-products from agro-industrial processes . A forthcoming FAO report, *Opportunities and Challenges in utilizing co-products of the biofuel industry as livestock feed*, documents the latest knowledge on this subject and provides guidelines and recommendations for the safe use of some co-products as livestock and aquafeeds. The Organization has more recently instigated a technical support initiative to assist smallholder livestock producers in improving the feeding management of animals using local resources.

Reducing the use of external animal feed inputs through these measures, including ongoing efforts to diversify and improve animal feed choices with local resources, make the livestock production systems more resilient, more efficient and energy-smart.

Fossil fuel consumption in livestock production systems

Meeting the growing demand for livestock products has been achieved mostly through industrialized production systems. These systems, which depend, directly or indirectly, on fossil fuel inputs, contribute slightly more than two-thirds of global production of poultry meat; less than two-thirds of egg production, and more than half the global output of pork (FAO, 2009d). Beyond the embedded energy in animal feed, energy is directly used in livestock production systems for a variety of operations, including transport to farm, storage ventilation, movement of feed from storage to pens, control of ambient environment through cooling or heating or ventilation, and animal waste collection and treatment. Energy use will depend on climate, the season and local infrastructure.

CALCULATING FUEL USE IN LIVESTOCK PRODUCTION

LEAD has produced the Livestock and Environment Toolbox. One of the tools it offers is a framework for calculating fossil fuel use in livestock systems. The framework provides a methodology for calculating direct and indirect consumption of fossil fuels for the various steps required for the production, processing, marketing and cooking of animal products. It can then be used to calculate (fossil) energy costs for animal products under different production systems.

A TOOL FOR BETTER MANURE MANAGEMENT AND ENERGY OPTIONS

LEAD has developed a decision support tool on manure management. The tool facilitates the identification, evaluation and selection of manure management options for confined pig production. The user is given a choice of manure management options based on the type of livestock housing structures, the way manure is collected and the impact that the collection has on the consistency of the manure. The management options are customized to offer alternatives for using manure to produce feed, power (biogas) or fertilization.

FAO's Livestock, Environment and Development Initiative (LEAD) has developed a methodological framework to quantify the consumption of fossil fuel energy in various animal feed crops and livestock systems, and identify potential areas for improving energy efficiency to make the systems more energy-smart (Sainz, 2003).

Livestock and energy-smart production

Livestock production systems can offer energy-smart solutions for meeting energy demands by using animal manure to produce organic fertilizers and energy from biogas. In developed countries, around 15 percent of the nitrogen applied to soils is believed to come from livestock manure (FAO, 2011f). In developing countries, the contribution can be higher, but it is not well documented. Methane from manure can be recovered using anaerobic digestion to produce biogas for cooking and other energy needs. Trends on biogas production are presented in Section 1.6. In addressing the environmental impacts of livestock production, FAO's work has focused on assessing manure management options to replace fossil fuel-dependent feeds and fertilizers, and generate energy in the form of biogas. In rural areas in developing countries, manure-based biogas can make a significant contribution to improving access to energy for domestic cooking and lighting. Beyond generating biogas to meet energy needs, the effluent from anaerobic digesters, (bio-slurry) can be used as a replacement for chemical fertilizers, such as urea. In Viet Nam, households with a biogas digester can reduce their fertilizer use by 45.5 percent

MANURE: AN ALTERNATIVE TO HIGH ENERGY FERTILIZERS

The nutrients and the organic matter in excreta are recognized as resources that can help reduce the use of chemical fertilizer in agriculture. Realizing these benefits requires carefully planning. LEAD through its Nutrient Balance Calculation Programme has developed the NuFluxAWI tool to properly advise farmers and extension officers on sustainable manure management. Based on data on the livestock production and manure management techniques, the tool calculates the nutrient excretion of livestock, as well as the amount and composition of different types of manure before and after storage, and compares the nutrients and heavy metal content in manure with the nutrient demand and uptake of crop production.

(de Groot & Bogdanski, forthcoming). A series of FAO publications have highlighted the importance of manure as a source of energy and inputs for agricultural production in developing countries (de Groot & Bogdanski, forthcoming; Campbell-Copp, 2011; Bogdanski, et. al 2010a; Bogdanski, et. al, 2010b).

2.4 FORESTRY[2]

In many parts of the world, particularly in rural communities in developing countries, wood from forests remains a very important source of energy for cooking and heating (OECD/IEA, 2010). Wood-based energy is also widely used in commercial applications such as fish drying, tobacco curing and brick baking (FAO, 1982). Total consumption of woodfuel is still increasing in much of Africa, largely due to population growth (FAO, 2008d). In rural areas of most developing countries, fuelwood is the predominant form of wood energy. Charcoal remains a significant energy source in many African, Asian and Latin American households in urban areas (FAO, 2008d).

Biomass energy resources from trees and forests vary geographically and are not evenly distributed (IEA, 2002; Reddy et al, 1997). The use of woody biomass for energy depends on a number of factors, including location, land-use patterns and cultural and socio-economic issues. Paramount to finding viable and sustainable solutions for energy access in rural and urban settings is a clear understanding of the local impacts of fuelwood collection in forests and from trees outside forests, its role in livelihoods; and its impact on forest degradation and deforestation.

The forest product industry: energy user and producer

The forest products industry, particularly the pulp and paper industry, is a major consumer of energy. In 2003, energy use by the pulp and paper sector was estimated to be 6 percent of total industrial energy use (FAO, 2006a). This sector is also often the single most important producer of electricity in some countries, with co-products and residues from pulp and paper production generating more than half of national energy needs (FAO, 2006a). In industrialized countries, particularly those with large wood processing industries, modern wood energy is used for both domestic and industrial purposes – often in significant amounts. Integrating energy generation into industrial forest operations is a competitive way of reducing risks, increasing profitability and improving forest management. It also strengthens energy security and contributes to climate change mitigation. It should be a priority area for exploration. In developing countries, especially in the tropics, opportunities exist for the forest product industry to use forest residues, and mill residues in particular, to generate energy and improve competitiveness (FAO, 2006a). New technologies are improving the economic feasibility of generating energy from wood, especially in heavily forested countries with well-established wood processing industries (FAO, 2006a).

2 This section is largely based on information from FAO's 2008 report on Forestry and Energy: Key Issues.

A Guide for Woodfuel Surveys provides recommendations on applying simple and fast methods to verify existing data and fill gaps; and build upon previous studies by means of more detailed and reliable procedures.
http://www.fao.org/DOCREP/005/Y3779E/Y3779E00.HTM

Unified Bioenergy Terminology (UBET) organizes terminology and definition of woodfuels and other biofuels used in forest and energy statistics, bioenergy balances and commercial trading operations. The aim is to enable the various institutions and organizations to exchange information more easily and to address the different problems of bioenergy utilization more clearly.
http://www.fao.org/docrep/007/j4504e/j4504e00.htm

Energy policies and woody biomass

In recent years, wood energy has attracted attention as an environmentally-friendly alternative to fossil energy, especially in industrial applications for heat and power generation and co-firing for bioelectricity generation. Trends on wood-based energy production are discussed in section 1.6 of this report. A key priority is aligning energy policies so that the production and use of woody biomass for energy is based on what can be sustainably supplied. FAO assists Member States to improve their wood energy situation in terms of social and economic viability, ecological sustainability, resource efficiency and greenhouse gas emissions. The Organization supports its Members by: (i) raising awareness of the importance of wood energy, (ii) collecting, improving and sharing accurate data, (iii) formulating, implementing and monitoring sound wood energy policies, (iv) facilitating cross-sectoral communication and collaboration, (v) and applying sustainable and resource efficient production and consumption practices.

KEY FACT

Wood residues from felling and processing operations generally constitute more than half of the total biomass removed from forests. In natural forests, up to 70 percent of the total volume may be available for energy generation. Most of this material is made up of tree crowns and other rejected pieces that are left in the forest after harvesting operations.

Wood energy is most competitive when produced as a by-product of the wood processing industry. Wood residues from forests provide possibly the greatest immediate opportunity for bioenergy generation given their availability, relatively low-value and their proximity to forestry operations. Wood residues from mills represent another, more easily accessible, source of residues. FAO regularly conducts wood energy outlook studies for different regions. The latest study for Europe presents comprehensive scenarios on wood energy development that offers decision makers from governments and industries information on the potential impacts of their decisions and provides guidance on how to prepare for future challenges (e.g. the intensive mobilization of wood resources).

An important activity for FAO in this area is its partnership with the United Nations Economic Commission for Europe (UNECE) in the development of the Joint Wood Energy Enquiry (JWEE). Currently being conducted on a two-year basis in UNECE'S 56 Member States, the JWEE is intended to allow countries to reconcile the often divergent data in energy and forests statistics. JWEE also helps to assess the developments of wood energy use and sources and track the achievement of the 2020 regional biomass-based energy targets. First results indicate that in countries with active forest-processing industries, the forest products sector is an important producer of heat and power. In addition, remainders from production, once considered as waste, are now considered as co-products with an increasing economic value. These co-products (e.g. chips, pellets, briquettes) are cost-effective sources of wood energy.

Improving the decision making process: generating information and supporting dialogue

Information is key for formulating modern, efficient and sustainable wood energy policies and programmes. Data availability on woodfuel use and production are often scattered and incomplete due to the informality of market structures. FAO collects and publishes statistical data on fuelwood and charcoal in a freely accessible database (faostat.fao.org), which will soon be exanded to include wood pellets. FAO constantly strives to systematically revise and improve data availability and quality. FAO also provides in-depth assessments at the country and regional level on the situation and development of woodfuel supply and consumption. These studies provide a clear picture of the importance of wood-based energy in the forestry and energy sectors, and offer a diagnostic tool that can be used by national, regional and international information systems. Gathering accurate and accessible data about woodfuels is a constant challenge because the vast majority of fuelwood is still produced and consumed locally used in mainly private households and often traded informally.

Wood energy is a cross-sectoral issue, requiring the engagement and strong communication between many different sectors and ministries. Adequate planning involves bringing together institutions with competencies in energy, forestry, agriculture and rural development. Patterns of woodfuel production and consumption, and their associated social, economic and environmental impacts, are site specific, which makes planning even more complex. Assessing the implications of the current patterns of woodfuel production and use and the sustainable potential of woodfuel resources, particularly within developing countries, requires a holistic view and a in-depth knowledge of the spatial patterns of woodfuel supply and demand to respond to these needs. FAO, together with the Institute of Ecology of the National University of Mexico (UNAM) have developed the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) (FAO, 2003). The methodology supports strategic wood energy planning and policy formulation through geographic representation of both woodfuel production and consumption, which allows for the identification of priority areas of intervention within a country. The methodology has been applied at various administrative levels (regional, sub-regional, national, national or city[3]) to address issues related to sustainable forest management, energy security and rural development. Some of WISDOM's findings from Serbia are presented in the box on this page. WISDOM has also supported the preparation of new national bioenergy policies in Argentina and Slovenia. At a sub-national level, WISDOM has been used in Mexico to define priority areas of intervention for a programme of efficient wood burning cook stoves and multi-purpose energy plantations. In Southeast Asia, WISDOM has been used to assess the links between poverty, subsistence energy and environment, and has contributed to the analysis and planning of urban wood energy systems.

WOOD ENERGY IN SERBIA

Below are some of the findings from a 2011 WISDOM analysis in Serbia:

- Wood energy consumption is almost 5 times higher than the value reported in the 2010 official energy balance of Serbia, accounting for about 13 percent of Serbia's total final energy consumption.
- Use of woodfuel prevented emissions of about 7 million tonnes of carbon dioxide from fossil fuels.
- Despite the much higher rate of wood consumption for energy, forests are increasing in area, with only 70 percent of the net annual increment being utilized.

2.5 FOOD PROCESSING AND POST-HARVEST LOSSES

A significant part of agricultural production goes through some degree of transformation between harvesting and consumption to make food edible and digestible. Energy is required to preserve food, reduce post-harvest losses and to extend the availability of food over a longer period. Food processing activities range from post-harvest operations and simple preservation methods, such as sun drying, to modern capital-intensive processing methods (FAO, 1997b).

In developing countries, only 30 per cent of agricultural production beyond the farm gate undergoes industrial processing as compared to 98 per cent in high-income countries (UNIDO, 2007). There is clearly untapped potential in developing countries to expand the agro-industrial sector, i.e. the component of the manufacturing sector where value is added to agricultural raw food or non-food products. Globally, sales figures of processed foods represent three-quarters of total food sales (Rabobank, 2008). The prospects for continued growth in demand for value-added food products is an incentive

3 For more detailed information on WISDOM: http://www.fao.org/forestry/energy/70070/en/

for giving increased attention to the development of agro-industries, particularly in developing countries.

Mechanical (machines, human labour, animal), electrical or heat energy is required for food processing operations. In some cases, the lack of reliable and affordable energy services limits agro-industrial development. Limited access to energy is one of the challenges that must be overcome for small-and medium-sized enterprises to establish themselves in rural areas (UNIDO/FAO/IFAD, 2008). Using biomass by-products for cogenerating heat and power represents an opportunity for food processing plants to meet this challenge. This energy is usually consumed on-site, but in some instances, excess electricity is produced that can be sold to the electricity grid to generate additional revenues (FAO, 2011a). In addition, rising energy prices affect the competitiveness of existing food processing enterprises and highlight the need for the food processing sector to reduce energy consumption. Increasing energy efficiency and integrating renewable energies can do much to improve the sustainability and economic competitiveness of food processing industries.

FAO's Rural Infrastructure and Agro-Industries Division (AGS) assists member countries to develop appropriate policies, strategies and methodologies for improving: agricultural support systems; the delivery of services and technologies for production and post-production activities; and the efficiency of food chains. The Division's current areas of work related to energy include: the global initiative on food loss and waste reduction; capacity development for improved livestock product handling, processing and value chains; guidance on appropriate food industry technologies and practices; guidance on strengthening smallholder market linkages and sustainable value chain development; and mechanization strategies and services for sustainable crop production intensification.

Within AGS Division, the Agro-food Industry group works on: appraisals to improve value addition and profitability, including potential of agro-food processing technologies and systems; support on the design, selection, operation and management of post-production facilities and services; development of strategies and practices to foster product, process and services innovation to increase value addition; assessments on technical and operational efficiency improvements, including through logistics, supply chain management, packaging, traceability and cold stores; and providing information on best practices and cost-effective technologies for small and medium-scale agro-processing enterprises for the handling, processing, preserving, transporting, and marketing of food and other agricultural products.

The Market Linkages and Value Chains group of AGS supports the implementation of value chain analysis to assess intervention options for improving value chain coordination and performance including logistical issues, such as energy, that affect value chain performance. It assists member countries on identifying post-harvest operations and technologies for the storage, cleaning, grading, sorting, handling, packaging, transporting, and marketing of fresh products and raw materials and on assessing technological options to preserve fresh product quality and reduce losses along the supply chains, including cold stores and cold chains.

Food losses and waste

A recent FAO study, *Global food losses and food waste – extent, causes and prevention* has shown that around one-third of the food we produce is not consumed (Gustavsson et al., 2011). A significant share of total energy inputs are embedded in these losses. In developing countries, most food losses occur during harvest and storage. For this reason, improving post-harvest activities in developing countries represents a priority area for increasing farmers' income. Food losses are often caused by a lack of access to energy for adequate post-harvesting operations, such as drying, storage and processing, as well as a lack of transportation and distribution. FAO is contributing to increasing the knowledge base in this area and transferring suitable post-harvest technologies for storage and drying to developing countries. As part of its work in this area, FAO has developed a web-based Information Network on Post-harvest Operations (INPhO- www.fao.org/inpho/) that provides information on a wide range of post-harvest issues. Work carried out by FAO and collaborating donor agencies on reducing post-harvest losses have led to the installation or construction of more than 60 000 metallic silos in 16 countries. More than 1 500 professionals, technicians and craftsmen have been trained in the construction and handling of these silos (FAO, 2008c). In addition, FAO has set up revolving funds and loans to facilitate the diffusion of better storage technologies and make them more accessible to small farmers who cannot afford them. FAO is now considering another critical aspect of post-harvest operations, the drying process, with the focus on looking at the energy implications for various drying technologies. The objective is to identify energy-efficient, affordable drying technologies that can work in rural settings.

KEY FACT

When food is lost, the energy used to produce the food is also wasted. Overall, the energy embedded in global annual food losses is thought to be around 38 percent of the total energy consumed by the agrifood chain (FAO, 2011a)

Small-and Medium-Scale Food processing operations

FAO supports research for, and establishment of, small-and medium-scale food processing industries. The emphasis has been on food preservation in rural and semi-urban areas, on small-scale, labour-intensive industries with low-cost available materials and on import substitution. Specific energy-related activities include a programme operating in 35 African countries to support the local construction of fuel efficient smoking ovens and the introduction of insulated storage containers that can preserve ice longer.

ASIAN FARMERS SAVING MORE RICE WITH IMPROVED SILOS

Rice post-harvest losses for Asia are estimated to have been about 14 percent in 1997, representing about 77 million tonnes and USD 7.7 billion. Most of these losses occurred as a result of inadequate storage and drying operations. FAO is playing an important role by contributing to the transfer of new post-harvest technologies for storage, including small metal silos for storing grains at the household level. The household metal silo vary in capacity from 100 to 4 000 kg. For a family of five people, a silo of 1 tonne capacity can maintain the quality and safety of rice for up to a year, contributing significantly to food security. A silo of this size costs about 55 USD and lasts between 15 and 20 years.
http://www.fao.org/rice2004/en/f-sheet/factsheet8.pdf

FAO is supporting small milk producers in setting up small-scale dairy enterprises to access new market opportunities. The Organization provides information on viable small-scale processing technologies for milk and traditional dairy products from a range of animal species in the different regions, and has carried out a study on the utilization of renewable energy sources and energy-saving technologies by small-scale milk plants and collection centres (FAO, 1992).

POWERING MILK PASTEURIZATION IN KENYA

FAO has recently field tested a low-cost, milk pasteurizing unit called the MILKPRO in Kenya. Built in South Africa, MILKPRO can handle up to 100 liters of milk an hour and costs just under 10 000 USD. At a daily outpur of 750 liters, the payback period for farmers can be as little as 12 months. The unit is operated simply by plugging into a standard single phase electrical power point, or by using a small diesel or petrol engine.
http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGAP/LPS/dairy/milkpro.htm

Utilization of food processing by-products, residues and waste for energy production

Another factor that influences the development of the agrifood industry is the need to manage industrial by-products, residues and wastes in an environmentally sound way. One management option is to use industrial wastes to produce bioenergy. FAO works to develop and adopt production systems that are productive, sustainable and leave the lightest possible environmental footprint (FAO & UNIDO, 2009). The Organization's activities in this area include investigating the recovery of waste process energy from food factories. FAO has also carried out assessment reports in China, India, Thailand and Viet Nam on the use of rice residues for energy purposes. These studies assessed the energy uses of rice straw (a field residue) and rice husk (a processing by-product). Findings in Thailand suggest that rice straw residue is not currently used for energy purposes and more than three-quarters of it is typically burnt in the field. However, as logistics is an important factor in the use of rice straw for energy generation, it may not be economically viable for areas with low rice production. Rice husk residue generated at rice processing mills presents a waste management problem for which energy production offers a potential solution. Rice husk is widely used by the Thai national power sector which uses it to generate about 140 megawatts. Trends indicate that demand for rice husk for power generation will increase. This can lead to competition among power plants as well as between power plants and other users of rice husk. Consequently, approaches used for determin how rice husk is allocated to the various competing users need to be carefully considered to avoid conflicts. The assessment also indicates that opportunities exist to upgrade power plant technology so that biomass is used more efficiently. (FAO, unpublished).

2.6 SUSTAINABLE BIOENERGY AND ENERGY-SMART AGRICULTURE

Bioenergy is energy generated from biomass, wood, energy crops and organic wastes and residues (FAO, 2004). Traditional bioenergy includes fuelwood, charcoal, dung and other residues. In some developing countries, traditional bioenergy is the most important source of energy, providing up to 95 percent of domestic energy. Modern bioenergy or biofuels refer to biomass converted to higher value and more efficient and convenient energy carriers, such as pellets, biogas, biethanol and biodiesel.

Bioenergy can contribute to mitigating climate change and diversifying energy options. It can be an important part of energy-smart food systems. Many view bioenergy as a means to enhance energy security, promote rural development and reduce greenhouse gas emissions. The development of the bioenergy sector has been further encouraged by technological advances in biomass conversion (Riso, 2008). However, bioenergy production, and liquid biofuel production in particular, carries some risks. Concerns have been raised about the sustainability of bioenergy production, especially its impact on land use, biodiversity and greenhouse gas emissions, land rights and food security.

Bioenergy covers such a broad range of fuels, feedstocks and production systems that its impacts cannot be generalized. Both the nature and the magnitude of these impacts will depend on a number of factors, related mainly to the type of feedstock and bioenergy technology; the way production is managed; and the environmental, socio-economic and policy context in which such development takes place. Sound bioenergy policy needs to be the outcome of a context-specific analysis of the technical and economic potential of bioenergy and the associated opportunities and risks.

Liquid biofuels

Currently the production of liquid biofuels made from agricultural feedstocks, such as ethanol and biodiesel, is mostly stimulated through government subsidies, tax incentives and mandates. Increases crude oil prices have also created significantly more interest and investment in liquid biofuels. However, while higher oil prices have increased returns on liquid biofuel production, the 'threshold' at which liquid biofuel production becomes profitable has also risen along with the price of agricultural feedstocks. This means that government policy support measures, particularly in OECD countries, remain an important driver in the expansion of production for most types of liquid biofuels.

In many developing countries, there is tremendous potential to increase agricultural productivity. Liquid biofuels could be a driver for realizing this potential. The new investments that liquid biofuel production could bring to agriculture should be used to improve productivity throughout the entire agricultural sector, increasing both food and energy production. To ensure that liquid biofuels contribute to food security by increasing incomes, liquid biofuel development ideally should include smallholder farmers. However, smallholder yields are often lower than those of large plantations and therefore require more land to produce the same amount of liquid biofuels. Outgrower schemes are also often less profitable as yield levels are lower and supply can be unreliable.

KEY FACT

Global ethanol production increased from about 20 billion litres in 2000 to almost 100 billion in 2010. The United States of America and Brazil are by far the largest producers. Global biodiesel production has grown from about 3 billion litres to 20 billion over the same period. Ethanol production is projected to grow to 154 billion litres by 2020, and biodiesel production is projected to grow to 40 billion litres (OECD-FAO, 2011).

Woody biomass and residues

Solid biomass has long been a key resource for generating energy. Today about 3 billion people, largely in rural areas, still rely on biomass to meet their basic energy needs for cooking and heating. Over the past years, there has been a growing interest in the use of wood and agricultural residues to generate bioelectricity and space heating. A number of countries, particularly in Europe, have introduced policies to promote the development of this market. Other countries, such as the United States of America, China and India are also starting to introduce policies to support biomass-based energy. This has resulted in increased consumption of solid biomass pellets (for heat and power), as well as the use of biomass in combined heat and power plants and in centralized district heating systems. An estimated 62 GW of biomass power capacity was in operation by the end of 2010 (REN21, 2011). A rapid increase in demand for residual biomass feedstock can generate competition between traditional uses and modern bioenergy. In most developing countries, woody biomass and residues represent a primary source to meet energy needs, especially for cooking. Greater competition for this resource can have an impact on the livelihoods of people who depend on these resources for their energy security. Furthermore, higher demand for residues may also harm the environment as it can lead to over-exploitation of forests and forest resources and more intense use of agricultural and woody residues. Understanding the potential availability of woody biomass feedstock and their existing uses is crucial to ensure that development of modern bioenergy production is sustainable.

THE GROWING MARKET FOR WOOD PELLETS

The ***UNECE/FAO Forest Products Annual Market Review for 2010-2011*** noted that the demand for woody feedstock for renewable energy generation has fostered the emergence of a true global trading market. International trade has formalized into the creation of a wood-energy commodity contract exchange market in a joint effort between APX-ENDEX and the Port of Rotterdam. Large investments in industrial pellet production capacity in North America and the Russian Federation have been made under expectations of a continuously growing demand. Nonetheless, demand is still dependent on public policy commitments in the form of renewable energy mandates, financial support to energy production and consumption, and other policy tools.
http://www.unece.org/forests-welcome/areas-of-work/forestsforestproductsmarketswelcome/forestsfpmoutputs/forestsfpmannualmarketreviews/2010-2011.html

Biogas

Biogas generated from manure and agro processing materials can be produced in a wide variety of scales, such as small-scale digesters, plug-flow digesters, covered anaerobic lagoons or advanced digesters. It can be used for different purposes in a variety of settings, including in homes for cooking and lighting and in commercial establishments to generate heat or electricity or both. Perhaps because of this large variety of different systems, there are currently no reliable global figures on the amount of biogas produced. Country reports however have shown an increasing interest in

KEY FACT

China leads the world in the number of household biogas plants (REN 21, 2011). By the end of 2009, 35 million household biogas schemes had been installed throughout the country (Hao 2010, cited in Bogdanski et al. 2010b). Experts also estimate that there are 57 000 medium and large-scale biogas digesters in livestock and poultry farms in the country (Hao 2010, cited in Bogdanski et al. 2010b). In Germany, Europe's market leader in terms of biogas, there were 5 905 biogas plants in operation in 2011, mostly based on corn (Fachverband Biogas, 2011). In the United States of America, there were about 176 anaerobic digesters in 2011 (U.S. EPA, 2011).

biogas technologies. Small-scale biogas digesters, for instance, are found predominantly in Asia, where their primary purpose is often wastewater treatment. The production of energy and biofertilizer is a welcome by-product. According to International Renewable Energy Agency (IRENA), there is also a growing practice to purify biogas and inject it into pipelines to replace natural gas in combined heat and power plants throughout Europe (REN21, 2011).

However, while biogas production is increasing and the benefits are promising, careful consideration must be given to the type of biomass feedstock used, its availability in light of existing uses and the potential social, economic and environmental tradeoffs between these different uses.

Bioenergy, sustainability and food security

To date, the rush to develop bioenergy alternatives to fossil fuels has tended to take place in the absence of a proper understanding of the full costs and benefits of bioenergy. The impacts of bioenergy, and specifically biofuels, on food prices, economic growth, energy security, deforestation, land use and climate change are complex and multi-faceted. These impacts will vary widely depending on the feedstocks, the production methods and the location. In addition, consumers and producers will be affected differently by these impacts. This complexity makes it difficult to draw general conclusions about the net impacts of bioenergy for developing countries and for particular segments of the population. The successful establishment and expansion of bioenergy production in developing countries needs to be based on sound technical, environmental and economic information. This will allow stakeholders to identify the sustainable bioenergy production options best suited for their particular context. This information should address issues of land suitability, water availability and economic competitiveness, as well as the socio-economic costs and benefits related to food security, economic growth and poverty reduction.

SUSTAINABILITY INDICATORS FOR BIOENERGY

FAO, as host of the GBEP Secretariat has significantly contributed to GBEP's work on sustainability indicators for bioenergy. GBEP's 24 indicators were agreed upon in May 2011 by 23 countries and 13 international organizations, with the involvement of a further 22 countries and 10 international organizations as observers. The sustainability indicators and their accompanying methodology sheets provide policy-makers and other stakeholders with a tool that can support the development of national bioenergy policies and programmes and monitor their impact. They can also help interpret and respond to the environmental, social and economic impacts of bioenergy production and use. The indicators cover a range of issues including greenhouse gas emissions, biological diversity, the price and supply of a national food basket, access to energy, economic development and energy security.

An integrated approach is required to address the multiple concerns raised by bioenergy and biofuels in developing countries. The approach needs to include:

- an in-depth understanding of the current bioenergy situation and related opportunities and risks, as well as synergies and trade-offs;
- an enabling policy and institutional environment, with sound and flexible policies and effective means for their implementation;
- policy instruments to enforce good practices by investors and producers to reduce risks and seize opportunities; and
- proper impact monitoring and evaluation and policy response mechanisms.

FAO'S Sustainable Bioenergy Toolkit: Making Bioenergy Work for Climate, Energy and Food Security

To promote an integrated approach to bioenergy, and particularly biofuel, development, FAO has elaborated a set of instruments that make up the 'Sustainable Bioenergy Toolkit'. The toolkit consists of the five principle elements listed below.

- The UN-Energy Decision Support Tool (DST) for Sustainable Bioenergy.
  Prepared jointly by FAO and UNEP, DST proposes a step-by-step guidance for strategy formulation and investment decision-making processes. It includes a repository of technical resources and links to existing tools, guidelines and information resources. An overview of DST is available at: http://www.fao.org/docrep/013/am237e/am237e00.pdf
- The Bioenergy & Food Security (BEFS) project
  The BEFS Project has developed an analytic framework to support countries develop and implement bioenergy policies that safeguard food security and are aligned with national socio-economic policy objectives. BEFS web site: http://www.fao.org/bioenergy/foodsecurity/befs/en/
- The Bioenergy & Food Security Criteria & Indicators (BEFSCI) project
  The BEFSCI project has developed a set of criteria, indicators, good practices and policy options for sustainable bioenergy production that foster rural development and food security. BEFSCI Project web site: http://www.fao.org/bioenergy/foodsecurity/befsci/en/.
  - Integrated Food Energy Systems (IFES) are one type of good practice being promoted by FAO. An overview of *Making Integrated Food Energy Systems Work for People and Climate* can be found at: http://www.fao.org/docrep/013/i2044e/i2044e.pdf.
- Bioenergy Environmental Impact Assessment Framework (BIAS)
  BIAS gives a brief overview of the main environmental issues related to bioenergy and examines methodological options, knowledge platforms and databases. It also identifies their limitations for evaluating environmental impact of bioenergy projects and policies. Issues covered include water, soil, biodiversity, greenhouse gas emissions, land use change and data and knowledge gaps.

- Global Bioenergy Partnership (GBEP)
  GBEP, whose secretariat is hosted by FAO, has developed a set of sustainability indicators for bioenergy (see box)
  GBEP web site: http://www.globalbioenergy.org/.

Policy and legal support for sustainable bioenergy development

A sound legal and regulatory framework is essential to ensure that socio-economic and environmental sustainability is taken into consideration in the production, promotion and use of bioenergy. Because bioenergy is a cross-sectoral issue encompassing agriculture, forestry, the environment, water and land management, and trade, an interdisciplinary approach is needed to design legal and regulatory frameworks. To establish a sound regulatory framework, legislators and policy-makers need to be fully aware of the range of implications in all sectors. The FAO Development Law Service of the Legal Office and the Energy Division in the Natural Resources Department are collaborating to provide Member States with assistance that integrates the various technical, policy and legal issues needed to ensure sustainable bioenergy development.

The FAO Development Law Service has published two legislative studies on bioenergy development that bring attention on the importance on legislative and regulatory aspects, and help identify areas of law that may affect bioenergy regulation and design key elements of national bioenergy laws. The first study, *Recent Trends in the law and policy of bioenergy production, promotion and use*, sought to stimulate discussion on the features of national legal frameworks for bioenergy, particularly in developing countries. A follow-up study, *Case studies on bioenergy policy and law: options for sustainably*, provided an in-depth review of bioenergy and bioenergy related legislation in Argentina, Brazil, Estonia, Mexico, Tanzania, Thailand and the Philippines. This study identifies legal tools that can significantly contribute to the economic, social and environmental sustainability of bioenergy production.

2.7 FAO'S BIOENERGY SUPPORT TO COUNTRIES

Africa

- In Tanzania, the BEFS Project analysis helped identify available suitable areas for bioenergy crop production that would not compete with existing food crops. Five crops were assessed: sugar cane, cassava and sweet sorghum for ethanol; and jatropha and palm oil for biodiesel. The assessment took into account rainfed conditions and four other agriculture management configurations. It found that under rainfed conditions palm oil and sugar cane would not be viable. From a production cost point of view, cassava is the most cost-competitive crop and is smallholder based. Sugar cane-based ethanol could also be produced competitively under a 40-60 smallholder-estate arrangement.

- Using the approach developed by the BEFS Project, FAO has been working in Sierra Leone since 2010 to foster inter-institutional dialogue on bioenergy and food security. In 2011 the Bioenergy and Food Security Working Group was established. It has been an integral mechanism for facilitating the coordination among representatives from each of the relevant ministries and technical experts from different sectors. The Working Group has also provided a forum for discussing a range of issues related to bioenergy, including food security, natural resource management and land tenure. To date, the focus of the FAO's support to the Working Group has been on raising awareness about the potential positive and negative aspects of bioenergy development on and food security; and collecting data and conducting baseline analysis of the positioning of Sierra Leone for bioenergy development. Over the course of 2012, FAO will help the working group develop guidelines for sustainable bioenergy investments. The guidelines, based on input from local communities affected by large-scale investments, will be prepared in collaboration with FAO's legal department to determine how legislation can support the implementation of the guidelines and foster sustainable bioenergy investment.
- In 2012, the Southern African Development Community (SADC) Secretariat and FAO organized the BEFS Capacity Development Forum in Johannesburg, South Africa. The Forum gave participants from 12 of the 14 SADC member countries the opportunity to reflect on the current status of bioenergy development. The Forum also improved the capacity of policy makers to evaluate bioenergy developments at the national and regional level using the BEFS analytical framework and the tools and guidance provided by the BEFSCI project.
- FAO has supported Congo Brazzaville in major policy orientation and preparing an action plan related to sustainable bioenergy development (2010-2011)
- In 2012, GBEP, and the Economic Community of West African States (ECOWAS) Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) organized the ECOWAS Regional Bioenergy Forum in Bamako, Mali. Part of a series of GBEP initiatives to promote the sustainable production and use of renewable bioenergy for cooking and other energy needs in West Africa. The Forum brought together over 200 delegates, speakers, and participants from 25 countries to discuss the benefits and challenges of modern bioenergy. The meeting initiated a regional dialogue and peer-to-peer learning to support ECOWAS Member States in developing regional and national bioenergy strategies.

Asia

- FAO is launching a new regional programme on bioenergy and food security to assist the Association of Southeast Asian Nations (ASEAN) Secretariat and ASEAN Member States ensure that bioenergy contributes to more effective energy services with minimal or no impact on food security and the environment. Using the BEFS analytical framework, the programme will address critical regional gaps in understanding about the impact of regional bioenergy policies on food systems and food security. In developing bioenergy strategies, a range of supplementary activities will be carried out at the national and regional level, including: capacity building measures to promote sustainable, food secure and climate-smart bioenergy systems and technologies; and the strengthening of national bioenergy policy bodies.

- In South Asia, in 2011, FAO organized national-level capacity building exercises on the BEFS analytical framework and conducted preliminary assessments of bioenergy development in Bhutan, India, Nepal and Sri Lanka. FAO will organize a sub-regional forum in 2012 to exchange experiences in bioenergy development in South Asia and consider follow-up actions at the national and regional levels.
- In the Greater Mekong Sub-Region, FAO in partnership with the Asian Development Bank is organizing two sub-regional forums on Bioenergy and Food Security and Household Bioenergy. These forums continue FAO's efforts to promote regional dialogue on harmonizing relevant policies, criteria and standards for investments related to bioenergy and food security; and gather knowledge and assemble best practices about bioenergy standards, technologies and business models.
- In the Lao People's Democratic Republic, FAO is providing financial and technical support to the Energy and Management Conservation Office (EMCO) of Khon Kaen University to develop an energy needs assessment toolkit and guidelines for implementation of gender-sensitive, community-scale, integrated food and energy systems for rural communities. This work is a component of EMCO's 'Energy Self-Sufficiency Village' and supported by the Energy and Environment Partnership (EEP) Mekong initiative. It is hoped that the materials developed by EMCO with FAO's support will be made available for future application in other community-based energy projects in the region.
- FAO is joining other UN partners to establish 'UN Energy: Asia-Pacific'. This regional group will work to coordinate more effective support to countries on a range of issues, including energy access in rural areas and energy efficiency in agriculture and other sectors.

Latin America

- FAO's Regional Office has established a network of 12 country focal points responsible for providing updates on the bioenergy status in their country. The information is used to analyse both the national situation and regional bionergy developments. The focal points provide valuable feedback about gaps and needs, which has allowed the Regional Office to organize specific activities and prepare projects based on the needs of each country.
- In collaboration with the Federal University in Viçosa Brazil, the Regional Office has developed software, Biosoft, to carry out economic and social evaluations for the development of vegetable oil and biodiesel projects. Biosoft training events have been held in Mexico, Chile, Argentina, Brazil and Central America; others are planned for Peru and Bolivia.

- In coordination with the UNDP and the Global Environment Facility (GEF), the Regional Office has commissioned a study to prepare a biogas manual. The Regional Office has also organized a series of international seminars and expos on bioenergy policies, food security and development.
- In Argentina, a three year project under FAO's Technical Cooperation Programme has been developed to support the country's efforts to promote the production of biomass-energy at local, provincial and national levels.
- In Bolivia a bioenergy and food security project under FAO's Technical Cooperation Programme is being prepared to assist the country assess the potential for producing energy from woody biomass and residues. The project will also consider legal frameworks and other technical and socio-economic implications of developing biomass-energy projects in the country. In addition, it will generate knowledge on wood energy supply and demand to enhance the national energy balances and modeling for long-term energy planning. The project results will also support the countries efforts to establish legislation for renewable, non-conventional energies.
- Under the BEFSCI Project, a national bioenergy and food security forum was held in Peru in 2012. During the forum BEFSCI supporting tools and components were presented. Discussions were also held with representatives from provinces on the assessments needs to support the development of bioenergy sector in each region. The discussion focused on the development of a national biogas plan and implications for agricultural productivity and energy security in isolated areas.

2.8 ENERGY, AGRICULTURE, GENDER AND ECONOMICS

The recent increase in food prices strengthened the perception that the global food system is inextricably tied to the price of oil (Schmidhuber, 2006). There is no single cause for the food price increases, but there is agreement that rising energy prices were a contributing factor (Heady and Fan, 2010). Energy and food systems are linked in two distinctive ways: the agricultural sector is an energy consumer; and it is also an energy producer through bioenergy. As mentioned earlier, agriculture has become increasingly reliant on chemical fertilizers derived from fossil fuels, natural gas and diesel-powered machinery (FAO, 2011a). Food storage, processing and distribution are also often energy-intensive activities. Higher energy costs, therefore, have a direct and strong impact on agricultural production costs and food prices (FAO, 2011a).

The economic research and policy work at FAO analyses overall economic development, poverty reduction and food security from a number of thematic perspectives, including direct and indirect impacts of energy markets. This work supports the aim of the ESF Programme to assist member countries in the formulation of energy-smart polices. In this regard, understanding the economic implications of a shift towards energy-smart food systems at the national and global level is necessary to identify the most appropriate policy mechanisms that maximize benefits and minimize risks.

OECD-FAO 2011 Agricultural Outlook highlights the fact that increasing links betewen energy and agriculture through inputs such as fertilizer and transportation, and biofuel feedstock demand, are transmitting price volatility from energy markets to agricultural markets.
http://www.fao.org/fileadmin/user_upload/newsroom/docs/Outlookflyer.pdf
Current world fertilizer trends and outlook to 2011/12 Prepared by FAO, in collaboration with experts from the Fertilizer Industry Working Group, this publication looks at fertilizer production and trade, and provides five-year forecasts of world and regional fertilizer supply and demand balances, incorporating possible impacts of biofuels on global fertilizer consumption.

A key element of FAO's work in this area is the OECD-FAO Agricultural Outlook, a joint collaboration between OECD and FAO that assesses the potential influence of agricultural and trade policies on agricultural markets in the medium term. This is done within the framework of the AGLINK-COSIMO model, which covers global annual supply, demand and prices for the main agricultural commodities produced, consumed and traded throughout the world. The model provides a consistent analytical framework to carry out the agricultural outlook and forward-looking policy analysis through the execution of alternative scenarios. The model captures the energy effects in agricultural production by considering the contribution that energy has in production costs through construction of a real price index using a GDP deflator, the world oil price and the exchange rate. The production of biofuels (ethanol and biodiesel) is modeled endogenously and is represented as a function of commodity prices, GDP and/or time trend variables, as well as important policy variables such as subsidies, credits, tariffs and mandates. This allows for a scenario analysis of the impact of increased bioenergy demand and policy changes on agricultural markets. FAO, in collaboration with experts from the Fertilizer Industry Working Group dealing with fertilizer production and trade, provides five-year forecasts of world and regional fertilizer supply and demand balances. The outlook on fertilizer incorporates the possible impact of biofuels on global fertilizer consumption.

The State of Food and Agriculture 2008 focused on analysing the prospects, risks and opportunities posed by biofuels. The report found that while biofuels will offset only a modest share of fossil energy use over the next decade, they will have much bigger impacts on agriculture and food security. Biofuels as a new and significant source of demand for some agricultural commodities contributes to higher prices for agricultural products. Higher prices can pose a serious threat to food security commodities in general. However, given appropriate policies and investments, high prices can trigger a response in terms of increased agricultural production and employment, which could contribute to poverty alleviation and improved food security over the longer term.
http://www.fao.org/docrep/011/i0100e/i0100e00.htm

Historically, FAO's long-term projections, presented in reports such as *World Agriculture Towards 2050*, have considered the biofuel production in a relatively limited way. However, the forthcoming revision of the *World Agriculture Towards 2030/50* includes a base case for biofuel production that assumes fulfillment of current policy obligations around the world with modest growth beyond those policies. Model systems under development, both partial equilibrium and general equilibrium models, will be used to examine other paths for biofuels including, but not limited to, those driven by changing oil prices.

Gender and Energy

In many developing countries, women are generally responsible for gathering woodfuel. These women are particularly affected by the lack of accessible and affordable energy services for cooking food and heating (FAO, 2006b). In areas with limited biomass resources, women walk long distances to find fuelwood. A study in Malawi found that, due to deforestation, elderly women had to walk more than 10 km a day to collect fuelwood. In Tanzania, women spend on average 300 hours a year gathering fuelwood; in Zambia the average is 800 hours. In East Africa, fuel wood scarcity has reduced in the number of meals cooked in poor households (FAO, 2011h). Beyond the physical demands that fuelwood collection places on women, the time spent collecting fuelwood limits their opportunities to engage in other productive income-generating activities. When young girls are taken out of school to help their mothers in fuelwood collection activities, the cycle of illiteracy and poverty is reinforced (Soma, 2005). Difference in responsibilities of men and women also mean that women suffer more from health impacts of wood energy use and production. Solid fuels, such as wood and dung, are used in open fires or in traditional stoves inside homes, which are often inadequately ventilated. The smoke creates high levels of indoor pollutants that pose significant health risks for women preparing meals and for small children.

Gender and Equity Issues in Liquid Biofuel Production: Minimizing the Risks to Maximize the Opportunities explores the potential gender-differentiated risks associated with the large-scale production of first-generation liquid biofuels developing countries. The study analyses hypothetical risks and identifies research and policy strategies to address them, in order to maximize the opportunities offered by biofuels production.
http://www.fao.org/docrep/010/ai503e/ai503e00.html

In recent years, questions have been raised about the different ways modern bioenergy production, especially liquid biofuels, affect males and females. The sector may offer new economic and employment opportunities for rural populations, but it may also create risks in terms of unfair conditions of employment, health and safety, child labour and forced labour (FAO, 2008g). These opportunities and risks tend to affect men and women differently (FAO, 2008g). This is due mainly to gender-differentiated access to both physical and economic assets such as land, natural resources, agricultural equipment and inputs, and credit. For example, one option suggested for bioenergy crop production is to grow these crops on marginal lands. However, marginal lands are particularly important for women, who traditionally use these lands for growing crops for domestic consumption (FAO, 2008g).

KEY FACT

According to the World Health Organization, in 2002 the use of solid fuels for cooking caused nearly 800 000 deaths among children and more than 500 000 deaths among women (WHO, 2006).

Although female-headed households generally represent a smaller share of the population, they are a vulnerable segment of the population that is hard hit by increases in prices of key food staples. By increasing demand for crop production, biofuel production can lead to higher food prices, making it more difficult for female-headed households to access food. However, by supporting an inclusive development path, under the right conditions women can benefit from the development of this new industry.

FAO's work focuses on mainstreaming gender into rural development, including energy planning and decisionmaking (FAO, 2006b). This requires, as a first step, the collection of relevant data to better qualify and quantify the relationship between energy and gender under different situations. For example, information is needed about how men and women consider their energy needs and what actions they perceive as most beneficial (FAO, 2006b). FAO's work provides a foundation to ensure that the gender issues are incorporated into assessments about how the impacts from energy production and energy use may impact men and women differently. Of particular interest is the production and use of gender-disaggregated data and gender-sensitive indicators to help promote greater gender equity and empowerment of women and enhance the effectiveness of interventions related to energy and agriculture. Also, the

The main food staple in Cambodia is rice. Bioenergy may not directly influence the price of rice, but if large areas of land are used for bioenergy crop production with knock-on effects on rice production or rice exports, this could result in implications for the price of rice. The analysis published in ***Bioenergy and Food Security: Household Level Impact of Increasing food Prices in Cambodia*** identifies the segments of the population that are most vulnerable to a rice price increase. The analysis differentiates impacts between female-headed and male-headed households and shows that gender of the household head matters. Urban female-headed households lose from a price increase while rural female households gain but less than male-headed households.
http://www.fao.org/docrep/012/i1664e/i1664e00.pdf

quality of jobs generated through these interventions should be attentively evaluated and monitored, for both women and men as well as adults and youth, to ensure that the green jobs generated satisfy the International Labour Organization (ILO) of decent work[4].

ENSURING GENDER IS TAKEN INTO ACCOUNT IN BIOENERGY DEVELOPMENT

In developing a set of criteria, indicators, good practices and policy options on sustainable bioenergy production that foster rural development and food security, the BEFSCI Project gave due consideration to the gender-related aspects of modern bioenergy development. Specific sections on gender equity were drafted as part of the BEFSCI Compilation of Good Socio-Economic Practices in Modern Bioenergy Production and in the Compilation of Tools and Methodologies to Assess the Sustainability of Modern Bioenergy. With the BEFSCI Operator Level Food Security Assessment Tool, data can be inputted – and results generated – in a gender-disaggregated way.

http://www.fao.org/docrep/015/i2599e/i2599e00.pdf

FAO activities generate data and information to fill knowledge gap related to energy and gender, particularly in developing countries. This data will inform the economic and gender work done by FAO to strengthen the assessment of the role that energy consumption and energy production from bioenergy may play in agriculture, food security, decent work, gender and poverty reduction. The ESF Programme offers a framework to assess economic and gender considerations in energy planning along the entire agrifood chain.

2.9 CLIMATE-SMART AGRICULTURE

Climate change poses many threats to agriculture, including a decline in agricultural productivity, greater instability in production and a reduction in incomes in areas of the world that already have high levels of food insecurity and limited means of coping with adverse weather conditions. Transforming agriculture to feed a growing population in the face of a changing climate without degrading the natural resource base will not only achieve food security goals but also help mitigate the negative effects of climate change. FAO along with other partners is promoting climate-smart agriculture, forestry and fisheries that can sustainably increase productivity; support adaptating to climate change; build resilience to shocks and variability; reduce and remove greenhouse gases; and enhance the achievement of national food security and development goals.

4 According to the ILO's definition, decent work involves opportunities for productive work that delivers a fair income, security in the workplace and social protection for families; better prospects for personal development and social integration; freedom for people to express their concerns, to organize and participate in the decisions that affect their lives; and equality of opportunity and treatment for all women and men (ILO,2006. Decent Work FAQ: Making decent work a global goal).

Building on field case studies, ***Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*** outlines a range of practices, approaches and tools aimed at increasing the resilience and productivity of agricultural production systems while reducing and removing greenhouse gas emissions. This report highlights practices related directly or indirectly to energy.
http://www.fao.org/fileadmin/user_upload/newsroom/docs/the-hague-conference-fao-paper.pdf

The priority of climate-smart agriculture is to strengthen livelihoods and food security through the improved management and use of natural resources, and the adoption of appropriate methods and technologies for the production, processing and marketing of agricultural goods. To maximize the benefits and minimize the tradeoffs, climate-smart agriculture takes into consideration the social, economic, and environmental context where it will be applied, assesses the resource and energy implications and adopts a integrated land based approach using principles for ecosystem management and sustainable land and water use (FAO, 2010a). The ESF Programme is an essential component of climate-smart agriculture as it assesses the energy implications of climate-smart interventions.

KEY FACT
Agriculture, together with land-use change and forestry activities, contribute approximately one-third of the greenhouse gas emissions (IPCC, 2007). The technical mitigation potential of agriculture is high, the equivalent of 5.5-6 billion tonnes of carbon dioxide per year by 2030 (IPCC, 2007), and 70 percent of this potential could be realized in developing countries where agriculture is generally practiced by smallholders (FAO, 2009e).

Energy-smart practices are also climate-smart

FAO in collaboration with other partners is currently preparing a sourcebook on climate-smart agriculture. The Sourcebook will clearly articulate the concept of climate-smart agriculture and describe how it addresses the objectives of food security and livelihoods, climate change adaptation and mitigation. All of these objectives may not be able to be achieved to the same degree and at the same time, so it will necessary to set priorities and limit trade-offs. The Sourcebook will also help stakeholders to plan climate-smart production systems and landscapes by providing an overview of key principles, areas of interventions and good practices in management and governance. Opportunities for reducing energy dependency while addressing climate change will also be included in the Sourcebook. A number of climate-smart agriculture practices, particularly those related to sustainable intensification production, can lead to a

BECOMING ENERGY AND CLIMATE-SMART IN WEST AFRICA BY REDUCING PESTICIDES

The Integrated Production and Protection Management programme (IPPM) in West Africa was established to reduce pesticide use in the region to the lowest level possible. A review of results indicates that median yields increased for all crops. The reduction of pesticide has shown that on average, farmers involved in this type of programme have substantially lowered input costs and increased yields and net incomes. This type of approach shows that productivity increases can be realized with more efficient management of external inputs resulting in reduction of indirect energy uses and contributing to climate-smart agriculture while also offering economic benefits for farmers. This approach is now being replicated in a number of other countries through a GEF funded project.
http://www.fao.org/fileadmin/templates/agphome/documents/IPM/WA_IPPM_2011.pdf

reduction in the use of external fossil-fuel derived inputs. *Integrated Pest Management* IPM, an ecological approach to manage pests through the use of biodiversity and biological processes, not only improves crop production, builds resilience, but also reduces the need for fossil fuel-based pesticides (FAO, 2011a). Likewise the application of low-carbon energy technologies contributes to climate-smart agriculture objectives. For example, the use of solar concentrators or ovens by cooperatives or small farmers associations can create new opportunities for food processing in rural areas and extend the shelf life of perishable products to avoid food losses. Becoming energy efficient increases climate resilience, reduces energy consumption and lowers greenhouse gas emissions.

INTEGRATED FOOD–ENERGY SYSTEMS (IFES)

Integrated Food Energy Systems (IFES) can contribute to local adaptation to climate change and provide options for access to sustainable energy (FAO, 2010b). IFES are based on the integration of cropping, livestock, forestry and fishery systems into energy production systems. These integrated systems provide opportunities for increasing overall production and economic resilience for farmers while at the same time providing basic energy requirements. The FAO publication, Making Integrated Food-energy Systems Work for People and Climate: An Overview draws some lessons on constraints to scale up IFES and opportunities to overcome and highlights the links between climate-smart and energy-smart interventions.
http://www.fao.org/docrep/013/i2044e/i2044e.pdf

BIOMASS USED TO DRY SPICES

The FAO publication, ***Small Scale Bioenergy Initiatives*** provides an overview of how wood biomass is being used to dry spices. The fuelwood, a by-product of pepper plants, is sold to dryer operators. This innovative scheme has diversified income streams and has increased revenue. It has also increased the resilience of small farmers who are now able to dry and preserve the spices. They also get a higher price for mature spices.

http://www.fao.org/docrep/011/aj991e/aj991e00.htm

Renewable energies contribute to climate-smart objectives

The introduction of renewable energies to substitute for fossil fuels in food production and processing contributes to efforts to mitigate climate change. Renewable low-cost energy technologies suitable for the rural poor have been developed and are beginning to show successes. Examples of these technologies include, improved biofuel cookstoves; low-cost solar pasteurizing units; pumps for irrigation; micro-hydro electrical generators suitable for agro-processing; and efficient manually-operated water pumping and agro-processing equipment. The potential for bioenergy use to reduce greenhouse gas emissions is the subject of much debate, particularly concerning the use of liquid biofuels and their impacts on food security.

Energy access and smallholder producers

The links between energy access and climate-smart agriculture objectives are twofold. First, biomass-based fuels, such as fuel wood are widely harvested in a non-renewable fashion and are combusted inefficiently in traditional stoves. Supporting the transition to more efficient and cleaner energy sources to address energy insecurity contributes to a clean development path and climate change mitigation. In particular, the promotion of low-carbon technologies, such as solar energy for food drying, to reduce pressure on forested areas, improved or new technology for firewood use and charcoal making and promotion of the use of energy-saving equipment among others. In addition, a decrease in agricultural productivity due to climate factors, such as pest outbreaks and less precipitation, will reduce the amount of biomass available for households to produce energy. Climate change vulnerability can reduce access to energy for the impoverished communities already struggling to meet their basic energy needs. Biomass is – and is likely to remain at least in the short to medium term–a major source of energy for many people in developing countries. There is a need to identify energy options to reduce the vulnerability of these households while ensuring their energy and food security.

2.9.1 The Mitigation of Climate Change in Agriculture (MICCA) Programme

The Mitigation of Climate Change in Agriculture (MICCA) Programme, established by FAO with the support of the governments of Finland, Germany and Norway, generates information and data on greenhouse gas emissions and mitigation options in the agriculture sector. It's objective is to help realize the substantial mitigation potential of agriculture, especially for smallholders in developing countries. The MICCA Programme supports the Climate-smart Agriculture Programme's efforts to address, in an integrated way, climate change mitigation, climate change adaptation and food security. In focusing on mitigating climate change in agriculture in developing countries, the MICCA Programme recognizes that any changes in practices must contribute to increased productivity and improve the resilience of farming systems.

Among its activities, the MICCA Programme is collaborating with FAO's Animal Production and Health Division to carry out a variety of activities including: emissions assessments of a range of animal food chains to determine their contribution to greenhouse gas emissions; evaluatations of how different livestock species and products contribute to emissions; and the identification of emission hotspots in the production chain. This work provides a starting point for understanding the sector's mitigation potential and identifies where to target mitigation interventions and what are the implications for implementing them. This process is being done using a life cycle analysis approach. A life cycle assessment of the dairy sector has already been completed (FAO, 2011i). The life cycle analysis work is complemented by biophysical and economic analysis of mitigation options to identify the most effective approaches, in terms of cost and technical feasibility, and support policy decision-making processes.

Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment examines the entire life cycle of dairy products from the production and transport of inputs (fertilizer, pesticide and feed) for dairy farming, transportation of milk off-farm, dairy processing, the production of packages, and the distribution of products to retailers. The assessment shows that in developing countries there are many opportunities for improving the performance of the livestock sector, reducing its greenhouse gas emissions and making it more environmentally sustainable. Among the recommendations included are the emission reduction potential from choosing energy sources with lower emission levels and the significant potential for anaerobic digestion of manure to produce biogas through proven technologies.
http://www.fao.org/agriculture/lead/themes0/climate/emissions/en/

Another component of the MICCA Programme identifies agricultural practices and technologies that faster food security, adaptation and mitigation to leverage win-win situations. The MICCA Programme is also carrying out pilot projects investigating agricultural practices and their contribution to climate change mitigation. The goal of these projects is to generate quantifiable evidence that climate-smart agricultural practices can mitigate climate change, increase agricultural production, improve farmers' livelihoods and make local communities better able to adapt to climate change. In Kenya's Rift Valley, the MICCA Programme pilot project is being undertaken within the framework of the East Africa Dairy Development Project (EADD), a regional industry development programme led by Heifer International. In this pilot project, the MICCA Programme, in close collaboration with the World Agroforestry Centre (ICRAF) and smallholder dairy producers, is using a life cycle analysis and other approaches to propose and test technical alternatives practices to reduce the climate change 'footprint' of the dairy industry. As part of its work to support farmer in raising climate-smart cattle and to improve the overall greenhouse gas balance of the farming systems, the pilot project is looking at ways of enhancing fodder production and improving manure management to produce fertilizer and biogas, along with introducing energy-saving cookstoves. In the United Republic of Tanzania, to reduce pressure on forests, decrease deforestation and improve livelihoods, the MICCA Programme pilot project is working with CARE in hillside communities to increase the use of CA practices and combine them with agroforestry. As part of their activities, the project team will develop a menu of climate-smart practices suitable to local conditions and work with families to install the energy-saving cookstoves to reduce the need for fuel wood.

CHAPTER 3

WHAT NEXT - BUILDING PARTNERSHIPS FOR A GLOBAL PROGRAMME ON "ENERGY-SMART FOOD FOR PEOPLE AND CLIMATE"

FAO's expertise on the specific components of the agrifood chain provides a solid foundation for supporting the implementation of the ESF Programme. It is also important to recognize that there are some specific areas along the agrifood chain in relation to energy (e.g. transportation, distribution and food preparation) that are outside of the FAO mandate. There is also a lack of in-house expertise in certain specialized areas, such as solar, wind and geothermal energies. These gaps will need to be filled if we are to realize the ESF Programme's full potential. A major effort of the Programme is to build a collaborative framework in order to have all the necessary expertise and specialized knowledge on board.

The ESF Programme is part of major international initiatives. It is an essential component of climate-smart agriculture and will make a major contribution to the 2012 UN International Year of Sustainable Energy for All and the Green Economy with Agriculture Programme in the context of Rio+20. The Programme also contributes to the broader UN Sustainable Energy for All (SEFA) Initiative by focussing on the energy issues in relation to the agrifood chain. SEFA's three interlinked objectives are to ensure universal access to modern energy services; double the rate of improvement in energy efficiency; and double the share of renewable energy in the global energy mix. The objectives of the ESF Programme are to improve energy efficiency, increase the use of renewable energy along the agrifood chain and improve energy access through food and energy systems. These objectives complement those of the SEFA.

The ESF Programme will focus on country action and provide international support functions. Operating on these two levels, the ESF Programme will initially cover the following core sets of activities:

1. knowledge management, including knowledge generation, dissemination and outreach at international and country levels;

2. capacity building, including technical and policy-level capacity building with international partners and at country level; and

3. country support through the implementation of the country-level analysis and support for the development of national ESF strategies.

Addressing the energy-water-food-climate nexus along the agrifood chain is a complex challenge. It requires a number of diverse technical, institutional and policy issues at the global, national and local level. While FAO and other organizations have been working on the ESF Programme for some time, scaling up the Programme will require more collaborative learning and action among other UN agencies, multilateral organizations, donors, policy-makers and the private sector. This is critical for the success of the ESF Programme. For this reason, the Programme will establish a collaborative framework with relevant United Nations organizations, including the UNDP, the UNEP, United Nations Industrial Development Organization (UNIDO), the International Fund for Agricultural Development (IFAD) and with other partners, including, among others, the World Bank, the International Renewable Energy Agency (IRENA) and the IEA. Government organizations (such as USAID), research institutions, and non-governmental organizations will also be included in the collaborative framework. This approach will accelerate information sharing and mobilize knowledge and action for addressing the energy-food security-water-climate nexus in an integrated manner. It will also help bring together actors from across the agriculture sector, (ie. fishing, forestry, livestock and water) with those from the energy, the environment and the industrial sectors to formulate integrated policies so that the food sector can adapt to future energy supply constraints and to the impacts of climate change, and successfully meet food security needs. Participation from the private sector will be essential for the promotion of energy-smart approaches. Some organizations have already expressed interest in ESF including World Business Council for Sustainable Development (WBCSD), Novozymes and Enel Green Power.

UN-ENERGY

UN-Energy was established in 2002 at the World Summit on Sustainable Development (WSSD) in Johannesburg to help ensure coherence in the United Nations system's multidisciplinary response and to support countries in their transition to sustainable energy. FAO is a UN-Energy member and has made a key contribution to its activities. UN-Energy will be a key partner in the ESF Programme.

The ESF Programme is a global mechanism designed to bring energy-food security-climate related initiatives together. Collaborative and coordinated initiatives can create an interactive feedback loop that can respond more effectively to fast-changing conditions. It also broadens the constituency of each group by connecting them with stakeholders beyond those targeted by each initiative separately. The ESF Programme will also coordinate closely with a number of ongoing international initiatives, a number of which are listed below.

- **USAID's Energy Grand Challenge for Development** focuses on powering agriculture with the specific aims of identifying and overcoming specific, critical barriers to off-grid access to clean energy for agricultural processing, pumping and storage in energy poor communities in the developing world.
- **Brazil's recently-launched low-carbon agriculture programme (2011-2020)** seeks to reduce greenhouse gas emissions in agriculture through more efficient use of natural resources; increase of the resilience of farming systems and communities; and support the adaptation of the agricultural sector to climate change.
- **The Global Alliance for Clean Cookstoves** is a new public-private partnership which calls for 100 million homes to adopt clean and efficient stoves and fuels by 2020. Its secretariat is hosted by the UN Foundation. FAO is a member of the Global Alliance for Clean Cookstoves and participates in its monitoring and evaluation group. A possible focus of the ESF Programme could be on improving the sustainability of the fuel supply for example through a more effective use of woody biomass and supporting integrated policy development.
- Through its Water project, the **WBCSD** is leading an international and multistakeholder initiative on the water, energy, food, and climate change linkages – the nexus approach.
- **The UN Framework Convention on Climate Change** has a number of associated climate funds and financing mechanisms [e.g. Green Climate Fund, Climate Investment Funds, CDM, Nationally Appropriate Mitigation Actions (NAMAs)] that are relevant to energy. NAMAs, for instance, could provide a suitable framework for agricultural sector-wide energy efficiency or renewable energy programmes. The ESF Programme could contribute in coordinating this work and act as clearing-house on existing funding mechanisms for ESF-related activities. It would cooperate with and complement, as appropriate, the above-mentioned funds, as well as the Technology Executive Committee and Climate Technology Centre and Network, particularly in support of South-South technology cooperation.

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ACRONYMS

AWI	Area Wide Integration
BEFS	Bioenergy and Food Security Project
BEFSCI	Bioenergy and Food Security Criteria and Indicators Project
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CSA	Climate-Smart Agriculture
COFI	Committee on Fisheries
Ex-ACT	Ex-Ante Appraisal Carbon-Balance Tool
ESF	Energy-Smart Food for People and Climate Programme
FAO	Food and Agriculture Organization of the United Nations
GBEP	Global Bioenergy Partnership
GDD	Gender Disaggregated Data
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
IEA	International Energy Agency
IFAD	International Fund for Agriculture Development
IFES	Integrated Food and Energy Systems
IFPRI	International Food Policy Research Institute
ILO	International Labour Organization

IRENA	International Renewable Energy Agency
JWEE	Joint Wood Energy Enquiry
Ktoe	kilo tonnes of oil equivalent
LEAD	Livestock Environment and Development Initiative
NAMAs	Nationally Appropriate Mitigation Actions
MASSCOTE	Mapping System and Services for Canal Operation Techniques
MDGs	Millennium Development Goals
MICCA	Mitigation of Climate Change in Agriculture
UNECE	United Nations Economic Commission for Europe
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Programme
USAID	United States Agency for International Development
WHO	World Health Organization
OECD	Organisation for Economic Cooperation and Development
SADC	Southern Africa Development Community
SEI	Stockholm Environment Institute
SCIP	Sustainable Crop Intensification Programme
SLOWA	State of the World’s Land and Water Resource
WBSCSD	World Business Council on Sustainable Development
WISDOM	Woodfuel Integrated Supply and Demand Overview Mapping

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