

"ENERGY-SMART" FOOD FOR PEOPLE AND CLIMATE

ISSUE PAPER

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Issue Paper

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"The General Assembly of the United Nations declared 2012 to be the International Year of Sustainable Energy for All. Initiatives by Member States and international organizations are being undertaken to create an enabling environment at all levels for the promotion of access to energy and energy services and the use of new and renewable energy technologies."

United Nations Secretary-General (UN General Assembly, 2011)

Acronyms

CHP	combined heat and power
CO2	carbon dioxide
DECC	Department for Energy and Climate Change, United Kingdom
DEFRA	Department for Environment, Food and Rural Affairs, United Kingdom
EJ	exa Joules (1018 Joules)
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
GPS	Global Positioning System
GJ	giga Joules (109 Joules)
IEA	International Energy Agency
IFES	integrated food-energy systems
IPCC	Intergovernmental Panel on Climate Change
LCA	life cycle analysis
MDG	Millennium Development Goals
MEPS	minimum energy performance standards
Mha	million hectares (10^6 ha)
MJ	mega Joules (10^6 Joules)
Mt	mega tonne (10^6 t)
MSW	municipal solid waste
MW	mega Watt (10^6 W)
NAMA	Nationally Appropriate Mitigation Action
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaic
RD&D	research, development and demonstration
SCPI	sustainable crop production intensification

EXECUTIVE SUMMARY

The global community is becoming increasingly concerned about the high dependence of the global food sector[1] on fossil fuels. This anxiety is compounded by FAO (Food and Agriculture Organization of the United Nations) projections indicating that by 2050 a 70 percent increase in current food production will be necessary to meet the expanding demand for food, primarily through yield increases. The use of fossil fuels by agriculture has made a significant contribution to feeding the world over the last few decades. Energy from fossil fuels has increased farm mechanization, boosted fertilizer production and improved food processing and transportation. However, if an inexpensive supply of fossil fuels becomes unavailable in the future, options for increasing food productivity may become severely limited.

The food sector currently accounts for around 30 percent of the world's total energy consumption. High-GDP countries use a greater portion of this energy for processing and transport. In low-GDP countries, cooking consumes the highest share (Fig. ES1). The food sector contributes over 20 percent of total GHGs emissions (Fig. ES1). Primary farm and fishery production[2] accounts for around one fifth of the total food energy demand, but produces two thirds of the GHGs. The great challenge the world now faces is to develop global food systems that emit fewer GHG emissions, enjoy a secure energy supply and can respond to fluctuating energy prices while at the same time support food security and sustainable development.

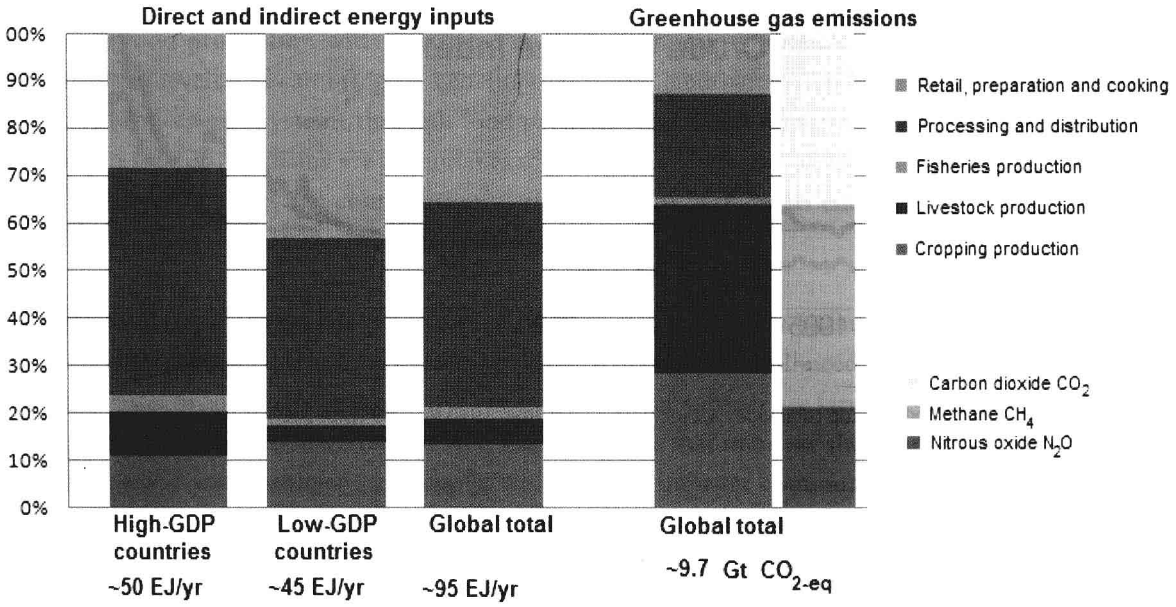

Figure ES 1. Indicative shares of final energy consumption for high- and low-GDP countries, the global total and total associated global GHG emissions for the food sector

NOTE: FAO's analysis is based on the best available data. However, this data is at times unreliable, incomplete and out of date. Results should be treated as indicative only and interpreted with care.

1 In this paper food sector, food systems and food chain are used interchangeably. They refer to all the stages from on-farm production (including input manufacturing) to the consumer's plate.

2 Primary production here includes cropping, pastoral and intensive livestock, aquaculture and fishing

A recent FAO study has shown that around one-third of the food we produce is not consumed. A significant share of total energy inputs are embedded in these losses. In low-GDP countries most food losses occur during harvest and storage. In high-GDP countries, food waste occurs mainly during the retail, preparation, cooking and consumption stages of the food supply chain.

The aim of this paper is to discuss how the entire food sector, from the farmer's field to the consumer's plate, can become more 'energy-smart'. Becoming energy-smart will require a transformation along the food chain that involves:

- relying more on low-carbon energy systems and using energy more efficiently;
- strengthening the role of renewable energy within food systems;
- providing greater access to modern energy services for development, and at the same time supporting the achievement of national food security and sustainable development goals.

This paper provides examples of energy-smart practices for both small-and large-scale enterprises and covers the entire food sector.

Commodity prices tend to be linked with global energy prices. As energy prices fluctuate and trend upwards, so do food prices (Fig ES2).

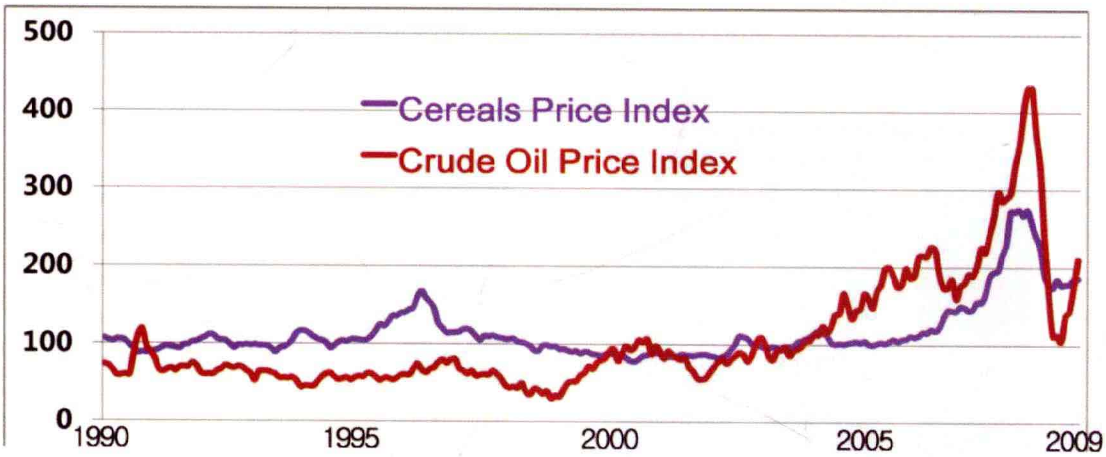

Figure ES2. Comparative trends of crop commodity and oil price indices from 1990 to 2009 (with 2004 as baseline) (Kim, 2010).

Decoupling increase in food production from fossil fuel use will require fundamental changes in global food systems. More analysis is required on how a shift to a less fossil fuel dependent food sector would affect food security, food prices, energy access, climate change resilience, technology uptake and capacity building.

Reducing energy demand. If energy prices continue to rise, the global food sector will face increased risks and lower profits. The efforts from low-GDP countries to emulate high-GDP countries in achieving increases in productivity and efficiencies in both small and large-scale food systems may be constrained by high energy costs. Lowering the energy inputs in essential areas, such as farm mechanization, transport, heat, electricity and fertilizer production, can help the food sector mitigate the risks from its reliance on fossil fuels. Existing production and processing practices behind and beyond the farm gate can be adapted so that they become less energy intensive in terms of energy consumption per unit of food produced, and at the same time deliver food in a safe and environmentally sustainable manner. Methods for improving energy efficiency are reasonably well understood. However, these methods should be applied only when they do not lower productivity, do not restrict energy access and do not threaten rural livelihoods. A simple 10 percent reduction in food losses and a change to diets for example to include the use of more fresh and local foods would help reduce overall demands for energy, water and land. However, implementing these changes would take time as they involve significant behavioral changes and present formidable social challenges.

Renewable energy systems. Increased deployment and use of local renewable energy inputs during the production and processing stages of the food chain can:

- help to improve energy access, particularly in rural areas;
- reduce the food sector's dependence on fossil fuels;
- allay energy security concerns;
- diversify farm and food processing revenues;
- lower GHG emissions and
- help achieve sustainable development goals.

Wind, solar, hydro, geothermal, and biomass resources are often widely available on farms. Potential also exists to produce bioenergy from food processing plants. In the future, it may be possible to harness ocean energy for fisheries. Applying technologies that use renewable energies, including bioenergy sources, for decentralized generation of heat and electricity and for the production of transport fuels is feasible in both low- and high-GDP countries. These technologies offer opportunities for generating usable energy on-site and when excess energy is generated, additional revenue may be earned by exporting and selling it off-site. Combining food production with renewable energy generation is possible at the subsistence, small-scale and large-scale levels and can bring co-benefits to farmers, landowners, businesses and rural communities. Integrated food-energy systems that link food production and natural resource management with poverty reduction in food value chains are potential examples of the landscape approach to sustainable agriculture. Further analysis to assess the contribution of these type of systems to energy-smart food production is needed before firm recommendations can be made.

Improved energy access. The provision of basic energy services is essential for meeting several of the MDGs. It is well accepted that food systems in low-GDP countries will need to use more energy if they are to increase food productivity and improve the livelihoods of subsistence farmers, fishers and their families. Adopting energy-smart food systems would help to ensure that impoverished rural families have access to an affordable and sustainable energy supply, which would improve community health and provide greater opportunities for earning livelihoods through improved refrigeration, communications and transport to markets.

Enabling policies. Strong and long-term supporting policies and innovative multi-stakeholder institutional arrangements are required if the food sector is to become energy-smart for both households and large corporations. Financial mechanisms to support the deployment of energy efficiency and renewable energy will also be necessary to facilitate the development of energy-smart food systems. Examples exist of cost-effective policy instruments and inclusive business schemes that have successfully supported the development of the food sector. These exemplary policy instruments will need to be significantly scaled up if a cross-sectoral landscape approach is to be achieved at the international level. Implementing these policies will require:

- investments in applied research development;
- the deployment of appropriate technologies;
- the introduction, sharing and adaptation of energy-smart technologies;
- fiscal support mechanisms and
- capacity building, support services and education and training.

A supporting policy environment without the appropriate allocation of financial and human resources is unlikely to succeed in establishing energy-smart food systems.

The way forward. Addressing the food/energy/climate nexus is a crucial and complex challenge. It demands significant and sustained efforts at all levels of governance: local, national and international. This paper recommends a major long-term multi-partner programme on "Energy-smart food for people and climate", as a key aspect of 'Climate-Smart Agriculture'[3], based upon three pillars:

- energy access,
- energy efficiency and
- energy substitution through the greater deployment of renewable energy systems.

As part of such a programme, local and national governments may want to consider developing and implementing policies and measures that combine food security with energy security to help meet sustainable development objectives while contributing to 'Climate-Smart Agriculture'.

3 Climate-Smart Agriculture defined as agriculture that simultaneously seeks to:
sustainably increase farm productivity and income;
adapt to climate change and improve resilience of livelihoods and ecosystems; and
reduce emissions of or remove Green House Gases (GHG);

CONTENTS

Introduction

The global food sector is dependent on energy inputs. The natural energy flows from the sun and the various forms of chemical energy stored biologically in the soils and oceans are essential for plant growth to produce food, fish and fibre. However, these natural flows are not discussed in this paper. In agricultural production, humans use external energy inputs to support natural processes so that a given area of land or water produces more than it would do otherwise. Practices for achieving this increased production vary widely between countries and cultures, but they all involve adding auxiliary energy to the natural system. This auxiliary energy can come in many forms: human labour, animal power, fossil fuels, renewable energy or mechanical energy obtained from the consumption of liquid fuels in engines. Meeting the global food demand of a growing world population over the past century has been achieved, at least in part, by the significant increase in the use of fossil fuels at all stages in the food system. Petroleum products power boats, tractors and other vehicles that transport food. Natural gas is used to manufacture chemical fertilizers and pesticides. Fossil fuels are combusted to generate electricity and heat for processing, refrigeration and packaging. A range of fuels are used for cooking. It is this increased reliance of global food systems on fossil fuels that is now becoming cause for concern.

By 2030 it is expected that population expansion and economic growth will increase the global demand for energy and water by 40 percent (IEA, 2010) (WEF, 2011) and the demand for food will increase by 50 percent, to be met primarily through yield increases (Bruisma, 2009). Meeting these demands is being made even more challenging by climate change, the limited availability of productive land and the fact that the planet's natural resource base is already under significant stress. The magnitude and complexity of this challenge, combined with the need for urgent action, explains the current importance being given to the energy-water-food-climate nexus. This 'perfect storm' of factors will have an impact on land use, land acquisitions and the environment at local, national and global levels. To address these challenges, the global economy will have to make a major transition from the business-as-usual approach. We will have to do more with less. FAO has articulated this new approach in its proposed "*Save and Grow*" paradigm shift (FAO, 2011a). This shift will require that stakeholders involved at all levels in the global food sector adopt fresh approaches to agricultural and fisheries production, develop innovative appropriate technologies and formulate new policies and institutional arrangements.

Making the transition to low-carbon 'climate-smart agriculture' can contribute to 'green economy', will improve human well-being and social equity while significantly reducing environmental risks and ecological scarcities (UNEP, 2011). This transition involves:

- using more ecologically-friendly farming methods that significantly improve yields for subsistence farmers;
- improving access to freshwater and using water more efficiently;
- promoting the efficient management of natural resources and energy;
- substituting fossil fuels with low-carbon resources and clean energy technologies and
- reducing losses and waste along the food chain.

These points are all pertinent to the sustainable development issues covered in this paper. However, it must be noted that the food supply chain, particularly the primary production sector, is a complex system relying on healthy soils, adequate supplies of water and careful management of resources.

The concept of energy intensity is introduced to measure the effective use of energy in the food chain. In this paper energy intensity is defined as the amount of energy used per unit of food produced (MJ per ton of food produced). By addressing the energy status of the whole food sector, the paper highlights options for lowering the energy intensity, reducing food losses and increasing the local use of renewable energy resources. Any attempts to reduce energy inputs to the food sector or to generate energy supplies from this sector that would be detrimental to productivity, processing activities, or food quality should not be promoted.

This paper discusses the challenges mentioned above and offers practical ways to meet them. Emphasis is placed on energy in relation to food systems and rural development. FAO has advocated for the development of national policies to stimulate the integration of energy into the agricultural sector for over a decade (FAO, 2000). This paper expands the case by covering the whole food system and commodity supply chain, including:

- agriculture, fisheries and animal feed production;
- the manufacturing of tractors, machinery, equipment, inorganic fertilizers and agri-chemicals;
- the building of infrastructure;
- post-harvest operations;
- food storage and processing;
- transport and distribution; and
- retail, preparation and consumption

The food sector uses around 30 percent of total global primary energy consumption. Energy consumption is typically disaggregated into direct or indirect energy. Direct energy is used at the operational level primarily on farms and processing plants, for example for irrigation, land preparation and harvesting. Indirect energy, on the other hand, is not directly consumed to operate farms, in fishing or processing plants. It includes the energy required to manufacture inputs such as machinery, fertilizers and pesticides.

This paper makes a distinction between direct and indirect energy **for** (used in) the food chain and energy **from** (that can be produced by) the food sector. Energy from the food chain includes renewable energy produced on farms or in processing plants. This type of renewable energy includes wind, solar, small-hydro and bioenergy. It can be used either on-site as a substitute for purchased direct energy inputs or sold for use off-site to earn additional revenue for the owner of the farm or processing plant.

Food losses along the whole supply chain are addressed, as avoiding this waste will lead to reductions in demand for land, water, energy and lower GHG emissions[4]. Forest production and the wood product processing industry are not included, except where woody biomass by-products can be used to provide energy for the food sector or agro-forestry systems in rural landscapes. International trade and 'food miles' will not be discussed in detail, nor will issues relating to the impacts of energy use and management on water quality, soil nutrients, groundwater supplies, biodiversity, or management of a farm enterprise, unless there is a direct relationship with energy supply technologies.

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4 This paper focuses on the mitigation of energy-related CO_2 emissions. More detailed analyses of mitigating CH_4, N_2O and HFCs produced from the food sector appear elsewhere, such as in the UK's *Foresight Project on Global Food and Farming Futures* (GoS, 2011) and in the USEPA (2006) report on non-CO_2 gases.

1.1 The key challenges

- The projected future higher costs of oil and natural gas, as well as insecurity regarding the limited reserves of these non-renewable resources (IEA, 2010), coupled with the global consensus on the need to reduce GHG emissions, could hamper global efforts to increase the volume and quality of food supplies to meet the growing demand for food.
- Food systems, from small local to large scales, will be required to produce more food, essentially through increased productivity . Over time, this will require improving access to modern energy services for subsistence farmers and rural communities.
- The global food system will need to provide sufficient, secure and 'climate-smart' food supplies over the coming decades. The losses along the food supply chain, currently around one-third of all food produced, will need to be reduced through appropriate policies, institutional and financial measurements.
- Becoming 'energy smart'along the food chain by reducing its high dependence on fossil fuels, will require new policies and institutions, increased public awareness and education, behavioural changes and significant investments in clean energy technologies.

1.2 Major related issues

- *Increasing food demand.* The 'green revolution' of the 1960s and 1970s solved the food shortage problem at the time. This revolution was accomplished not only through improved plant breeding, but also by tripling the application of inorganic fertilizers, expanding the land area under irrigation and increasing energy inputs to provide additional services along the food chain. Today, the annual incremental yield increases of major cereal crops are declining and fossil fuels are becoming relatively more scarce and costly. Historical trends indicate an evident link between food prices and energy prices (Fig. 1).

Further intensification of crop and animal production will be required to feed the world's population, which is projected to expand to over 9 billion people by 2050. The report, *"How to Feed the World by 2050"* (FAO, 2009a) indicates that a 70 percent increase in food production compared to 2005-2007 production levels will be needed to meet the increased demand. This equates roughly to the additional production of around 1 000 Mt of cereals and around 200 Mt of meat and fish per year by 2050. These production gains are largely expected to come from increases in productivity of crops, livestock and fisheries. However, unlike the 1960's and 1970's green revolution, our ability to reach these targets may be limited in the future by a lack of inexpensive fossil fuels.

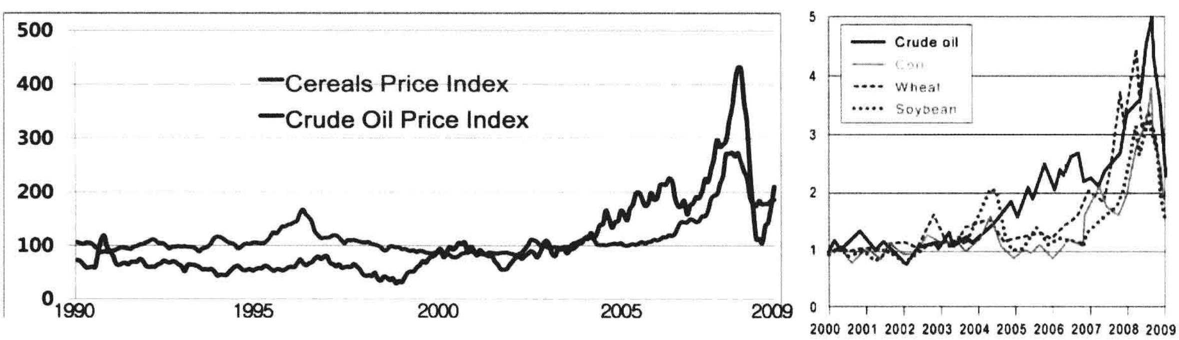

Figure 1. Comparative trends of crop commodity and oil price indices from 2000-2009 (Heinberg and Bomford, 2009) and from 1990 to 2009 (with 2004 as baseline) (Kim, 2010).

- *Economic viability.* The volatile prices and possible future supply scarcity of fossil fuels and the heavy reliance of the food industry on these non-renewable energy resources, raises concerns about the availability and affordability of food as well as on the economic viability of some food-related businesses in the years to come. If fossil fuel prices continue to rise and carbon charges are added to cover the externality costs of GHG emissions released during their combustion, the costs of tractor and boat fuel, agri-chemicals and fertilizers, food processing and transportation will all increase. This situation could cast doubt on the premise that, since farm land and fishing stocks are limited, future increases in food production will come mainly from crop yield increases, particularly through the application of higher external energy inputs in less intensive systems. Further intensification in primary agricultural production, together with any land expansion and intensification in activities beyond-farm gate, should ideally be gradually disconnected from additional fossil fuel demands if the world is to move towards a low-carbon, less fossil fuel dependent, food sector.
- *Environmental impacts.* Primary production and the entire food supply chain contribute approximately 22 percent of total annual GHG emissions. An additional 15 percent of GHG emissions results from land use changes, particularly changes linked to deforestation brought about by the expansion of agricultural land (IPCC, 2007). Additional risks from potential impacts of climate change on food supply security requires a careful evaluation of the resilience of the food sector. Analyses of probable climate change impacts on agricultural productivity up to 2050 have shown that negative impacts on the sector are most likely. These impacts may reduce the availability of food and cause declines in human well-being, particularly in developing regions (Spielman and Pandya-Lorch, 2010; Fischer *et al.*, 2009).
- *Competing land uses.* Income growth in developing countries will lead to higher consumption of milk and meat products (FAO, 2011a), which will increase the demand for cereals for livestock feed. In addition, if the demand continues to grow for commodities such as maize as feedstock for liquid biofuels for transport, pressure will increase to boost cereal production. In some areas, urban development and desertification are also placing significant pressures on land. All the above factors are contributing to increasing competition for agricultural land.
- *Energy access.* The poor availability of efficient modern energy services in many regions is a fundamental barrier to sustainable development and to meeting the MDGs. Providing these energy services is a basic necessity that would improve both the health and livelihoods of many people living in rural areas in low-GDP countries (section 3.3).

In summary, fluctuating energy prices, future energy security and concerns on GHG emissions present challenges for the food sector as it seeks to reduce its environmental impact and support sustainable development. A new paradigm of agriculture and food production is needed to respond to the increasing competition for land and water, rising energy costs and the subsequent price increases for inputs produced from fossil fuels and the anticipated impacts of climate change. In this new paradigm, farmers, fishermen and food processors and distributors will need to learn to 'save and grow' (FAO, 2011a).

1.3 The relative scales of food systems

The spectrum of food systems is complex and diverse. These systems range from basic subsistence smallholder farmers growing food for their own consumption to large commercial, corporate farms supplying huge supermarket chains across the world. All of these systems are dependent on energy. Human and animal power is commonly used in the small scale operations. but is being increasingly substituted with fossil fuels in regions where these are relatively inexpensive. In most countries, small-scale farmers provide fresh food not only to local markets, but to processing plants as well. Demand for low-input, chemical free, organic food continues to grow, mainly in OECD countries. Section 4.4 discusses in more detail the relationships between low-input, chemical free and organic agriculture with energy consumption and intensity.

In some developing countries, modern food systems are evolving rapidly. In China, for example, supermarkets are starting to dominate the food supply chain (Vorley B, 2011). Therefore, when discussing the linkages between energy and food, it is no longer practical to classify countries using standard comparisons such as OECD or non-OECD, developed or developing, traditional or conventional, and subsistence or industrialised. It can be helpful for comparison purposes to classify countries according to their major differences in the food chains. For this paper, it was decided to use the terms *'high-GDP'* and *'low-GDP'*. The term high-GDP describes the top 50 or so countries measured in terms of their GDP on a purchasing power parity basis divided by their population. The term 'low-GDP' applies to the remaining 176 or so nations.[5]

To assist the reader better understand the energy concepts being discussed and their relation to practical primary production enterprises at various scales, this paper will mostly differentiate between 'small' farm and 'large' farm enterprises, even though defining rigidly clear boundaries between these two terms is not possible. Table 1 illustrates the relationship between the concepts discussed throughout this paper. However, there are many exceptions to this typology. For example, small enterprise tea plantations employ many pickers or small family fishing boats have relatively high fossil fuel dependence and related costs.

Scale of producer	Overall input intensity	Human labour units	Animal power use	Fossil fuel dependence	Capital availability	Major food markets	Energy intensity
Subsistence level	Low	1-2	Common	Zero	Micro-finance	Own use	Low
Small family unit	Low	2-3	Possible	Low/medium	Limited	Local fresh/process/ own use	Low to high?
	High	2-3	Rarely	Medium/high	Limited	Local fresh/regional process/own use	Low to high?
Small business	Low	3-10	Rarely	Medium/high	Medium	Local/regional/export	Low to high?
	High	3-10	Never	High	Medium	Local/regional/export	Low to high?
Large corporate	High	10-50	Never	High	Good	Regional process/export	Low to high?

Table 1. Simplified typology of typical 'small' and 'large' scale farms and fisheries based on qualitative assessments of unit scale, levels of production intensity, labour demand, direct and indirect fossil fuel dependence, investment capital availability, food markets supplied and energy intensity. (Notes: 1) Supplying supermarket retailing companies is feasible at all levels other than subsistence. To do so, small or large producers usually have to invest in modern storage facilities that require fossil fuels or electricity. 2) The table shows that no automatic correlation exists between input intensity and fossil fuel dependency).

Subsistence. Households engaged in the most basic forms of small-scale, agricultural and fishing activities produce food solely for their own consumption. Subsistence producers use very low energy inputs, usually deriving from human and animal power. These energy inputs are usually not included in world energy statistics, in part because they are so diffuse. Also, energy balance data is unavailable on the total additional food and feedstuffs needed to offset the energy input required for human and animal power use . Gaining access to energy and securing an adequate livelihoods are the main priorities for subsistence farmers and fishers. However, lack of financial resources limits their ability to meet these priorities. (section 3.3).

5 Index Mundi web site: http://www.indexmundi.com/g/r.aspx?v=67.

Small farms. Depending on the degree of modernization, 'small' family units may engage in a variety of activities, including cultivating small gardens or rice fields, growing organic vegetables, tending orchards, raising livestock, operating privately-owned fishing boats and maintaining dairy herds (from a few up to dozens of cows). Energy efficiency options usually exist for these small enterprises, except for those that depend solely on human and animal power. Small mixed farms may utilize other forms of direct energy such as solar heat for crop drying, on-farm produced biogas for cooking, and electricity generated from a solar photovoltaic (PV) system.(Fig. 2).

Small businesses can be family-managed but are usually privately-owned. They operate at a slightly larger scale and employ several staff. These businesses have opportunities to reduce their fossil fuel dependence by improving energy efficiency and generating on-farm renewable energy, which could provide additional benefits for the local community.

Large farms. At the other end of the spectrum, corporate[6] food systems are dependent on high direct external energy inputs throughout the supply chain (Fig. 3). Examples of these systems include fishing trawler fleets, beef feedlots, sugar companies and palm oil plantations. Large farm estates may be owned and managed by a processing mill company. When they are owned by a growers co-operative, some benefits are more likely to flow to the local community. Large corporate organizations usually have access to finance for capital investment for energy efficient equipment and renewable energy technologies. Energy may be used on-farm or sold off-farm for additional revenue.

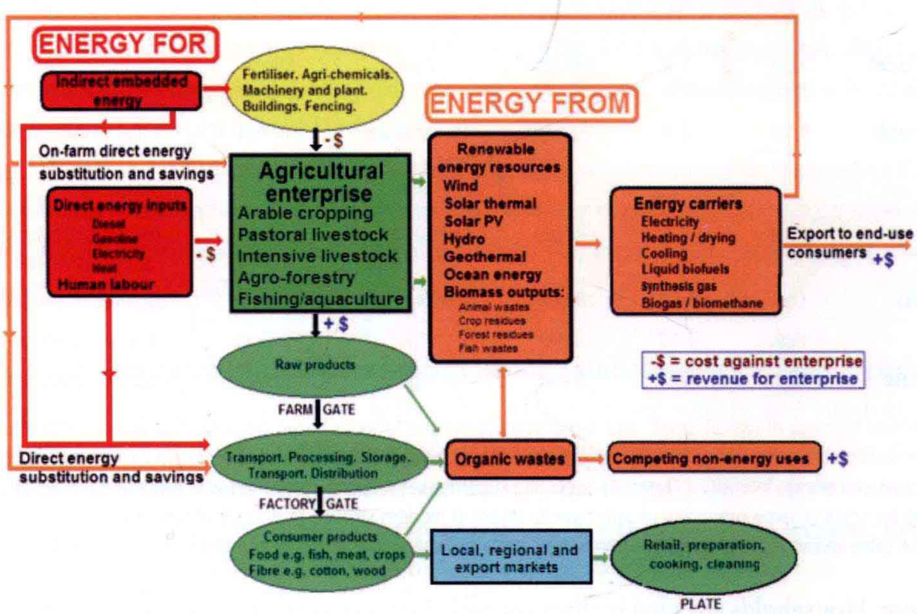

Figure 2. Example of a 'small-scale', low-input, family-managed, farming enterprise showing energy flows through the system. Outputs are primarily fresh food for local consumption, although they may also be delivered to local processing companies. Along with human and animal power, some direct energy inputs can be obtained from other sources, such as solar thermal and solar PV systems and biogas produced using a simple anaerobic digester.

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6 'Industrialized', 'market-based', 'commercial' and 'multi-national' are terms used synonymously with "corporate" to describe modern, large-scale, food systems that produce food, fish, feed or fibre.