45

Making Integrated Food-Energy Systems Work for People and Climate

An Overview



ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER
ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

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Making Integrated Food-Energy Systems Work for People and Climate

An Overview

Anne Bogdanski, Olivier Dubois, Craig Jamieson, and Rainer Krell

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FOREWORD

A safe integration of food and energy production may be one of the best ways to improve national food and energy security and simultaneously reduce poverty in a climate smart way. This study on Integrated Food-Energy Systems (IFES) draws some lessons on constraints to scale up IFES and opportunities to overcome them from examples from Africa, Asia and Latin America as well as from some developed countries.

Farming systems that combine food and energy crops present numerous benefits to poor rural communities. For example, poor farmers can use the left-overs from rice crop to produce bioenergy or in an agroforestry system they can use the debris of trees used to grow crops like fruits, coconuts or coffee beans for cooking. Other types of food and energy systems use by-products from livestock for biogas and compost production. Yet others combine biofuel crops and livestock on the same land.

With these integrated systems farmers can save money because they don't have to buy costly fossil fuel for their energy needs, nor chemical fertilizer if they use the slurry from biogas production. They can then use the savings to buy necessary inputs to increase agricultural productivity such as improved seeds - an important factor given that a significant increase in food production in the next decades will mainly have to come from yield increases. All this increases their resilience, hence their capacity to adapt to climate change.

At the same time, integrating food and energy production particularly, through the use of by-products, can also be an effective approach to mitigate climate change, especially indirect land use change (iLUC). Implementing IFES leads to increased land and water productivity, therefore reducing greenhouse gas emissions and increasing food security. Moreover by combining food and energy production, IFES reduce the need to convert land to produce energy, in addition to land already used to agriculture. This further reduces the risks associated with land conversion – hence that of additional GHG emissions.

This document presents a comprehensive overview of different options which make the various benefits of IFES materialize while addressing risks and constraints associated with current bioenergy productions schemes.

Promoting the advantages of IFES and improving the policy and institutional environment for such systems should become a priority. FAO is well placed to coordinate these efforts by providing knowledge and technical support for IFES through a programme aimed at promoting IFES. Enhancing IFES practices will contribute to the progress towards achieving the Millennium Development Goals (MDGs), including MDG 1 to reduce poverty and hunger and MDG 7 on sustainable natural resource management.

Alexander Müller
Assistant Director-General
Natural Resources Management and Environment Department

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EXECUTIVE SUMMARY

Background

Reducing "Energy Poverty" is increasingly acknowledged as the "Missing Development Goal". This is because access to electricity and modern energy sources is a basic requirement to achieve and sustain decent and sustainable living standards. It is essential for lighting, heating and cooking, as well as for education, modern health treatment and productive activities, hence food security and rural development. Yet three billion people – about half of the world's population - rely on unsustainable biomass-based energy sources to meet their basic energy needs for cooking and heating, and 1.6 billion people lack access to electricity.

Small-scale farmers are globally the largest farmer group and of key importance to local and national food security in developing countries. Therefore safely integrating, intensifying and thus increasing food and energy production for this large group of producers may have the best prospect to improve both local (rural) and national food and energy security and reduce poverty and environmental impact at the same time.

While biomass has been – and continues to be – the primary energy source for the rural poor in developing countries, it has also been of special interest in the Organisation for Economic Co-operation and Development (OECD) countries in recent years, mainly due to the production of liquid biofuels for transport. This has caused strong controversy, mainly regarding the potential risk that the production of biofuels may pose to food security of the rural poor in developing countries, but also regarding issues related to global climate change.

IFES as a Solution to Climate-Smart Agricultural Development

Integrated Food Energy Systems (IFES) aim at addressing these issues by simultaneously producing food and energy, as a possible way to achieve the energy component of sustainable crop intensification through the ecosystem approach. This can be achieved in two ways: Type 1 IFES combine the production of food and biomass for energy generation on the *same land*, through multiple-cropping systems, or systems mixing annual and perennial crop species, i.e. agroforestry systems. Either system can be combined with livestock and/or fish production. Type 2 IFES seek to maximize synergies between food crops, livestock, fish production and sources of renewable energy. This is achieved by the adoption of agro-industrial technology (such as gasification or anaerobic digestion) that allows maximum utilization of all by-products, and encourages recycling and economic utilization of residues. In many situations, the production of renewable energy can feasibly go well beyond bioenergy alone. Other locally available (non-biological) renewables can be incorporated such as solar thermal, PV, geothermal, wind and water power.

IFES can function at various scales and configurations, from small-scale systems that operate at the village or household level mainly for the purpose of self-sufficiency, to large-scale systems adjusted for industrial operations, but involving and benefiting small-scale farmers.

The main driver for implementing IFES in *developing countries* is the need for food and energy security - the basic requirement for poverty reduction and rural development. In developed countries, the growing interest in IFES is backed by the general trend towards increased resource efficiency, especially in land use, and the need to risks related to reduce direct and indirect land use change through biofuel developments. This particularly links to the challenges posed by climate change and climate variability. IFES can help to adapt to, and mitigate, the consequences of a changing climate, and reduce dependence of agricultural development on fossil fuels.

Barriers and Development Needs

The concept of IFES as such, is not new. *Simple* integration of food and energy production at both small and large scales has shown many successful results. However, there are fewer successful examples of the more *complex* and resource-efficient systems. Examples of long-term implementation and uptake exist for simpler systems like biogas, but are also relatively scarce for more complex IFES operations.

This paper draws on an extensive review of literature and the findings of an FAO technical consultation held in July 2010 on "How to make integrated food-energy systems work for both small-scale farmers and rural communities in a climate-friendly way" which aimed to identify what hinders the uptake of IFES, in particular, and to find some key solutions that could help realize their benefits on a wide scale.

Barriers to the implementation and wide-scale dissemination are manifold, and concern various aspects at both farm and beyond farm level:

- The complexity of some IFES requires high levels of *knowledge* and skills. *Technical support* is essential, but not always available.
- *The technology* used needs to be reliable and economical. Ensuring good quality of the conversion device is crucial for the success of IFES, and has often been overlooked in systems aimed at being rapidly scaled up, e.g. some large-scale biogas programmes in the past.
- *Financing* is mostly related to the investment required for the energy conversion equipment. Very often, the better they are from an energy and GHG point of view, the more expensive they are. This is often not affordable for individual small-scale farmers, and *access to financing mechanisms* such as micro-credit schemes is not always given.
- The increased *workload* often experienced with IFES makes the systems less attractive to farmers. Where multiple crops are grown on one piece of land, as in Type 1 IFES, or where there is a diverse array of inter-connected crops and livestock, as in Type 2 IFES, there tends to be less scope for specialization and mechanization, and therefore IFES often require significant manual input.
- *Competition between different uses of residues* refers to the fact that the use of residues for energy production should not negatively affect their use for soil fertility and protection and/or for feeding animals. *Trade-offs* in the use of resources (land,

water and nutrients) are becoming increasingly hard to balance, as competition for biomass for food, feed, fertilizer and fuel increases.

- *Access to markets* for agricultural and/or energy products is often a key factor to ensure economic viability of the IFES, since most of the time IFES operators earn the bulk of their revenues from the sale of their agricultural products. However, adequate access to markets and product competitiveness should not always be assumed.
- *Access to information-communication and learning mechanisms* regarding the above-mentioned factors is as important a production factor as "classic" land, labour and capital. Difference in levels of access to information is a well-known power factor in rural development.
- *Politics*, i.e. how things really work and are decided at local level, might influence the above-mentioned factors. *Few gov*ernment *policies* encourage all aspects covered by IFES, and some sectoral technical support policies even play against the *replicat*ion and scaling up of IFES, especially more complex ones. Possible ways to overcome these barriers are: (i) agricultural - through sustainable farming practices that reduce residue competition; (ii) institutional arrangements; and (iii) policy options that support the development and scaling-up of IFES initiatives.

Agricultural Solutions

The use of soil residues for energy production might, in some cases, interfere with the need to maintain and enhance soil quality, or with other residue uses such as animal feed provision. To be used in a sustainable way, residue must only be removed when it does not hamper soil quality. In some regions the combination of crop, management practice, soil, and climate, work together to produce more than is needed to maintain soil health. In this case, excess residues could potentially be used for conversion to biomass energy. However, it is important to discern in what systems residue harvest for energy purposes is possible, or even beneficial, and at what rates. This is particularly true for tropical and sub-tropical climates where the soil organic carbon pool is below the critical level.

In some cases, trade-offs can be found, for instance, when too much crop residue can create problems (e.g. diseases, fires in dry areas) or residues substituted with alternative sources for soil protection and livestock feed (e.g. cover crops). In others, win-win solutions are possible, such as biogas and use of its by-product as compost, or using soil amendments such as biochar produced from residues. However, literature that addresses the trade-offs between competing uses of crop residues is relatively scant. Given the importance and the complexity of the topic, it certainly warrants more research and development in the coming years.

Institutional Solutions

Institutional arrangements that support the scaling-up of IFES concern two different issues, i.e. the workload and financial constraints. Often both types of issues are addressed through the division of labour and costs, when individuals specialize and work together, rather than individually, to implement all the components of IFES. The obvious way to achieve this is to let farmers handle what they do best – farming, including the supply of residues from their farming activity – while having other operators handle the energy component of IFES. A further division of labour through area-wide integration is advocated in the case of integrated crop-livestock systems, i.e. where crops and livestock do not have to be operationally integrated (within the same management unit) to have functional integration (e.g. feed-manure). Integration can be achieved through supplies from different farmers, all with their specialized contributions and comparative advantages. By dividing labour and allowing specialization, the efficiency of complex IFES can be increased and more easily managed. Such a system requires co-ordination and often collective action, which may come from different institutional structures, such as farmer cooperatives, social businesses or companies that wish to market or process the produce, as is often the case, for example, with outgrower schemes.

Knowledge management and supporting services in the case of *simple* IFES are usually provided through vertical integration of the supply chain, which also allows for labour division, with private sector companies or cooperatives entering into contracts with small-scale farmers (contract farming). Farmers supply the feedstock, while the company or cooperative guarantees the purchase and provides support in the input supply side of the value chain. Tenant farming and sharecropping, whereby small holders farm the land belonging to companies, is another type of agribusiness-smallholder partnership which often includes provision of technical services and sometimes inputs to the farmer.

More efficient but also more *complex* and knowledge-intensive IFES do not lend themselves easily to vertical integration. They require knowledge management and support systems that combine better articulation of demand and managing the institutional responses to the demands in a pluralistic way. Developments in agriculture and rural development and their related new policy requirements (such as those related to the MDGs), increasingly require that organizations involved in agricultural and rural development take the role of coherent, competent and engaged service providers, which can act as counterpart to the better-articulated demands on farmer's part. In other words a combination of "demand-side approaches" and "supply-side approaches" seems the best way forward. Such systems often rely on local-level learning systems, such as the farmer-field school and the success-case replication approach.

In many countries there are formal mechanisms set up to provide credit to small-scale farmers and entrepreneurs in rural areas. Small-scale farmer organizations such as cooperatives, can help increase access to micro-credit for small-scale producers where rural banks are reluctant to engage. Some simple IFES systems, such as those using biogas, are good candidates for carbon finance, given the significant potential they hold to reduce GHG emissions, and are relatively simple to monitor.

Policy Solutions

Institutional arrangements require *policy instruments* to support their implementation. Policies relevant to IFES concern both their agricultural and energy components. Those related to the agricultural component concern the need to increase productivity to meet future global food and energy needs. Policy measures to promote this concern research and development and technology adoption (e.g. input subsidies, tax incentives, and technical and financial support). But agricultural policies also need to promote environmental conservation and social equity. The former can be achieved through a combination of market based measures following the "provider gets-polluter pays principle" and regulations such as zoning. Policies regarding more environmentally-oriented agriculture, for instance, through the ecosystem approach to agricultural intensification promoted by FAO, face serious challenges. These constraints include: the lack of institutional coordination of concerned government bodies; inadequate links with research; a focus on commodity agriculture and lack of incentives to reward ecosystem stewardship and low carbon agriculture; subsidies to chemical fertilizers; and lack of support to measures favourable to small-scale producer involvement in the local food supply chain.

Land tenure security is an essential component of social equity, as are investments in agriculture. The critical factor is that the State must be able to guarantee, in practice, the rights accorded to all land users by law. Only then can investors – big and small, entrepreneurs and communities – make financial and longer-term plans with the confidence that the parameters shaping their long-term vision will not change. There are ways to address this challenge, and these are being developed and discussed in some recent major international initiatives.

Policy instruments, in support of the energy component of IFES and more broadly renewable energy (RE), are manifold. Two areas of support stand out:

- The promotion of renewable energy markets through quotas/mandates and/or feed-in tariffs. However, these are probably not the most appropriate instruments to promote RE development for small-scale farmers and rural communities in developing countries. The former tend to favour large and centralized plants and to concentrate development in best-endowed areas, while the latter require a grid to feed into, and tend to favour relatively wealthy households which are already grid connected. They are also more relevant to the operations and maintenance phase of RE initiatives, whereas a lot of the challenges in rural areas of developing countries lie at the start-up phase.
- Financial incentives in the form of grants, subsidies, micro-credits, carbon finance or tax breaks. Effective financing mechanisms should fill an existing investment gap, increase private sector involvement and awareness and have the ability to be phased out over time, leaving a long-term private sector financing solution in place. The most effective finance mechanisms do not distort the market, but rather help to build it into a financially viable alternative to conventional energy. A major reason for the success of recent RE financing schemes stems from the fact that they have focused on the main actors of RE development – entrepreneurs and end users – to provide incentives, so that, instead of 'dropping' RE projects on completion, these actors have an interest in their continued success.

Other policy instruments regarding RE include support to infrastructure development, standards, capacity-building and stakeholder involvement. Subsidies are an important aspect of energy policies. Energy markets should factor in all types of societal costs (economic, social and environmental). It often makes sense to establish time limits or "sunset clauses" in subsidy schemes right from the outset, and mechanisms to regularly assess the appropriateness of reforming subsidies.

IFES vary in types and sizes. They do not develop spontaneously in a vacuum. Solutions to their constraints evolve according to local circumstances, scale and the stage of development time. Therefore, any support mechanism must be predictable, long-term and consistent, with clear government intent. It must be simple, transparent, appropriate, flexible, credible and enforceable.

Policy-makers and supporting partners (donors, private sector, farmers, etc.) need to be convinced about the benefits of promoting and implementing IFES. A first step in that direction is the development of a critical mass of tangible arguments, to be obtained through documenting IFES experiences and showing concrete examples of successful IFES. In parallel, decision support tools (DSTs), could be developed to help policy-makers and investors in IFES to make the right choices, both at strategic and project levels. Rigorous evidence and decision-making support can lead to political willingness to introduce the policies and institutional changes needed to replicate and scale up successful IFES.

Future Work

Concrete actions related to the above-mentioned sequence were proposed during the FAO Technical Consultation on IFES in July 2010. These include:

- FAO playing the role of international information platform and repository of knowledge *related to IFES*. To start with, FAO could set up an IFES website within its bioenergy website, and develop a very simple Newsletter to be circulated to the participants of the July 2010 meeting, but also other likely interested individuals and organizations.
- Promotion of simple IFES systems, e.g. through the collection and dissemination of information related to the scaling up of successful large-scale simple biogas programmes (e.g. from China, Viet Nam and Nepal), including policy and institutional aspects. This information would be placed on FAO's IFES website, and shared with FAO's decentralized offices.
- Documentation of cases, and more particularly, more complex IFES. A starting point would be the development of a rapid assessment methodology regarding IFES, starting at farm level. This would then allow for comparative assessments of different types of IFES, but also of IFES with and without the energy component (e.g. integrated crop-livestock systems with or without biogas).

Work on unresolved issues. Three topics stand out: (i) the IFES assessment methodology mentioned above; (ii) residue competition; and (iii) links between IFES and land use changes caused by liquid biofuel development (both direct and indirect land use changes).

CONTENTS

CHAPTER 1

INTRODUCTION

Reducing "Energy Poverty" is increasingly acknowledged as the "Missing Development Goal". This is because access to electricity and modern energy sources is a basic requirement to achieve and sustain higher living standards. It is essential for lighting, heating and cooking, as well as for education, modern health treatment and productive activities, hence food security and rural development.

Yet three billion people – about half of the world's population - rely on unsustainable biomass-based energy sources (UNDP/WHO 2009), to meet their basic energy needs for cooking and heating, and 1.6 billion people lack access to electricity (IEA 2002). National policies and programmes aimed at providing broader access to energy services for the rural poor can significantly contribute to sustainable development and achievement of the Millennium Development Goals (MDGs), including those on poverty reduction and sustainable natural resource management in the face of climate change. This can be significantly supported and partially achieved through the design and implementation of livelihood-oriented, gender-sensitive small-scale bioenergy schemes, adapted to local conditions.

Small-scale farmers are globally the largest farmer group and of key importance to local and national food security in developing countries. According to an analysis by the Consultative Group on International Agricultural Research (CGIAR), the world's one billion poor people (those living on less than one dollar a day), are fed primarily by hundreds of millions of small-holder farmers (most with less than two hectares of land, several crops and perhaps a cow or two) and herders (most with fewer than five large animals) in Africa and Asia (Herrero *et al.* 2009). Therefore, safely integrating, intensifying and thus increasing food and energy production for this large group of producers may have the best prospect to improve both local (rural) and national food and energy security and reduce poverty and environmental impact at the same time.

While biomass is, and has been, the primary energy source for the rural poor in developing countries, it has also been of special interest in the Organization for Economic Co-operation and Development (OECD) countries in recent years, mainly due to the production of liquid biofuels for transport. This has caused strong controversy, mainly regarding the potential risk that the production of biofuels may pose to food security of the rural poor in developing countries, but also regarding issues related to global climate change. While some energy crops provide a positive greenhouse gas emission balance, others are significantly negative. Another unresolved issue is the indirect land use change (ILUC) that might occur when food crop plantations are replaced by energy crops and

BOX 1

THE ECOSYSTEM APPROACH

The Ecosystem Approach is defined as a strategy for the management of land, water and living resources that promotes conservation and sustainable use in an equitable way. While similar to a number of other holistic approaches to conservation, development and natural resource management, it has some key distinguishing features, i.e.:

- it is designed to balance the three CBD objectives (conservation, sustainable use and equitable benefit sharing of genetic resources);
- it puts people at the centre of biodiversity management;
- it extends biodiversity management beyond protected areas while recognizing that they are also vital for delivering CBD objectives; and
- it engages the widest range of sectoral interests.
- The key principles of the Ecosystem Approach are:

Principle 1. The objectives of management of land, water and living resources are a matter of societal choice.

Principle 2. Management should be decentralized to the lowest appropriate level.

Principle 3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Principle 4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should: a) reduce those market distortions that adversely affect biological diversity; b) align incentives to promote biodiversity conservation and sustainable use; and c) internalize costs and benefits in the given ecosystem to the extent feasible.

Principle 5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Principle 6. Ecosystems must be managed within the limits of their functioning.

Principle 7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

Principle 8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Principle 9. Management must recognize that change is inevitable.

Principle 10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Principle 11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations & practices.

Principle 12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Source: Smith and Maltsby, 2003

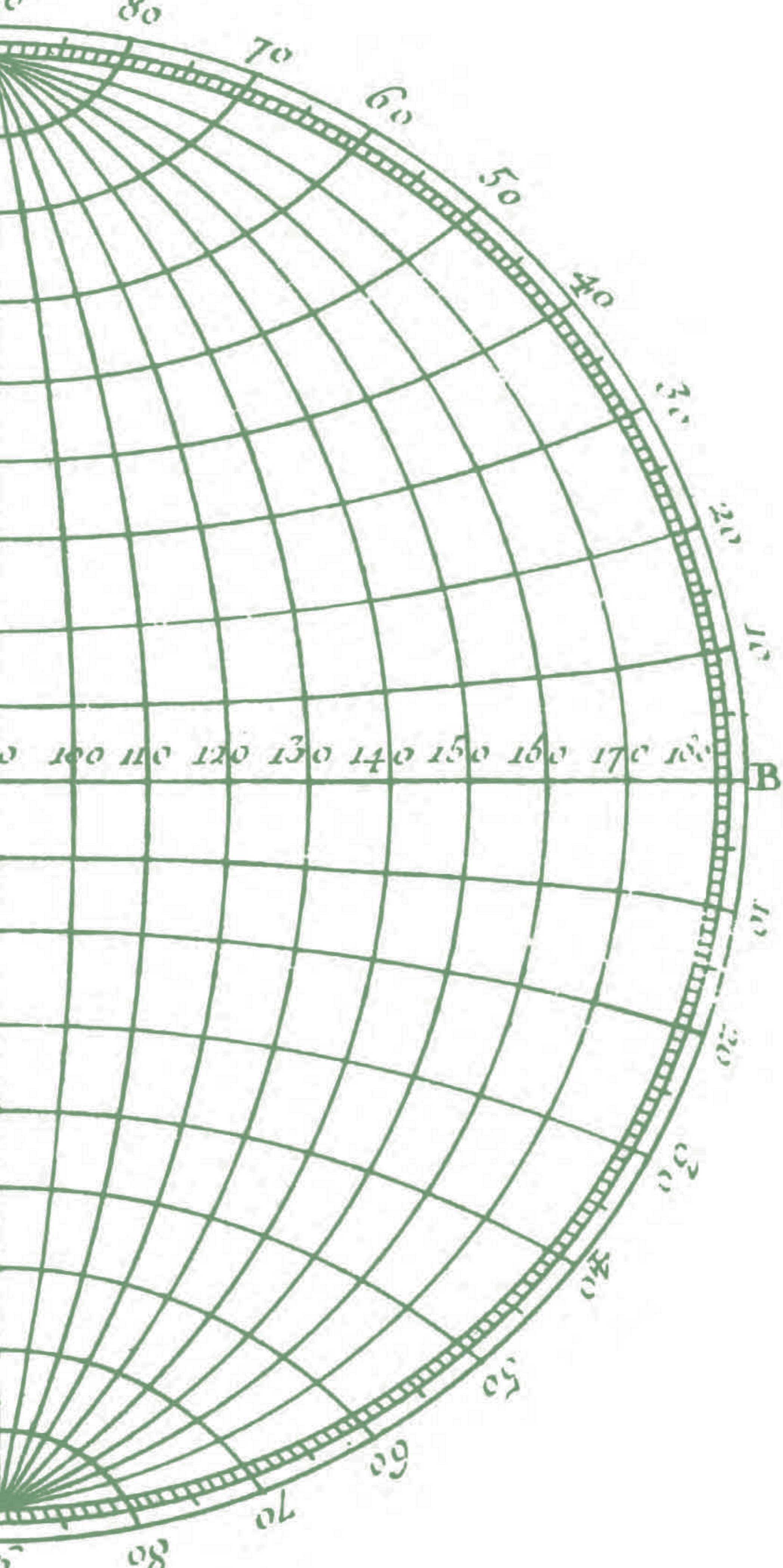
food production is then shifted to other regions, potentially causing the depletion of natural resources (see Box 4 in Chapter 2.4.3.).

Integrated Food Energy Systems (IFES) aim at addressing these issues by simultaneously producing food and energy as a way to address the energy component of sustainable crop intensification through an ecosystem approach, as defined in Box 1. This can be achieved in two ways: by combining the production of food and biomass for energy generation on the same plot; or by making multiple uses of each agricultural product and its residues.

The concept of Integrated Food and Energy Systems (IFES) as such is not new. Simple integration of food and energy production at both small and large scales has shown many successful results. However, with the increasing complexity of the system, - and hence higher resource use efficiency, the number of successful cases diminishes. Concrete results on wide-scale implementation of more complex IFES are scarce. Few attempts have been made to assess the challenges that true resource-efficient IFES face (Sachs *et al.* 1991; Woods *et al.* 2006), and proper reports that evaluate research and pilot projects years after their implementation are hard to find.

Given this situation, FAO held an international technical consultation in July 2010 on "How to make integrated food-energy systems work for both small-scale farmers[1] and rural communities in a climate-friendly way". This paper draws on an extensive review of literature and the findings of this technical consultation to identify what hinders IFES, in particular, and some key solutions that could help to realize their benefits on a wide scale. It starts by introducing the IFES concept and potential benefits, as well as some example of IFES in both developed and developing countries. It then briefly discusses the constraints related to IFES implementation, both at the farm level and beyond the farm, before venturing to suggest some possible solutions to overcome these constraints.

[1] There is no consistent definition of small-scale farmer, smallholder or small-scale agriculture. The most common approach is to define small-scale farmers by the size of their landholdings, e.g. farmers with less than two hectares of land (CGIAR 2009). Others use these terms often albeit not always appropriately, interchangeably with smallholder, family, subsistence, resource poor, low-income, low-input, or low-technology farming (Heidhues and Brüntrup 2003). Narayanan and Gulati (2002) characterize a small-scale farmer as a "farmer (crop or livestock) practising a mix of commercial and subsistence production or either, where the family provides the majority of labour and the farm provides the principal source of income". This latter definition allows for the inclusion of local markets, i.e. households and rural communities, but also non-local markets for sale of additional surplus, and outgrower schemes related to large-scale production and processing. It will therefore be the one used for the purpose of this paper.



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CHAPTER 2 WHAT ARE IFES?

2.1 DEFINING IFES

Integrated Food Energy Systems (IFES) (Sachs *et al.* 1991) refer to farming systems designed to integrate, intensify, and thus increase the simultaneous production of food and energy in two ways:

Type 1 IFES are characterized through the *production of feedstock for food and for energy on the same land, through* multiple-cropping patterns or agroforestry systems.

Type 2 IFES seek to maximize synergies between food crops, livestock, fish production and sources of renewable energy. This is achieved by the *adoption of agro-industrial technology (such as gasification or anaerobic digestion) that allows maximum utilization of all by-products, and encourages recycling and economic utilization of residues.*

2.1.1 Type 1 IFES

Farming systems that are based on diversification of land use and production are either systems combining the growth of different annual crops, such as multiple-cropping, or systems mixing annual and perennial crop species, i.e. agroforestry: either system is sometimes combined with livestock and/or fish production.

Multiple-cropping patterns are described by the number of crops per year and the intensity of crop overlap. *Double cropping or triple cropping* signifies systems with two or three crops planted sequentially with no overlap in growth cycle. *Intercropping* indicates that two or more crops are planted at the same time, or at least planted so that significant parts of their growth cycles overlap. *Relay cropping* describes the planting of a second crop after the first crop has flowered; in this system there still may be some competition for water or nutrients. *Mixed cropping, strip cropping, associated cropping, and alternative cropping* represent variations of these systems (McGraw-Hill 2007).

Agroforestry is a collective name for land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined in the same management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence (Lundgren 1982). Agroforestry systems fulfil two important roles, providing ecosystem services and productive services. The first role includes practices that ensure food diversity and seasonal nutritional security, and that strengthen resilience to climatic fluctuations. The ecosystem services they provide at landscape level for watershed protection and biodiversity conservation can also be significant. In its second role, agroforestry includes practices that help protect and sustain agricultural production capacity which provides food, fodder, fuelwood, building materials and medicine to the user.

2.1.2 Type 2 IFES

The goal of Type 2 IFES is to maximize synergies between food crops, livestock, fish production and sources of renewable energy. This is achieved by the adoption of agro-industrial technology (such as gasification or anaerobic digestion) that allows maximum utilization of by-products. Type 2 IFES and similar concepts have been described under several different names in the world, e.g. Concept of Circulative Farming System or Biomass Town in Japan, Integrated Three-In-One, Four-In-One or Five-In-One Models in China, or Cascade systems in Germany. However, they all have one core set of characteristics:

- *High productivity:* The cultivation of high-biomass crops should be the first step in establishing IFES, which means basing the production on plants with high photosynthetic efficiencies.
- *Optimal use of biomass, based on the idea that nothing is considered 'waste'*: By-products or leftovers from one process become the starting point for another in cycles that mimic natural ecosystems. This has some practical requirements, i.e. the cultivation of crops that are easily fractionated into food/feed components (the nutritional part of plants) and fuel energy components (the fibrous structural elements of plants); and the means for converting the fibrous elements into usable or saleable energy.
- When appropriate, *crop and livestock integration*: Bioenergy production can reduce the environmental footprint of livestock through the multiple use of animal feed crops. Given that about one third of the existing arable land worldwide is used for growing crops to be fed to livestock rather than humans, there is potential for this to also co-produce bioenergy without significantly reducing the amount of livestock supported.
- *Linking food and energy production:* Anaerobic digestion and pyrolisis are processes that produce both energy and fertilizer, therefore addressing some potential conflicts between food and energy production.

In addition to the characteristics mentioned above, Type 2 IFES sometimes include a microalgae and fish pond component. The nutrient rich slurry from anaerobic digesters can be released into ponds containing microalgae and other aquatic plants that become feed for fish. However, this additional component requires the right climatic conditions which are usually only found in the humid tropics.

Sometimes, both the food and energy component come from the same plant, e.g. sweet sorghum where the grain is used as food or fodder, and the stems are used to produce ethanol. This is a *multiple product crop*, which does classify under Type 2 IFES, since different parts of the plant are used for different purposes. Food security is not threatened since the energy use does not interfere with the food use. However, there are other crops that can supply both food and energy, which do not necessarily classify under IFES schemes. These are plants that can be used as food or as energy feedstock. Since both applications come from the *same* part of the plants, there is competition between the different uses, hence potentially having a negative impact on food security. The production of oil palm or sugar cane in monocultures would fall under this category, when the oil produced goes entirely into bioethanol or biodiesel production. These systems can become IFES when the by-products such as the molasses of the sugar cane processing are used for animal feed. Furthermore, the right policies would need to be in place to ensure the exclusive production of vegetable oil from oil palm, or sugar from sugar cane, in times of food crises. This is the case for sugar cane processing in Brazil, for example.

Type 2 IFES can be fairly simple, such as the production of biogas at farm level described in the Vietnamese case study in Box 2, or rather sophisticated, with recycling of waste as both energy feedstock and animal food, as shown in the Colombian case study (Box 8).

BOX 2

NATIONAL BIOGAS PROGRAMME, VIET NAM

Viet Nam embarked on an integrated land management scheme, following land rights being given to individual farmers. This is supported by the Vietnamese Gardeners' Association (VACVINA), which works at all levels, and has national responsibility to promote this concept – called the VAC integrated system. It involves gardening, fish rearing and animal husbandry, to make optimal use of the land. Traditional fuels such as wood and coal for cooking, are becoming increasingly scarce and expensive, and can contribute to deforestation. Increasing livestock production in rural communities with high population density leads to health and environmental issues from the quantity of animal dung being produced. Biogas digesters are part of the solution offered by this initiative, using the waste to generate energy, and the resultant slurry as a fertilizer to improve soil quality. A market-based approach has been adopted to disseminate the plants. The service provided to those buying the digesters is comprehensive. The customer must have at least four to six pigs or two to three cattle that provide all the inputs (animal dung). Households use the biogas as fuel and slurry as fertilizer. They pay the total installation cost for the digesters to local service providers, and operate the biodigester using instructions provided by local service providers. A biodigester produces enough daily fuel for cooking and lighting. It improves the surrounding environment, whilst livestock produces meat, milk and fish products for local consumption and subsistence farming. Vegetable production is enhanced through use of biogas slurry. Latrines can be added to the system to enable human waste to be used for energy.

Source: FAO / Practical Action, 2009

A recent review of algae-based IFES shows some of the opportunities such systems present, but also the many challenges they would face to be developed on a large scale (FAO, 2010a).

2.2 IFES SCALES AND CONFIGURATIONS

IFES can function at various scales and configurations, from small-scale systems that operate on the village or household level, to large-scale systems adjusted for industrial operations:

- *small- or community-scale,* are mainly for the purpose of self-sufficiency of the rural population;
- *large-scale*, are mostly owned by a large-scale farmer or the corporate sector, and based on commercial activities, but involving and benefiting small-scale farmers.

It is important to know that large-scale IFES can benefit small-scale farmers when they fulfil *two characteristics*:

- adequate involvement of small-scale farmers in decisions and benefits along the value chain; and
- positive impacts on rural communities.

The involvement of small-scale farmers in large-scale schemes can be achieved through *outgrower schemes.* An outgrower scheme is a contractual partnership between growers or landholders and a company for the production of commercial products, in this case feedstock that will be processed into bioenergy by a large-scale unit. This is further discussed in the Section on "Potential solutions" (6.), and also in FAO (2001b); FAO (2007a) and Vermeulen & Goad (2006).

Be it small- or large-scale, the fundamental distinction lies in the ultimate purpose of the system (Sachs *et al.* 1991):

- One is *"farm-centred"*, such as the Vietnamese biogas farm described in Box 2, or in the case of agribusiness, *enterprise-centred*, where the production of energy is a spin-off of agricultural production.
- Another system is the *"energy farm"* unit designed for the production of energy, usually for distribution via conventional means to distant urban markets. One example of this is the Itaipu biogas project in Brazil (FAO 2009), where biogas produced in small to medium farms is transformed into electricity, and part of this electricity is fed into the local grid. This type of system could be expanded into a kind of "public utility" system that provides a social service other than food production, for example, waste water treatment in a manner that simultaneously produces food and energy and reduces the environmental load. Examples of this include urban latrine systems in India, which, coupled with a biogas generator, produce both hot water and street lighting while reducing the sewage treatment problem.
- A third type of IFES is the "*community focused*" system. It seeks to energize daily life in a variety of ways that answer domestic and community needs, such as

cooking and sanitation, as well as individual and community productive needs in agriculture and industry.

2.3 COMBINING DIFFERENT RENEWABLES IN IFES

In many situations, the production of renewable energy can feasibly go well beyond bioenergy alone. Other locally available (non-biological) renewables can be incorporated, such as solar thermal, photovoltaic (PV), geothermal, wind and water power. Technologies for small-scale renewable applications are mature and may often have synergies with agricultural production. For example, small wind pumps can provide water for irrigation to increase productivity. Wind turbines can provide electricity without competing for cropland: by siting them in or around fields, they can harness the wind whilst the crops harness the solar energy, making double use of land.

Technological diversity combined with reasonable simplification can provide more reliable and more flexible solutions that allow IFES to also provide energy needs for modern communities, i.e. electricity, heat and transport energy. Bioenergy combined with other renewables can give greater reliability than if they were separated, as in the case of wind power or solar heating with biomass back-up. Use of other renewables can reduce wood fuel needs, which can reduce the size of a wood lot needed, or create the opportunity to use wood fuel for other things, such as in agricultural processes.

The balance between food and energy production and between self-consumption and excess for markets, needs to be adapted to local needs, farmer capacities (knowledge and economic), physical and environmental conditions. It will change over time and possibly quickly, particularly if economically successful. Thus, it also needs to be able to adapt and change. A lock-in to very high investment technologies, unless economically remunerable in a relatively short time span, may need to be avoided under most conditions.

An example of such an IFES based on different renewable energy systems, combining the use of PVs and biodigesters, is the Tosoly farm presented in Box 8, where solar panels have been recently acquired as a backup and complementary energy source to the anaerobic digester and gasifier. Another such system has been proposed for the Brazilian Northeast Region. It builds on experiences taken from different combined renewable energy systems (RES) in Brazil, and stresses the need to adopt a strong and long-term energy policy towards small size RES, in order to avoid their discrimination by rural and regional communities. Moreover, it emphasizes the importance of acquiring consumer confidence first; people must be invited to participate in the process of decision-making (Borges Neto *et al.* 2010).

2.4 POTENTIAL IFES BENEFITS

2.4.1 Food and energy security

The main driver of implementing IFES in developing countries is the need for food and energy security - the basic requirement for poverty reduction and rural development.

According to the 1996 World Food Summit, food security represents "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."

This implies that energy is available and accessible. Without energy security, there is no food security. Energy is required for cooking most foods, and for boiling (and purifying) water. Energy is needed to make most food eatable and digestible. If energy is scarce, women may be forced to ration cooking time. This can lead to decreases in food consumption or meal frequency. In turn, the nutritional well-being of household members may suffer. Additionally, lack of energy may increase the incidence of illness through bacterial or parasitical contamination resulting from contaminated water or improperly prepared food. Improved access to modern bioenergy such as biogas, wood pellets, or bioethanol or other sources of renewable energy, significantly improves the health condition of rural people in developing countries, especially women and children, and IFES can contribute to this improvement.

IFES can directly improve the farmer's livelihood when the farmer or local community becomes self-sufficient in terms of food and energy production, or when the food and/or energy generated provides income to the farmer or community. Access to sufficient energy for basic services and productive uses therefore represents the key to improve livelihoods in the poorest countries and drives local economic development on a sustainable basis. Basic services comprehend the provision of electricity for lighting, health, education, communication and community services (50-100 kWh per person per year) and modern fuels and technologies for cooking and heating (50-100 kgoe of modern fuel or improved biomass cooking stove). Energy for productive use is given when electricity, modern fuels and other energy services are in place to improve productivity, e.g. water pumping for irrigation, fertilizer production, agricultural processing, and transport fuels (AGECC 2010).

Finally, by reducing the use of fossil fuels in agriculture, IFES also reduce the risk that inputs, which are necessary to increase productivity, become unaffordable due to the high price of fossil fuels. This is an important consideration, given that the necessary significant increase in food production in the decades to come will be achieved mainly through yield increase (FAO, 2010d).

2.4.2 Maximizing resource efficiency

Although food and local energy security are usually taken for granted in *developed countries*, there is still an increased interest in combining food and energy production. This is mainly based on the fact that land is anything but an abundant resource in most industrialized nations. In densely-populated regions such as the Netherlands, energy crop introduction is strongly hampered by lack of available land (Londo 2002), and improving resource efficiency is therefore among the top priorities in today's world, as governments, businesses and civil society are increasingly concerned about natural resource use, environmental impacts, material prices and supply security (OECD 2008).

Resource efficiency, at its most basic, means the efficiency with which resources such as land, water, biomass and workforce are used in simple processes and turned into valuable products (AGECC, 2010). This is achieved when the same level of a given output or service is produced with a lower total amount of inputs and resources e.g. reducing the amount of land cultivated by intercropping food feed and fuel crops. Alternatively, resource use becomes more efficient when more goods or services are produced with the same amount of resource inputs, e.g. producing food, feed and fuel production from one crop, by making full use of all by-products.

2.4.3 Addressing climate change

While the main drivers behind IFES are often safeguarding food, feed and energy security and improving resource efficiency, IFES also addresses several challenges posed by climate change and climate variability. These are among the most important challenges facing developing countries due to their strong economic reliance on natural resources and rain-fed agriculture. Adaptation should enable agricultural systems to be more resilient to the consequences of climate change. Mitigation addresses its root causes, thereby limiting, over time, the extent and cost of adaptation, as well as the onset of catastrophic changes (FAO 2009).

Agriculture accounts for roughly 14 percent of global greenhouse gas emissions (GHGs) or about 6.8 Gt of CO_2 equivalents (e) per year (IPCC 2007). When combined with related land use changes, including deforestation (for which agriculture is a major driver), this share becomes more than one-third of total GHG emissions. About 74 percent of total agricultural emissions originate in developing countries (IPCC 2007) where food, feed and fuel for the consumption of both developing and developed countries are produced. With regards to emissions from energy use, it is necessary to distinguish between basic energy needs and productive uses. While universal access only to the most “basic human needs” levels of energy services will have a limited impact on GHGs, as basic universal electricity access would add around 1.3 percent of total global emissions in 2030 (IEA 2009). Increasing the level of energy provision and consumption for productive uses could increase emissions substantially (AGECC 2010).

2.4.3.1 Adaptation to Climate Change

In order to minimize the risks of climate change and climate variability, it is important to diversify farming systems through the integration of cropping, livestock, forestry and fisheries systems, the conservation of ecosystems, their biodiversity, and resilience and ecosystem services. It is also necessary to link climate change adaptation processes to technologies for promoting carbon sequestration, substitution of fossil fuels, and promote the use of bioenergy (FAO 2007).

This is closely related to the “Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change” of the United Nations Framework Convention on Climate Change (UNFCCC).

As of October 2008, the UNFCCC Secretariat had received National Adaptation Programmes of Action[2] (NAPAs) from 38 Least Developed Countries (LDCs), of which 80 percent are falling under the category "Food Security and Agriculture". Among these, IFES are suggested by different countries as a local means of adaptation to climate change, sometimes explicitly, as in the case of São Tomé and Principe – see Box 3, and sometimes indirectly as part of the country's energy strategy, as in the case of Rwanda (UNFCCC 2008a).

BOX 3

INTEGRATED LIVESTOCK DEVELOPMENT IN THE NORTH OF SÃO TOMÉ ISLAND

Climate change enhances the lack of animal foods in the northern part of São Tomé, due to the occurrence of drought. This might lead to the loss of cattle, as happened recently in Kenya. Among livestock, the goat is most adapted to drought conditions, since it can feed on pastures of smaller nutritional value and it needs less drinking water than other livestock, such as poultry and pigs. It produces milk, cheese and local meat - products that are deficient in the country. Goat manure can be used for fertilizer production, and/or energy generation through biodigestion. This pilot project should be implemented by the livestock sector, through the establishment of dynamic partnerships between the Agriculture, Forest, and Environment sectors and international, bilateral or multilateral technical cooperation. The results could be disseminated by local companies and family producers, and be further economically and technically developed.

Adapted from UNFCCC (UNFCCC 2008b)

More specifically, IFES have the potential to contribute to local adaptation to climate change through:

- *Soil conservation* when IFES systems include the incorporation of organic matter in the soil (e.g. compost from crop residues or slurry from biogas production). Climate change adaptation for agricultural cropping systems requires a higher resilience against both excess of water (due to high intensity rainfall) and lack of water (due to extended drought periods). A key element to respond to both problems is soil organic matter, which relies primarily on the incorporation of crop, forest and livestock residues in the soil. In addition, residues deliver essential minerals, and constitute an important source for soil carbon and a medium for soil's micro-and macro-organisms.

[2] NAPAs provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs to adapt to climate change – those for which further delay would increase vulnerability and/or costs at a later stage.

- *Increase of biodiversity* when IFES are based on diversified land use and production. Biodiversity increases resilience to changing environmental conditions and stresses. Genetically-diverse populations and species-rich ecosystems have greater potential to adapt to climate change. Through the use of different types of crops in multiple cropping patterns or agroforestry systems in Type 1 IFES, the risk of biodiversity loss decreases, and sometimes local biodiversity even increases.
- *Financial resilience* due to IFES, especially those relying on the use of by-products Type 2 IFES, can lead to more self-sufficiency in some inputs, such as organic fertilizer and/or animal feed and energy; hence reduced debt and easier access to inputs which become more important under uncertain production conditions.

2.4.3.2 Mitigation of Greenhouse Gas Emissions

Mitigation of GHGs in agriculture and other land use sectors includes measures that: (i) reduce emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Cole *et al.* 1997; IPCC 2001; Paustian *et al.* 2004); (ii) sequester carbon in soils or biomass; and (iii) avoid emissions from fossil fuels or displace them with biomass energy. IFES have the potential to contribute to the global mitigation of climate change through GHG emission reduction, carbon sequestration and the avoidance of emissions.

i. Reduction of GHG emissions

Emissions of CO_2, CH_4 and N_2O can be controlled through sustainable agricultural practices. For instance, practices that deliver added N more efficiently to crops often suppress the emission of N_2O (Bouwman 2001). Improved manure management in the livestock sector can reduce CH_4 emissions by capturing the gas in covered manure-storage facilities (biogas collectors). Captured CH_4 can be flared or used to provide a source of energy for electric generators, heating or lighting (which can offset CO_2 emissions from fossil fuels) (FAO 2009b).

Furthermore, IFES reduce pressure on land use through intercropping of food and energy feedstocks and/or the use of residues such as food, feed or fuel. As a consequence, GHG emissions that would have occurred from new land conversion for food, feed and fuel production are reduced or avoided. A recent study found that the more systematic use of by-products could amount to a reduction of ten to 25 percent of land needed to produce liquid biofuels, depending on the GHG reduction targets and use of second generation biofuels (Croetzen *et al.* 2008).

By-products used in Type 2 IFES also affect indirect land-use change (ILUC). When bioenergy crops generate feed as by-products and feed production elsewhere can be avoided, the indirect land-use change is smaller. For instance, using the example of animal feed products from rapeseed and wheat as a substitute for imported soybean in Europe, Ros *et al* (2010) contend that, based on the protein content of the by-product and soybean, the land use for soy cultivation can be reduced by 50 to 100 percent compared to the land used for the cultivation of the rapeseed and/or wheat depending on the yields of the concerned crops and by-product characteristics (see Box 4 for how IFES can mitigate the risk of indirect land use change).

BOX 4

HOW IFES CAN MITIGATE THE RISK OF INDIRECT LAND USE CHANGE

Approaches to address indirect land use change (iLUC) through expansion of biofuel crops have intensively been discussed between different stakeholder, particularly for the purpose of biofuel certification, e.g. under the GBEP and RSB. Most efforts have been undertaken to quantify potential iLUC effects through modeling. This exercise has shown many different results to-date, mainly due to different assumptions underlying the given models, and an agreement between different stakeholders is not to be expected in the near future. However, a necessary complement to risk quantification, has hardly been taken into account so far – i.e. the prevention and/or mitigation of unwanted effects related to iLUC.

There are several mitigation options available that can address this issue, but the current debate lacks concrete information on **how to make mitigation options work in practical terms**: How do farming practices look like in technical and agronomical terms? How should intuitions be structured to support the implementation of the options available? Which policies need to be in place to incentivize certain models and best practices? Which would be the best option for reducing greenhouse gas emissions and environmental impact in general? How can small-scale farmers and private companies benefit alike?

Integrating food and energy production through *physical integration* of different crops (Type 1 IFES) and, mainly, through the *use of by-products* in one production system or across regions (Type 2 IFES) is suggested to be an effective approach of mitigating iLUC (e.g Ecofys 2010, Tilman *et al.* 2009). Implementing IFES leads to increased land and water productivity, therefore reducing greenhouse gas emissions and increasing food security. Moreover by combining food and energy production, IFES reduce the need to convert land to produce energy, in addition to land already used to agriculture. This further reduces the risks associated with land conversion – hence additional GHG emissions Several recent scientific studies substantiate the mitigation of iLUC through IFES options, particularly Type 2 IFES, with concrete data. A report commissioned the Netherlands Environmental Assessment Agency (Ros *et al.* 2010) comes to the conclusion that if by-products from rapeseed and wheat are used for feed substituting soy meal, the land use for soy cultivation can be reduced by 50 to 100% compared to the land used for the cultivation of the rapeseed and/or wheat depending on the protein content. Therefore, by-products used for feed may substantially change indirect effects of land-use change and overall greenhouse gas emission reductions from biofuel production. An in-house literature review conducted for DG Energy as part of the European Commission's analytical work on iLUC (EC 2010) finds that taking into account of co-products reduces the estimated land requirement significantly - between 23% and 94%.

The significant GHG reduction potential of (mainly type 2) IFES makes these systems good candidates for carbon finance, as illustrated in Box 5.

BOX 5. CARBON FINANCE FOR SMALL-SCALE FARMERS

Only ten percent of Nepalese households are connected to the power grid, and most energy comes from traditional fuels. The dependence on fuelwood has contributed to deforestation, resulting in fuelwood scarcity and widespread erosion. Fossil fuel is expensive for many rural people. The villagers often spend hours collecting fuelwood in order to cook a proper meal each day. The project aims to develop biogas use as a commercially viable, market-oriented industry in Nepal. Between 2004 and 2009 the project planned to install 162 000 quality-controlled, small-sized biogas plants in Nepal. The provision of subsidies has been a key element in making these biogas plants accessible to poor households. The biogas plants displace traditional fuel sources for cooking-fuel wood, kerosene, and agricultural waste and introduce the proper treatment of animal and human wastes, as well as produce a high-quality organic fertilizer. Each biogas plant can reduce 4.6 tCO_2e annually. The project will generate a total of approximately 6.5 million t CO_2e during the crediting period of ten years.

Source: World Bank, no date

ii. Carbon sequestration

Agricultural ecosystems hold large reserves of carbon (IPCC 2001), mostly in soil organic matter. Any practice that increases the photosynthetic input of C or slows the return of stored C via respiration or fire will increase stored C, thereby 'sequestering' C or building C 'sinks' (Smith *et al.* 2008). This can be achieved by avoiding burning and soil movement during land clearing, avoiding deforestation, afforestation, increasing soil organic matter levels, and by crop and grazing land management, in particular, by avoiding soil tillage. Soil carbon sequestration is estimated to be nearly 90 percent of the technical mitigation potential of agriculture (IPCC 2007).

IFES contribute to carbon sequestration though the inclusion of perennial crops in farming systems, which characterize Type 1 IFES, such as agroforestry systems which are explicitly recommended as mitigation strategy by the IPCC (Smith *et al.* 2007); and through Type 2 IFES ('zero-waste' systems) which provide alternative sources of energy to traditional fuelwood. Such use often leads to forest depletion, and even deforestation in areas under severe population pressure (e.g. refugee camps, peri-urban areas).The significant climate change mitigation potential of IFES implies that such systems should be considered as important ways to achieve objectives under REDD[3] in developing countries.

However, the use of primary biomass residue for energy can compete with its use to directly sequester carbon in soils. Only in cold and moist climates is the quantity of biomass produced higher than the carbon storage potential for organic matter in soils. In those cases, removing biomass for bioenergy production can work. In tropical conditions this might not be feasible for at least the next 30 to 50 years, until the carbon gap in the soils is closed [Friedrich, personal communication].

Therefore, bioenergy generation which produces energy and soil fertilizer and amendments (such as slurry from anaerobic biodigestion, and biochar from gasification) and at the same time, allows for about 50 percent return of carbon to the soil (UNCCD 2008), should be favoured.

iii. Avoidance or displacement of fossil fuel use

Crops and residues from agricultural lands can be used as a source of fuel. This is only sustainable if the feedstocks produced have lower life-cycle GHG emissions than fossil fuels and do not compete with food production for land and water. Biomass can be converted to liquid transport fuels such as bioethanol or biodiesel (Cannell 2003; Schneider *et al.* 2003). After initial enthusiasm for liquid biofuel production, concerns arose around the danger of displacing either food production or natural habitats due to mass production of crops specifically for biofuels. While the issue is still highly controversial, some argue that food production and feedstock cultivation for bioenergy generation are not necessarily mutually exclusive. By combining food and energy production simultaneously, the food-energy dilemma related to biofuels could be significantly mitigated, and impacts regarding elevated GHG emissions could perhaps be solved in a sustainable way.

Tilman *et al.* (2009) sum it up neatly in a recent paper: "*Recent analyses of the energy and greenhouse-gas performance of alternative biofuels have ignited a controversy that may be best resolved by applying two simple principles. In a world seeking solutions to its energy, environmental, and food challenges, society cannot afford to miss out on the global greenhouse-gas emission reductions and the local environmental and societal benefits when biofuels are done right. However, society also cannot accept the undesirable impacts of biofuels done wrong. Biofuels done right can be produced in substantial quantities. However, they must be derived from feedstocks produced with much lower life-cycle*

[3] Reducing Emissions from Deforestation and Degradation, in short REDD, in Developing Countries - is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. For further information, please refer to http://www.un-redd.org.

greenhouse-gas emissions than traditional fossil fuels and with little or no competition with food production".

Combining the production of food and energy crops on the same piece of land, or making full use of all by-products as food, feed, fuel and fertilizer belong to "biofuels done right". Hence, IFES present a potential solution to produce biofuels for transport in a more sustainable way.

Several initiatives support this view. The German Advisory Council on Global Change (WBGU), for instance, suggests to follow an integrated food and energy security strategy to mitigate risks associated with the current bioenergy boom, adding to recommendations given by the German Federal Cabinet in its report on "Global food security through sustainable development and agriculture" (Bundeskabinett 2008). This is further elaborated in WBGU's recent publication "World in Transition – Future Bioenergy and Sustainable Land Use (WBGU 2010), stating that "the strategy would be especially valuable for the least developed countries".

A recent report by FAO, "State of Food and Agriculture 2009", focusing on livestock-related issues (FAO 2009b), further stresses the importance of mixed crop livestock systems, and points to beneficial synergies that might occur when mixed farming systems and bioenergy production for transport, or other energy purposes, are linked in a sustainable way. However, at the same time, the report shows the negative impacts that large-scale biofuel production for transport can have, and has had, on the agricultural sector, when the wrong approach is taken (Box 6).

BOX 6

CROP LIVESTOCK SYSTEMS AND BIOFUEL PRODUCTION

Most traditional livestock production systems are resource driven, in that they make use of locally available resources with limited alternative uses, or, expressed in economic terms, low opportunity costs. Examples of such resources include crop residues and extensive grazing land not suitable for cropping or other uses. At the same time, in mixed production systems, traditionally managed livestock often provide valuable inputs to crop production, ensuring a close integration.

The rising demand for livestock products is changing the relationship between livestock and natural resources. Modern industrial production systems are losing the direct link to the local resource base and are based on bought-in feed. At the same time, some of the resources previously available to livestock at a low cost are becoming increasingly costly, because of growing competition for the resources from other economic sectors and other activities such as production of biofuels.

The separation of industrialized livestock production from the land used to produce feed also results in a large concentration of waste products, which can put pressure on the nutrient absorptive capacity of the surrounding environment. In contrast, grazing and mixed farming systems tend to be rather closed systems, in which waste products of one production activity (manure, crop residues) are used as resources or inputs to the other.

Growing use of cereals and oilseeds to produce fossil fuel substitutes – ethanol and biodiesel – represents a significant challenge for the livestock sector in terms of competition for resources, especially regarding elevated prices and lower availability of crops for feed. However, biofuel production creates valuable by-products, such as distillers' dried grains with solubles (DDGS) and oilseed meals that can be used as animal feed and can substitute grain in animal rations. Biofuel by-products can offset feed costs for the livestock industry. At the same time, biofuel by-products represent an important component of biofuel industry revenues.

Source: FAO 2009b

CHAPTER 3

IFES IN DEVELOPED COUNTRIES

The use of biomass as a renewable source for energy and bio-based chemicals has become of increased global interest in recent times. However, a growing bio-based economy is recognized to pose several challenges to maintaining both food security and natural resources. While the conservation of natural resources, such as the prevention of nitrogen leaching into rivers in highly intensive agricultural settings, has been on the agenda of developed nations for some time, safeguarding food security has been mostly considered a challenge that the developing world is facing.

Nonetheless, with an increasing shift from a petroleum-based to a bio-based economy, and a trend towards increased resource efficiency, especially land use efficiency, integrating food and energy production has become visible on the agenda of industrialized nations too. Academia, industry and governments, have addressed this need and made suggestions as to how to put sustainable farming systems combining food, feed and energy production, into practice.

The nature of IFES will greatly depend on the type of agriculture prevailing in the region. Climate will influence the kind of crops grown; labour costs will have a bearing on the scale of production and degree of mechanization. As a contrast to systems in developing countries, this section will outline some examples of Type 1 and Type 2 IFES in the developed world.

3.1 TYPE 1 IFES

Heggensteller *et al.* (2008), for instance, suggest double-crop systems that have the potential to generate additional feedstocks for bioenergy and livestock utilization, and also to reduce nitrate-nitrogen leaching relative to sole-crop systems. Field studies were conducted near Ames in the United States to evaluate productivity and crop and soil nutrient dynamics in different bioenergy double-crop systems. The results demonstrated that both forage triticale together with corn and forage triticale and sweet sorghum biomass double-cropping systems have the capacity to produce more combined dry matter yields than dry matter production by conventionally managed, sole-crop corn. They further found that the combined biomass and grain output of a triticale and corn double-cropping system could be used to generate greater quantities of ethanol per unit land area than the biomass and grain output of a sole-crop corn system. However, the study also showed that sustained removal of large quantities of nutrient-dense biomass from double-cropping systems would necessitate increased fertilization or integration with nutrient recycling mechanisms.

While multiple cropping systems, including energy and food crops do receive increased attention in industrialized countries, the distribution of agroforestry systems in developed nations is much lower than in developing nations. In Europe, for example, most types of agroforestry practices described around the world existed at different levels of intensity in the past. However, there was a notable decline in the implementation of agroforestry practices in Europe in the 20th century, when agriculture was intensified, specialized and promoted. Most extended agroforestry practices nowadays in Europe are silvopasture and silvoagricultural (Mosquera-Losada *et al.* 2009).

In Spain, for instance, as in the rest of the Mediterranean basin, land use shaped and organized the present landscape for centuries. Agriculture (mainly grazing) and forest management, created an integrated and structured mosaic landscape of agroforestry systems with high cultural and biological values. Nevertheless, as a consequence of the shift from the primary to the tertiary sector which took place throughout Spain during the second half of the last century, traditional and sustainable multifunctional activities were abandoned or substituted with more purely production-oriented ones. As a consequence, traditional uses of agroforestry systems, mainly extensive livestock and multipurpose forestry for timber, wood fuel or charcoal declined (Casals *et al.* 2009). While recent EU Rural Development policy clearly recognizes the economic, ecological, and social advantages of agroforestry systems, to date the (re)implementation of such systems remains poor throughout most of Europe (Rigueiro-Rodríguez *et al.* 2009).

Some traditional agroforestry systems do still exist. The Dehesa and Montados are the largest agro-silvo-pastoral systems in Europe, located in Spain and Portugal, covering about 3 million hectares of widely spaced oak trees, which are used mainly for fodder and shade for livestock, but also for provision of fuelwood. They are mixed with pastures or intercropped with fodder crops or cereals.

Recently, agroforestry systems that focus on wood production for energy purposes have become particularly popular. Short rotation coppice (SRC) plantations, consisting of fast growing trees or shrubs, which are characterized by higher wood productivity than conventional cultivated forests, are mainly grown for producing wood fuel for heat and power production. SRC of willows (*Salix spp.)* operates on a commercial basis in Sweden over some 15–17,000 ha for biomass energy production, but remains experimental elsewhere in Europe (Eichhorn *et al.* 2006). Most SRC plantations are monocultures or do not include a food component. However some studies have looked at the potential to intercrop SRC trees with food producing perennials such as nut and fruit bearing trees, or agricultural annual crop species (CFS 2010; Clinch *et al.* 2009).

Inter-cropping or alley cropping of poplar (*Populus spp.*) with agronomic and horticultural crops, and for silvopastoral systems, is another common approach, practiced in northern countries. According to Isebrands (2007), the duration of inter-cropping opportunities varies with the spacing between the poplar rows in the field. Traditional ten foot rows allow alley cropping for the first two to three years before tree canopy closure which limits the light, water and nutrients available for the companion crop. Longer duration is possible with wider spacing such as 20 to 30 feet between rows. The following crops have been successfully used for inter-cropping with poplars in different parts of the world (Nair, 1993): barley, buckwheat, clover, corn, lespedeza, melons, oats, potatoes, rye, soybeans, sugar beets, sunflowers, vegetables, vetch and wheat. Poplar wood, chips, or pellets can be burned directly for energy purposes or mixed with coal to produce electricity.

There are also opportunities for silvopastoral operations as commonly practiced in Italy and New Zealand (Isebrands 2007) where poplars are grown at wide spacing and on long rotations. Poplars must be protected from livestock in the first five years or more of the rotation. Silvopastures provide mutual benefits for poplars and animals. The animals benefit from the shelter provided by the poplars, and the trees benefit from the animal manure and weed control provided by controlled and managed animal grazing that minimizes compaction. Furthermore, the foliage from poplars is rich in protein and can provide a valuable source of animal feed.

3.2 TYPE 2 IFES

In Europe and North America, agricultural production and processing tends to be large-scale. The starting point for a Type 2 IFES may be an annual biofuel crop such as corn or wheat. Where grains are grown primarily for biofuels, the co-products can be used for animal feed. Where they are grown for food, the crop residues can be used for bioenergy.

In the latter case, much attention has been given, particularly in North America, to cellulosic ethanol from food crop residues such as corn stover, therefore not competing with food production, but this technology still faces obstacles to commercialization. However, there are currently commercial energy uses for biomass: in the UK, a 38 MW power station near Ely in Cambridgeshire (see also Box 10) runs on straw, taking 200 000 tonnes per annum. As fertilizer costs increase, the recycling of nutrients becomes a commercial, as well as environmental imperative and ash from straw combustion can be returned to local farmers' fields. A proportion of biomass needs to be returned to the soil, usually in the form of crop residues or manure, to maintain structure and fertility.

Slurry from pig or dairy farms can be used for anaerobic digestion for biogas production, which is another way of generating bioenergy without competing with food production. A study in the UK (Mistry *et al.* 2007) showed that centralized anaerobic digestion can bring about significant benefits for treating dairy slurry, with the biogas being fed into a combined heat and power (CHP) unit. Payback times for different scenarios varied from three years to never (running at a loss). The economics depended on factors such as transport costs incurred taking the slurry to the digester, which constituted around a third of the operational costs.

The other IFES approach is to grow a crop primarily for biofuels and use the co-products and by-products for food production. Again, wheat or corn may be used, as well as sugar beet for bioethanol, and occasionally oilseed rape for biodiesel. Large volumes of biomass can be processed, with typical world scale ethanol plants taking around 1 million tonnes of grain or more per year. The animal feed co-products are often dried and transported to a feed producer, but may be fed fresh to livestock nearby. Such scales of operation create great challenges for adding correspondingly large livestock units to make use of the feed co-products. One solution may be to feed a portion directly to livestock and export the rest. Some have opted for smaller-scale ethanol plants with livestock integrated from the outset, seeking to add value to all the co-products rather than export them. A good example of this is the Canadian company, 'Poundland,' which has been raising cattle next to an ethanol plant since 1970. The cattle feedlots have benefited from the distillers' grains from the corn ethanol plant, which are high in protein. This saves on costs of drying and transporting the product to feedlots further away, which is the standard practice. More than a third of distillers' grains in the USA are fed wet to livestock (Renewable Fuels Association 2008), which signifies that the animals are kept in the vicinity of the ethanol plants.

Whilst there are many examples of the systems outlined above, a small handful of companies have gone further and brought the two together. Biofuel crops are grown with the co-products used for animal feed. The livestock by-products are themselves used for energy (usually AD of manure). In such integrated systems it can be quite difficult to distinguish a main product, as all the processes are intertwined with multiple outputs and recycling. This approach is sometimes called a 'closed loop' system. The following table (Table 1) provides a summary of 'closed loop' bioethanol plants in North America, which typify this approach. The systems are all broadly similar, resulting in the co-production of ethanol and beef or dairy products.

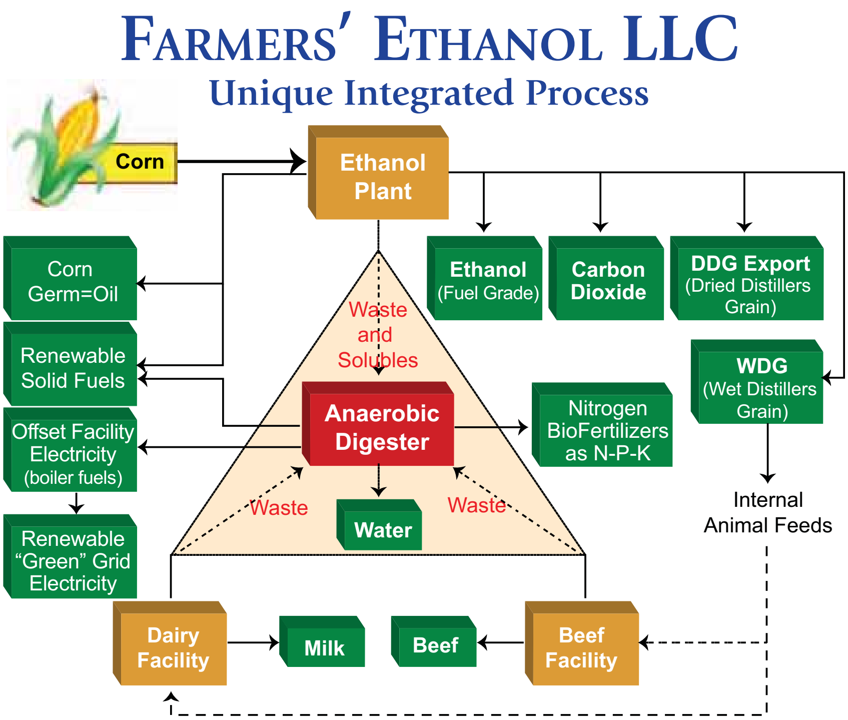
TABLE 1

Summary of 'closed loop' bioethanol plants in North America

Name	Location	Litres Ethanol/yr	Head/Livestock	Status
E3 BioFuels	Mead, Nebraska	114 million	30,000 (dairy)	Closed 2007
Panda Ethanol	Hereford, Texas	435 million	Unspecified (beef)	Closed 2009
Bion	New York State	225 million	70,000 (beef)	Planning
Poundmaker	Saskatchewan, Canada	13 million	28,500 (beef)	Operating since 1970
Farmers' Ethanol	Cadiz, Ohio	Unspecified	10,000 (beef) 2,000 (dairy)	Planning / Construction

Each of the companies above has integrated – or plans to integrate – cattle with ethanol production, to make use of the high protein co-product as livestock feed. The two that closed were reported to have struggled mainly with issues not directly related to the 'closed loop' element, but rather engineering or construction problems with the 'standard' part of the plant. With any system, the manure from the cattle can be used in various ways. Some have opted for anaerobic digestion, which is particularly appropriate for dairy slurry, because of its high moisture content. Panda chose gasification and Bion has developed a proprietary wastewater treatment technology to extract energy and nutrients from the manure. In each case, the energy is used in the ethanol plant to process heat, strengthening the synergies between the two operations. Farmers' Ethanol (Figure 1) is a company planning to open several plants utilizing this principle, starting in Cadiz, Ohio. The schematic below gives an overview of their multi-product approach, with anaerobic digestion making up a key element.

FIGURE 1
Farmers' Ethanol, Ohio



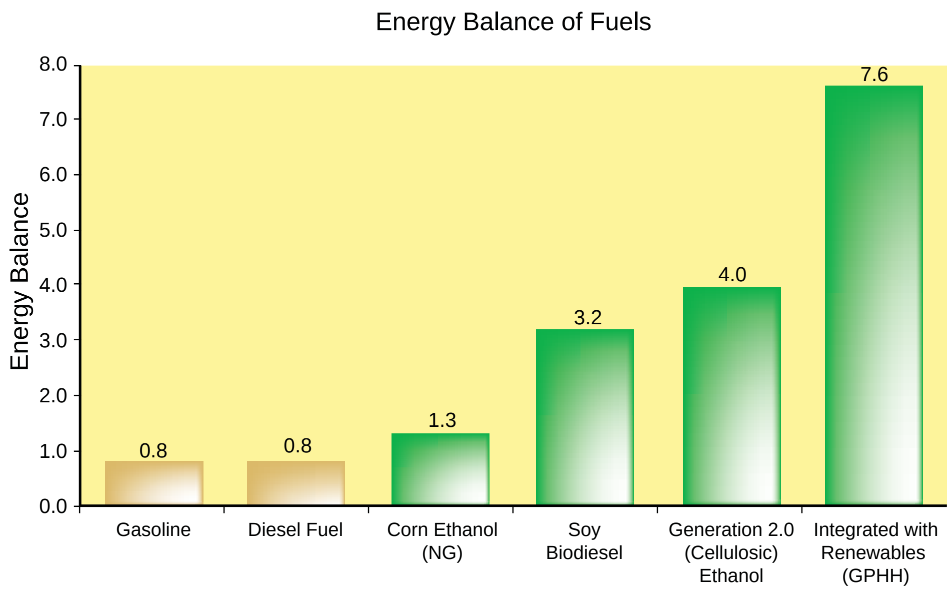
Source: Farmer's Ethanol LLC (no date)

Although most plants seek to extract energy from the livestock manure, the exception among our examples is Poundmaker, who simply return the manure to the local farmers' fields and consider the low-cost animal feed alone as sufficient incentive to co-locate the livestock. Although this may appear to be a missed opportunity, the carbon in the manure is not wasted as it replenishes the soil carbon levels. A recent report from Michigan State University illustrates how livestock manure is more effective in this regard than returning crop residues to the soil. Therefore, by integrating livestock with arable cropping, more crop residues can be harvested for bioenergy if desired, rather than ploughing back into the soil to maintain organic matter (Thelen *et al.* 2010).

Anaerobic digestion of manure can be a stand-alone technology, as can any other element of the 'closed loop' systems described: they do not have to all be integrated in one system. However, there are numerous benefits from doing so, both economically and environmentally. A recent study of the potential for Type 2 IFES in the UK listed some of the economic benefits as economies of scale (in livestock production, AD and biogas use), reduced costs of biomass drying and transport, and lower livestock feed costs (Jamieson *et al.* 2010). Environmentally, the energy balance (energy out compared with energy in) has been estimated to be as high as 7.6 to 1 for corn ethanol in a Type 2 IFES, as illustrated in the right hand bar of Figure 2 below, which is approaching that of sugar cane ethanol at 9 and a drastic improvement on 'conventional' corn ethanol of around 1.3 to 1.7.

FIGURE 2

Energy balance of selected transport fuels[4]



[4] http://highmark.ca/index.php?area_id=1006&page_id=1027&article_id=29

CHAPTER 4

IFES IN DEVELOPING COUNTRIES

4.1 TYPE 1 IFES

Most Type 1 IFES cases in the developing world are agroforestry systems which, next to other productive uses, serve as a provider of fuel wood. In India, for example, an estimated 24,602 million (Prasad *et al.* 2000) trees outside forests supply 49 percent of the 201 million tonnes of fuelwood consumed by the country per year (Rai and Chakrabarti 2001).

Integration of trees in cropping systems can provide significant financial benefits to the farmer, given the existence of a local fuelwood market (Kuersten 1999). The introduction of living fences in Central America was shown to have a significant positive impact on small farm incomes with an estimated internal rate of return of 28.80 percent (Reiche 1991). In El Salvador, intercropping of eucalyptus trees with maize proved to be more profitable than monocultures of either maize or eucalyptus, which was 20 558, 12 013, and 17 807 Salvadoran Colones per hectare respectively (Juarez and McKenzie, 1991).

CIRAD (2010) has promoted the replanting of tree fallows that have been abandoned after three years of slash-and-burn cultivation in Congo. These systems provide both food crops and wood trimmings that can be transformed into charcoal and sold on the local market. Total charcoal production from the plantation, which is divided into plots of 25 hectares and allocated to 320 farming families, currently varies from 8 000 to 12 000 tonnes per year (t/year). In addition, the farmers produce 10 000 t/year of cassava, 1 200 t/year of maize and 6 t/year of honey. For further details see Box 7.

Yet another example from Africa is the successful integration of crops which deliver both food and energy for basic household needs. The "pigeon pea" IFES model in Malawi is an intercropping model between staple foods (mainly maize, sorghums, millets) and pigeon peas (*Cajanus cajan*), a nitrogen fixing double purpose plant, which delivers protein-rich vegetables for human consumption, fodder for animals, and woody plant material for cooking. In contrast to 'improved' varieties that yield more crop but as little biomass as 80g per stem, one stem of local pigeon pea varieties can weigh over 800g. Depending on the variety, the stove technology and the type of meal, on local plant can provide enough energy for a family of five to cook 1-2 meals per day. The average need for cooking fuel on a 3-stone-fire is 3-4 kg/day. On an improved stove like a simple clay stove it reduces to 1.5-2 kg/day. A former GTZ programme on Integrated Food Security in Mulanje promoted pigeon peas among farmers with an average landholding size of less than 0.4 hectare, and many families use pigeon peas now as cooking fuel for 3-8 months per year. If complemented by other agricultural residues like sorghum stalks and maize combs, some manage to cook with their home-grown fuel throughout the entire year using a simple cooking stove, thus omitting the need to collect fuelwood in the nearby forest reserve. Some families claim that they have not bought or collected any firewood in the last 5 years (Christa Roth, personal communication).

BOX 7

SUSTAINABLE FOOD AND CHARCOAL PRODUCTION IN AGROFORESTRY SYSTEMS, DEMOCRATIC REPUBLIC OF CONGO

Kinshasa, the capital of the Democratic Republic of Congo, has a population of 8 million inhabitants and consumes up to 6 million tonnes of bioenergy equivalent per year. The city is surrounded by grasslands and patches of forest. The bioenergy used by the urban households consists mainly of fuelwood (charcoal and firewood). Charcoal needs, but also most of the staple starchy foods in the diet (cassava and maize), are provided by slash-and-burn shifting cultivation and by carbonization of the patches of forest and tree savannahs, which continue to deteriorate. Production obtained from these tree stands is becoming scarce and expensive. Soil fertility is declining, crop yields after fallow are decreasing, springs are drying up and fires are increasingly frequent.

Slash-and-burn cultivation gives rise to tree fallow after one to three years of cropping, due to the exhaustion of soil reserves. Improving tree fallow consists in planting tree legumes, whose roots combined with microorganisms fix atmospheric nitrogen. Organic matter and nitrogen storage in the soil is thereby accelerated. This is especially true for acacias, trees that are also known for their large biomass/wood production. The trees can already be planted during the cropping period and continue to grow rapidly after harvesting, during the fallow phase.

The development of the plantation and the integration of the local population

The Mampu plantation, about 140 km east of Kinshasa, was originally designed as the pilot phase in a vast reforestation project covering 100 000 hectares of sandy soils on the Bateke plateau. Between 1987 and 1993, 8 000 hectares of Acacia auriculiformis were planted. From 1994 onwards, the Mampu plantation was divided into plots of 25 hectares allocated to 320 farming families. Farmers were required to manage their new tree plantation following a novel agroforestry technique that combines food crops with acacia.

Two or three years after planting the trees, once agricultural products have been harvested, the acacias reach a height of three metres. After around ten years, a veritable acacia forest, mixed with a few local species, becomes established. Farmers can then exploit it, process the wood into charcoal and sell it in town. In the unharmed humus, they can replant a new crop cycle.

Total charcoal production from the plantation currently varies between 8 000 to 12 000 tonnes per year (t/year). In addition, the farmers produce 10 000 t/year of cassava, 1 200 t/year of maize and 6 t/year of honey. For the individual farmer, using 1.5 ha of his parcel, this means in income of about US$9 000 per year (US$750 per month). In comparison, a taxi driver in Kinshasa earns between US$100 to US$200 per month.

Training of the settlers in agricultural and business practices is an integral part of the project, which is managed and organized by the Mampu settlement centre. There are now a nursery, a reproduction box for cassava, a brick factory, a carpentry shop, a workshop, two schools, a hospital, a market and a classroom.

From project development to autonomous management

The project started off with the pilot phase (8 000 ha), which had been implemented by the Company Hollandaise Agro-Industries under the control of the Zaire Trading Engineering Company. The pilot phase was funded by the European Development Fund. From 1992, the Government entrusted the Congolese Hanns-Seidel Foundation with the task of maintaining the infrastructure of the project. After this period, a Memorandum of Understanding was signed between the Congolese Government, the Hanns-Seidel Foundation and the European Union (EU), the latter giving a credit for the maintenance of the plantation. After the completion of the last EU-project cycle in February 2009, the plantation has been independently managed by the "Centre d'Appui au Développement Intégral de Mbankana" (CADIM), a Congolese NGO for rural development, and the Council of the settler community in Mampu, Union des Fermiers Agroforestiers de Mampu (UFAM). Direct consequences are the charging of the well water and the electricity produced. The revenue will be used to maintain the community centre. The Hanns-Seidel-Foundation is now acting as an advisory and controlling body.

Source: CIRAD 2010; Bisiaux et al 2009; Hans Seidel Foundation 2009

While the energy component of traditional agroforestry systems is generally provided through wood-based fuels such as fuelwood, woody agricultural residues or charcoal, recent developments in the biofuel sector have stimulated interest in integrating perennial "biofuel" species such as Jatropha and oil palm into agroforestry systems. However, reports assessing these systems are still scarce, and seldom go beyond research and demonstration level.

Traditionally, jatropha has been planted as a living fence. In Central America, for example, it was demonstrated that it is possible to incorporate a forestry component within small farms by using living fences with fast growing species. This is advantageous for farm delimitation, protection from soil erosion, prevention of trespassing, and keeping animals away from crops (Reiche 1991), at the same time as providing fuel wood. In Africa, jatropha has traditionally been used as a source for herbal medicines, as material for candles and as a hedge to protect crops against animals. Only recently, it has been heavily promoted as a potential source for Pure Plant Oil (PPO) and biodiesel production in some African countries, such as Mozambique (Bos 2010), and Kenya (GTZ 2009).

A field survey was recently undertaken by GTZ (2009) of 289 farmers in Kenya on the agronomic and economic viability of jatropha for biofuel production. The survey concludes that the plant currently does not appear to be economically viable for smallholder farming when grown either within a monoculture or intercrop plantation model. According to the study, the only model for growing jatropha that makes economic sense for smallholders is growing it as a natural or living fence with very few inputs. However, it should be noted that jatropha intercropping systems assessed in this particular study included different types of intercrops, varying from maize, beans, peas, cassava to even bananas and vanilla. Since different crops have different needs in terms of inputs (water, soil, nutrients) and do react differently under the influence of other crops (in this case jatropha), potential synergies or competition will vary greatly. For example, banana can completely shade jatropha and reduce yields and branch development unless sufficient space is allowed (Miyuki Iiyama, personal communication). Some intercrop models can work better for smallholder farmers if proper knowledge and extension service are in place, while others cannot work, but this needs intensive research to verify, and models need to be developed to examine the competitions of water, light, and nutrients (Miyuki Iiyama, personal communication).

Systems integrating oil palms with food crop or livestock constitute yet another approach to Type 1 IFES. Many examples can be found throughout Malaysia, for instance, where these kinds of agro-pastoral systems have been promoted to increase farmers' income and to create new jobs (Agro-Info Bulletin 2007), although not all of the plantations produce oil for biodiesel production, but rather for human consumption. According to plans of the East Coast Economic Region (ECER) of Malaysia, it would be optimal to introduce one cow on every four hectares of oil palm plantation, which will amount to 135 000 animals in the entire ECER. The Malaysian Palm Oil Board (MPOB) estimates that about half of the one million hectares of land planted with oil palm in the region would be suitable for integration of cattle and palm oil. Grazing would need to be rotational in order to avoid harm to the production of oil palm. While MPOB stresses the potential for smallholders, they point out that smallholders with less than three hectares of land may need to form a cooperative in order to achieve a minimum economic size of 100 cows in an area of 400 hectares. Recommendations are based on the successful adaptation of these IFES by smallholders in other Malaysian regions, under the supervision of the Federal Authority for Land Development.

Some companies even integrate different kinds of livestock into palm oil plantations. Ruminant Livestock Sdn Bhd (Ternakan Ruminan SDN BHD 2006) combines the rearing of cows, sheep and goats, mostly for meat production, under palm oil trees. The combination of Type 1 and Type 2 IFES would be feasible here, once the livestock manure has been used to produce biogas and fertilizer.

4.2 TYPE 2 IFES

At the simplest level, Type 2 IFES involves the extraction of energy from agricultural wastes and residues, making use of freely available biomass. A good example of this is the installation of simple anaerobic digesters for biogas production, as illustrated in the Vietnamese case study (Box 2). Higher resource-efficiency can be reached by integrating more and more components into the system. However, the management of such systems becomes increasingly complex, as can been seen in the case of the Tosoly Farm in Santander, Colombia (see Box 8 below).

Type 2 IFES in developing countries usually operate at *household level*, either driven by personal choice (Tosoly farm), or promoted by governments through national support programmes, i.e. small-scale biogas digesters for household use in Viet Nam or China, where the energy produced is usually just enough to provide heat for cooking and house heating.

BOX 8

TOSOLY FARM, SANTANDER, COLOMBIA

TOSOLY Farm is a more complex Type 2 IFES: a highly integrated farm, aiming to produce food and energy for family consumption and for sale in a crop/livestock-based system. The cropping is based on sugar cane (feed for pigs, food and energy) and coffee and cocoa (food and energy), with multi-purpose trees. The 7 ha farm is situated in the Colombian foothills, in the Department "Santander Sur" which is located north of Bogotá. The region is characterized by relatively uniform rainfall and soils that are acidic (pH 4.0-4.50). In order to promote biodiversity, the crops on the farm are replicated in different areas.

Key crops and by-products

The principal crop is sugar cane, presently occupying 1.5 ha but projected to increase to 2 ha as the pasture areas are gradually displaced with more productive crops. Tree crops include coffee, cocoa, and forage trees (chiefly mulberry [*Morus alba*]), and "Botón de Oro" [*Tithonia diversifolia*], forage plants (New Cocoyam [*Xanthosoma Sagittifolium*] and Water Spinach [*Ipomoea aquatic*] and trees for timber and fuel, including a grove of "Guadua(*Guadua angustifolia*), for shading the coffee.

The livestock and fuel components are chosen for their capacity to utilize the crops and by-products produced on the farm. Sugar cane stalk is fractionated into juice and residual bagasse. The tops, including the growing point and some whole stalk, are the basal diet for dual purpose cattle and goats. The juice is the energy feed for pigs and the source of "sweetener" for cooking for the farm family. The bagasse is the fuel source for a gasifier that provides combustible gas for an internal combustion engine linked to an electric generator.

The goats are the means of fractionating the forage trees, consuming the leaves, fine stems and bark as sources of protein, with the residual stems being another source of fuel in the gasifier. The goat unit has ten breeding does and two bucks. There are three pens for two crossbred cows and progeny, kept for multi-purpose production of milk, meat and manure. The pig unit has capacity for 40 growing-fattening pigs and five sows. Forty hens and six ducks are raised in foraging, semi- confinement systems for eggs and meat. Rabbit production is a new venture on the farm, applying the principles of 100 percent forage diets developed in Cambodia, Laos and Viet Nam (Merkan, no date). A horse transports sugar cane and forages. All high moisture wastes are recycled through plug-flow, tubular plastic (Polyethylene) biodigesters.

Pig and human excreta are the feedstock for four biodigesters. Waste water from coffee pulping, washing of dishes and clothes go to a fifth biodigester.

System Integration and Recycling

Effluents from all biodigesters are combined and recycled to the crops as fertilizer. The pens for the *goats and cattle have clay floors covered with a layer of bagasse to absorb the excreta. Periodically* this manure is recycled to the crops as fertilizer and a source of organic matter.

Energy Balance

Most of the energy on the farm is produced by gasification of the sugar cane bagasse and the stems from the mulberry and Tithonia forages. The 800 W installed capacity of photovoltaic panels are estimated to yield 8 KWh daily. The eight biodigesters produce 6m^3 daily of biogas, two thirds of which are converted to electricity (6 KWh/day) using it as fuel in the same IC motor-generator attached to the gasifier. The remainder is employed for cooking. Low grade heat energy, produced by the solar water heater and the wood stove, are not included in the energy balance.

After deducting the electricity used to drive the farm machinery and to supply the house, the potentially exportable surplus is 104 KWh daily, which at the current price of electricity (US$0.20/KWh), would yield an annual return of US$7 600. The gasifier produces 4.4 tonnes of biochar yearly which is returned to the soil. Assuming that the 65 percent of carbon in the biochar is not oxidized in the soil (Lehmann 2007), then the effective sequestration of carbon dioxide is in the order of 11 tonnes annually. The house and machinery combined use 11 KWh/d of electricity. The farm produces ten times this amount, mostly through the gasifier but 8.0 KWh/d comes from the solar panels and 6.0 KWh/d from the biodigester. Therefore, 104 KWh/d is sold to the grid for around US$20, or US$7 558 per year.

Source: Preston, 2010

China has been supporting the development of household biogas installations since the 1970s, and different biogas models have been implemented since then. The “Three in One” model combines a biogas digester with a pigpen and a toilet; the “Four in One” model adds a solar greenhouse to the concept, in regions where agricultural production is compromised by cold weather conditions; the “Five in One” model combines a biogas digester with solar powered barns, water-saving irrigation systems, a water cellar and a toilet (Chen *et al* 2010). Currently 18 million households use small biogas technologies. In addition, 1.4 million people are provided with gas from 700 larger, communal biogas installations through distribution grids (Recycling-Portal 2009). According to the Medium- and Long-Term Development Plan for Renewable Energy in China, 80 million households will be using biogas technologies by 2020 (NDRC 2007).

On a slightly larger scale, on the *community or local levels*, biogas is also given productive uses, including the generation of electricity, as shown on the "*energy farm*" model from the Itaipu biogas project in Brazil (FAO 2009). Biogas produced in small to medium farms is transformed into electricity, and part of this electricity is fed into the local grid.

While biogas technologies are the predominant form of energy generation in Type 2 IFES, there are several innovative technologies forthcoming which might have a large potential for household and community level use. The pyrolitic Lucia Stoves, for example, are efficient cooking and heating stoves, home furnaces, and combined heat and power (CHP) units, which at the same time produce charcoal. While standard charcoal production methods in countries like Madagascar require 5-7 tonnes of premium wood to make 1 tonne of charcoal, the LuciaStove technology allows the end user to take between 2-3 tonnes of waste biomass to produce 1 tonne of biochar, while creating 50-90 percent fewer emissions (Worldstove 2010). Pilot programmes have been conducted in several locations throughout Africa, Asia, and Central America.

Systems at the *larger scale* (mostly industrial), are predominantly in the hands of one company, and do not involve small-scale farmers as feedstock providers. The main purpose of integrating biogas technologies is usually the treatment of wastewater, rather than biogas production, as such. China has a steadily growing livestock and poultry industry, and consequently problems with environmental pollution. An example is Fushan farm in Hangzhou, with 32.47 ha of paddy fields, 4 ha of tea trees, 13.7 ha of water shields and 7.3 ha of fishponds. It also produces 30 000 laying hens, 150 000 broilers, and 8 000 pigs a year, with 15 tonnes of solid waste and 70 tonnes of wastewater discharged daily. By using biogas digesters to deal with the pig and poultry wastes, biogas energy becomes available for processing tea and heating the chicken coop, and so do fertilizers for tea trees and paddy fields. Pollution to surrounding areas decreases (Kangmin & Ho 2006).

In most cases, some members of the rural communities find employment on these large-scale plantations, which provide them with a small income. However, this does not necessarily mean that the workers have enough income to be food secure. The money made might not compensate for the food that they did not have time to produce themselves. Some companies that involve farmers as plantation workers therefore support their employees with their own farming at home. This can either be through the provision of inputs, or through the lending of machinery. It can also encompass the transfer of knowledge through technical advice and agricultural research. Additionally, some companies provide affordable and good quality health and education services. In doing so, although farmers spend a fair amount of time at the plantation, they are given support to produce food crops for their own consumption, and/or are provided with affordable or free energy services. This can be seen in the case of the Pravara Nagara sugar cane cooperative in India, explained in further detail in Box 11. While the company is producing sugar for human consumption and ethanol production, it also produces gas from sugar cane bagasse, part of which is delivered to the rural population.

Large-scale operations combining IFES Types 1 and 2 have become of increasing interest due to the search for more sustainable forms of liquid biofuel production for transport. These projects are still at a conceptual or demonstration stage, however, and still have to prove their commercial feasibility. A promising approach has been developed by the Tsinghua University, which established a demonstration plant in Inner Mongolia Province in China, where sweet sorghum stalks are transformed to ethanol using the Solid State Fermentation (SSF) Technology. Sorghum grains and the fermented bagasse are used as feed for cattle. Their manure is turned into biogas and fertilizer through anaerobic biodigestion. While the biogas is used to generate electricity, the fertilizer is brought back to the fields (Li 2010).

CHAPTER 5

BARRIERS TO IFES IMPLEMENTATION

With so many potential advantages of integrating food and energy production, it would be natural to ask the question: "Why are such systems not more widely adopted?" There may be general barriers that are not specific to IFES: hindrances to agriculture and modern bioenergy in developing countries are many and varied. It would be beyond the scope of this report to cover general issues such as access to inputs, transport infrastructure and health. If IFES projects have not progressed due to such general issues, this is worth noting, but would not explain the lack of uptake where other projects and concepts have succeeded.

However, as already stated, the central purpose of this research is to get to the root cause of issues that are particularly challenging to IFES, when compared with other agricultural systems. On paper, the concept appears very attractive and sustainable, yet examples of long-term implementation and uptake, while existing for simpler systems like biogas, are relatively scarce for more complex IFES operations. We therefore develop high-level hypotheses to explain this, based on an analysis of the various systems.

The diagram below (Figure 3) illustrates some possible constraints of IFES and solutions to overcome them at both farm, and beyond the farm level. It is meant to be illustrative and is not exhaustive. The issues are outlined in more detail as follows:

Constraints at farm level:

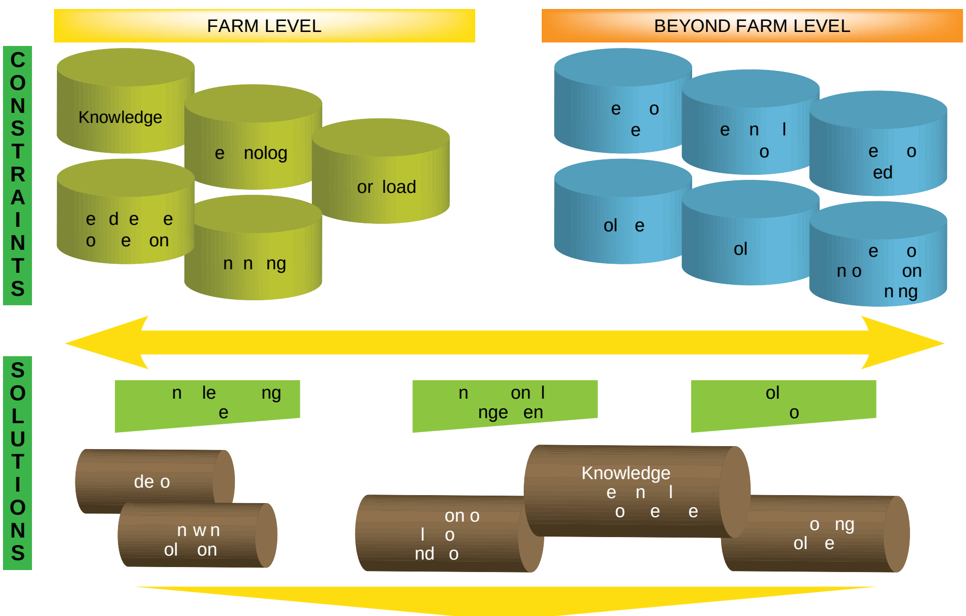
a) knowledge;
b) technology;
c) financial;
d) workload;
e) residue competition.

Constraints beyond farm level:

a) access to markets;
b) technical support;
c) access to financing mechanisms;
d) access to information and training;
e) politics;
f) policies.

FIGURE 3

Possible constraints and solutions for the scaling up of IFES



Potential solutions:

a) sustaining farming practices;

b) institutional arrangements; and

c) policy instruments.

5.1 CONSTRAINTS AT FARM LEVEL

5.1.1 Knowledge

One fundamental challenge is the sheer complexity of some of the IFES that have been developed, which is a product of scale. If a small-scale farmer grows a main crop and then wishes to make use of the co-products, such as animal feed, other crops will need to be grown to make up the remainder of the animal's diet. Those other crops may well have co-products or by-products with other uses; possibly as feed for other animals. Now, instead of growing one crop, the farmer has a multitude of crops on smaller and smaller scales, feeding a 'zoo' of animals in complex interdependence. The final use of biomass is often for energy: in the case of Tosoly (Box 8), anaerobic digesters were used and also gasifiers to fuel an engine to power a generator. The Tosoly case study outlined the following components (Table 2):

TABLE 2

Components of Tosoly Farm

Crops	Livestock	Technology
Pasture	12 Goats	AD + biogas cooker
Coffee	2 Cows + calves	Gasifier + engine
Cocoa	40 Hens	+ generator
Sugar cane	6 Ducks	Solar PV Panels
New Cocoyam (forage)	Rabbits	
Mulberry (forage)	1 Horse	
Plantain	Fish	
Tithonia (forage)		
Bamboo (construction)		
Mandarins		
Oranges		
Vegetables		
Water spinach		
Timber (e.g. Guadua)		

Therefore, to adopt such a system, a farmer would need to become an expert in fruit production, grassland management, forestry, cash crops and vegetables. Then, the correct tools and skills for carpentry and construction are required, as well as knowledge of multiple and diverse animal husbandry and aquaculture. Finally, engineering skills are necessary, to install and maintain the various thermal, biological and electrical technologies outlined.

Admittedly, such systems do not have to be quite so complex, but a number of experiences around the world have shown that even installing and maintaining a basic anaerobic digester can be a hurdle, with many falling into disrepair over time.

The farm at Tosoly is seven hectares, whereas many small-scale farmers in developing countries have less than one hectare to cultivate. This creates a physical barrier to the number of crops and livestock that can be maintained, quite apart from the expertize to ensure it runs smoothly.

All of the above issues are related to the complexity of the system. The more crops and processes involved, the greater the losses in economies of scale and the greater the skills required if a small-scale farmer is to be expected to manage such an array of crops and equipment. Those who demonstrate and promote such systems may be more highly educated than most, and/or particularly dynamic and entrepreneurial in their approach. Since such exceptional people are, by definition, in the minority, it is perhaps unsurprising that their complex agricultural systems do not transfer easily to others and, often when these ‘champions’ leave or die, so do their ways of doing things.

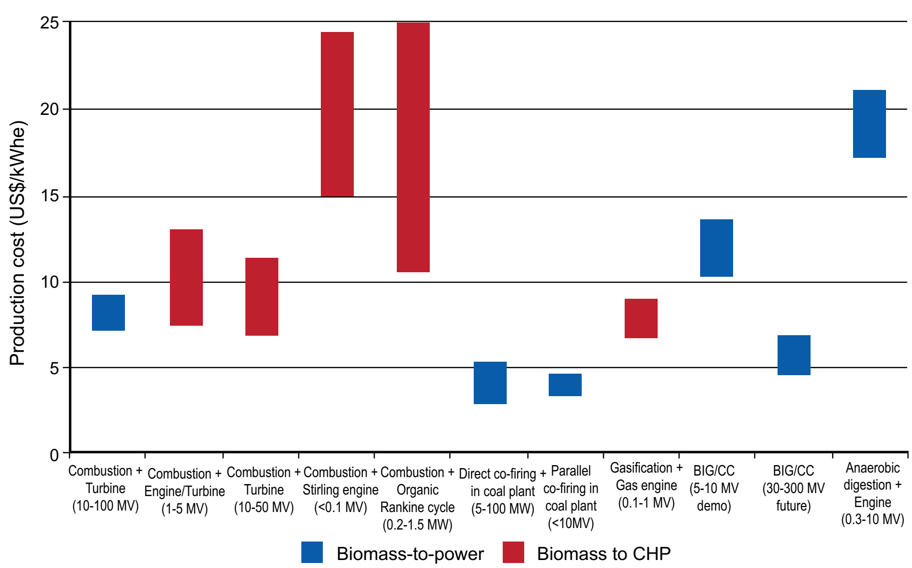
5.1.2 Technology

Technology refers to the complexity, reliability and economy of conversion technologies. Ensuring good quality of the conversion device is often crucial for the success of IFES, and has often been overlooked in systems aimed at being rapidly scaled up (e.g. some large-scale biogas programmes in the past).

Gasification offers a range of advantages over direct combustion of the fuel because it transforms about 80 percent of the chemical energy in the biomass fuel into chemical energy in the gas phase. The resulting syngas can be utilized in a range of applications, including steam boilers and gas engines for conversion to heat and electricity, with potentially increased efficiency. The Scandinavian countries lead in gasification technology, with Foster Wheeler (Finland) and Babcock & Wilcoz Volund (Denmark) being key large-scale suppliers. Most systems are for electricity and heat, while smaller systems are mainly for district heating networks. Biomass gasification is also used in Scandinavia to co-fire coal power stations, whilst avoiding the boiler corrosion and fouling problems associated with co-firing solid biomass. Where gasification is linked directly to a gas engine, this is less proven technically and creates operational challenges in gas cleaning and increased costs that can be a deterrent to investors (Biomass energy center, no date). The exception may be on a small scale, with a down draft gasifier, where the tars in the syngas are largely removed as they pass through the hottest lower part of the gasifier. This is the configuration used at Tosoly and, in combination with mass-produced car engines, it can be one of the most economical ways of producing heat and power from biomass, as illustrated in the chart below (figure 4). However, it can be seen in figure 5, that various configurations for gasification (power or small-scale heat production) are at the early commercialization stage, so there is scope for refinement, cost reduction and wider dissemination in the future.

FIGURE 4

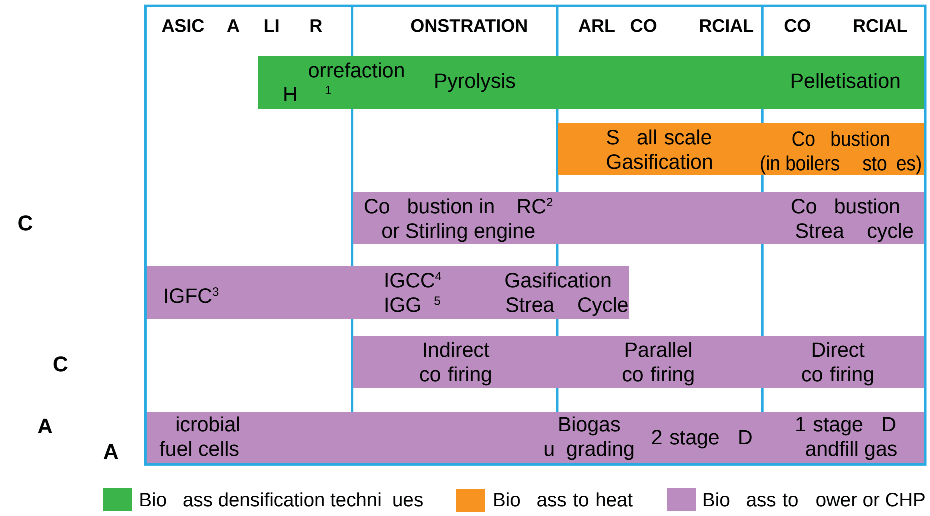
Production Costs of Various Bioenergy Options (IEA 2009)



Note 1: Anaerobic digestion can also be operated in CHP mode.
Note 2: Production cost be reduced by 60-80% (depending on techology and plant size) if free biomass feedstock is used, such as MSW, manure, waste water etc.

FIGURE 5

Development status of upgrading technologies (green), biomass-to-heat technologies (red) and biomass to power and CHP technologies (blue) (IEA 2009)



[1]Hydrother al u grading [2] rganic Ran ine Cycle [3]Integrated gasification fuel cell
[4] [5]Integrated gasification co bined cycle (CC) gas turbine (G)

Anaerobic digestion (AD) is often the central bioenergy technology in Type 2 IFES. The charts above show AD to be at the commercial stage, but one of the more costly options. Therefore, it may not be the first route chosen, but can have a useful niche in treating wet biomass and recycling nutrients. It benefits from the fact that the feedstock is often free. Additionally, centralized AD plants (CAD) can be more profitable, as long as the costs of transporting feedstock are minimized (Mistry *et al.* 2007). Small-scale AD has a trade-off in developing countries between performance and ease of use, with many preferring to sacrifice some output and economy, in favour of lower maintenance (Woods *et al.* 2006).

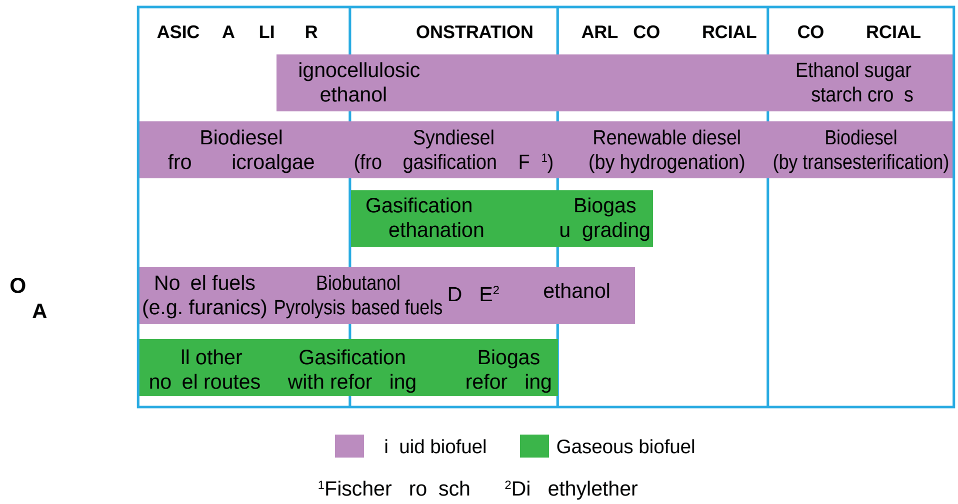
In terms of liquid biofuels for transport, it can be seen from the chart (figure 6) that first generation biofuels or bioethanol and biodiesel are the only two commercially mature technologies at present. In general, sugar cane ethanol in Brazil is considered to be economical without subsidies, whilst mandates and incentives have been driving other liquid biofuel routes, such as corn ethanol in the USA. New crops and technologies are likely to increase profitability of first generation biofuel production.

Even if IFES technology is reliable and economical, experience has shown that it can be rejected or abandoned if it is unfamiliar to those who use it. This can be through lack of knowledge, or simply resistance to change, preferring the comfort of familiar technology (Woods et al 2006).

One perennial problem with bioenergy and renewables in general, is the issue of market failure. Whilst agriculture has a monopoly on food production, it does face competition with fossil fuels when making electricity or transport fuels. However, fossil fuels do not always include appropriate taxes to allow for their GHG emissions and the environmental

FIGURE 6

Development Status of Liquid and Gaseous Biofuels (IEA 2009)



cost of damage caused - indeed in some countries their use is even subsidised - so renewables are unable to compete on a level footing. This can be detrimental to the energy component of IFES.

5.1.3 Financing

Financing is linked mostly to the investment required for the conversion system. Very often the better they are from an energy and GHG point of view, the more expensive they are. This is often not affordable for individual small-scale farmers.

IFES require investment and long-term planning. Consider, for example, the number of perennial plants and trees in the Tosoly case study (Box 7). These take years to mature and yield a full return, requiring an initial outlay and long-term planning that can be difficult for farmers focused on feeding their families from day-to-day.

Consider also the machinery involved. Purchasing a gasifier and engine with an electricity generator would be a very significant investment, beyond the reach of most small-scale farmers. Such investment can be difficult to find for a number of reasons. Farmers are often in remote rural areas and beyond the reach of formal microfinancing services, except for middlemen whose deals are often less favourable. Those who do reach them may incur high costs in doing so, find little competition and consider agriculture a high risk area. Therefore, costs of borrowing money tend to be high, if available at all. Finally, farmers may not even own the land. This is a common problem, leading to short-term decision-making by tenant farmers who have no incentive to invest in someone else's assets, especially in the short term. The lack of assets, in turn, creates problems raising finance because of a lack of collateral against which to secure the loan (De Soto 2000). Finally, the high transaction costs related to credit schemes with many small-scale farmers, compared to the relatively low amount of each credit operation, is often a deterrent for banks to invest in that type of client, or in small-scale IFES initiatives.

Possible ways to address the financial issues are discussed further in the paper (Sections 6.2.3.1. and 6.3.2.2).

5.1.4 Workload

Where multiple crops are grown on one piece of land, as in Type 1 IFES, or where there is a diverse array of inter-connected crops and livestock, as in Type 2 IFES, there tends to be less scope for specialization and mechanization, and therefore IFES often require significant manual input.

This could be a good opportunity to create employment in deprived rural areas, but in reality, quality labour is not always readily available. More and more healthy, young people who would traditionally farm are seeking employment in cities instead and manual labour is seen as less appealing (Jamieson, 2008).

5.1.5 Residue competition

Competition between *different uses of residues* refers to the fact that their use for energy production should not negatively affect their use for soil fertility and protection and/or for feeding animals. Pressure on biomass is already high. *Trade-offs* in the use of resources (land, water and nutrients) are becoming increasingly hard to balance in these systems, as competition for biomass for food, feed, fertilizer, and fuel increases.

For instance, primary crop, forestry and livestock residues have important ecosystem functions when left on, or integrated into the soil. They prevent soil erosion, reduce soil water evaporation, help increase rain water infiltration and capture precipitation from snow. They deliver essential minerals and constitute an important source for soil carbon, a media for soil-life, a habitat for micro- and macro-organisms and hence provide the right conditions to increase biodiversity in agricultural production systems. The protection of the soil resources entails savings on external inputs, such as fertilizers and soil amendments, as well as pesticides, concurrently lowering the need for external energy consumption. To find an adequate balance between soil residue removal for energy production and soil residues left on the field for soil quality is crucial, and therefore needs to be carefully addressed.

The same applies to the competition between residues that could potentially be used as livestock fodder or as feedstock for energy production.

5.2 CONSTRAINTS BEYOND THE FARM

The constraints that affect IFES beyond the farm level are actually very similar to those commonly identified for other commodity chains, and are briefly discussed hereafter.

5.2.1 Access to competitive markets

Access to markets describes access for agricultural products and/or energy products, as a key factor to ensure economic viability of IFES. Most of the time, IFES operators earn the bulk of their revenue from the sale of their agricultural products. This is usually the case for most biogas systems supplied to small-scale farmers (e.g. the Viet Nam case described earlier in the paper). Sometimes, as in the case of the Tosoly farm in Colombia, and the charcoal production in agroforestry systems case in the Democratic Republic of Congo, both agricultural and energy products are sold. In any case, adequate access to markets and product competitiveness are crucial. Regarding the former, contract farming is often an interesting mechanism to guarantee a market for smallholders' products, as discussed further in chapter 5.2.2. However, this is not always enough, as shown in the Biodiesel Social Seal Programme in Brazil (Box 10). Despite interesting policies related to contract farming, most of the feedstock has been soybean, because other products are not competitive compared to other possible market outlets (for instance, pharmaceutical companies in the case of castor oil).

5.2.2 Technical support

This is usually a challenge in many countries, especially when it relies too much on sectoral and government support. The challenge is more important in the case of more complex IFES, which often require a wide spectrum of knowledge, hence pluralistic technical support. A possible issue lies in the type of IFES technology needed, and its availability at local level, compared to the need to import it, which would make the system more vulnerable to outside influence.

5.2.3 Access to financing mechanisms

This is primarily linked to the cost of the processing device for energy production, but it may also relate to the complexity of IFES, i.e. the more complex the system, the more different crops and animals are needed, at a cost. More often than not, IFES development requires significant subsidies for the initial development phase. It must then gradually become commercial to ensure financial viability. The crux of the matter lies in the transition between these two phases – which is sometimes coined as "the valley of death" of rural development initiatives. There are all kinds of local finance systems for different IFES farm technology/enterprise scale models, based upon type of ownership, management, cost/benefit sharing. Some of these will be presented in the Section on "Possible solutions" (Sections 6.2.3.1. and 6.3.2.2.).

5.2.4 Access to information-communication and training

This actually relates to the need for adequate access to information-communication and learning mechanisms regarding the above-mentioned factors. Given the increasing trend towards more interconnected and knowledge-based societies, knowledge and information are key factors for innovation and equitable development. Therefore, agricultural producers must begin to recognize the value of information and share in paying for it. These dynamics have led some to contend that information is as important a production factor as "classic" land, labour and capital. Finally, asymmetry in access to information is a well-known power differentiation factor in rural development.

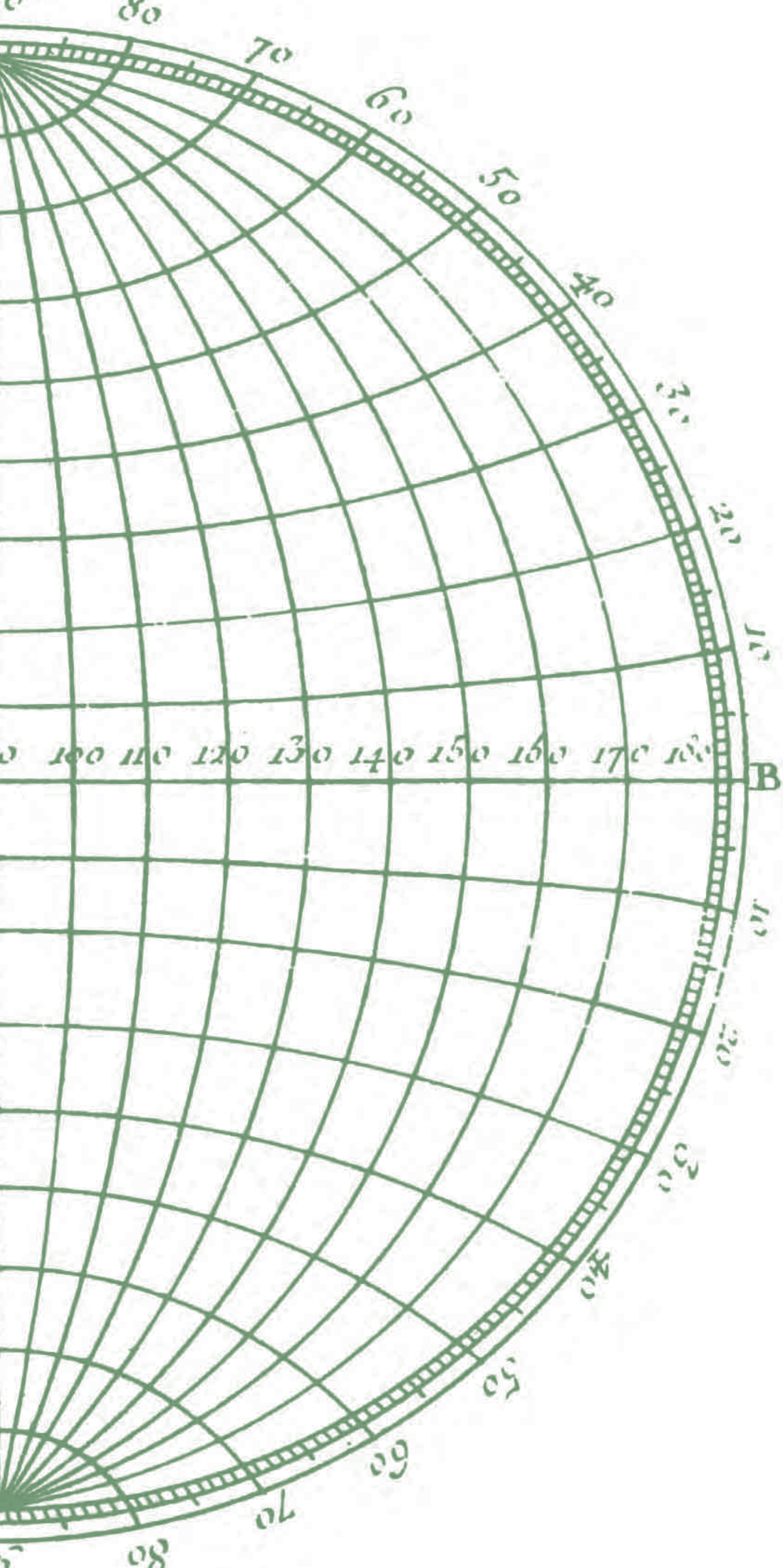
5.2.5 Politics

Politics refers to the actual "rules of the game", i.e. how things really work and are decided at local level. This applies to the above-mentioned factors that matter in the supply chain. There may be deliberate discrimination of some IFES developers regarding the above-mentioned factors.

5.2.6 Policies

Few government policies encourage all aspects of IFES, and in particular the overall environmental management of natural resources that they propose. Most international and national policy and legal frameworks separate action on agricultural productivity, ecosystem management and rural livelihoods, and policy-making institutions reflect this separation. Most policy-makers are unfamiliar with the opportunities for eco-agriculture, including integrated farming systems. In the European Union, for example, in the case of agroforestry systems, traditional silvo-agricultural landscapes, whose benefits are widely recognized, have received little attention from policy-makers and research organizations (Manchon *et al.* 2002). Dupraz *et al.* (2004) states that "across Europe the integration of trees and arable agriculture is currently unattractive to farmers, simply because the available grant or subsidy schemes are designed for forestry or agriculture, and don't permit agroforestry. In some countries, agroforestry systems can actually be declared illegal, because they are a category, which is not recognized for taxation purposes. A mixed or combined status of agroforestry plots is currently not available, neither at the European level nor at the national level preventing both forest and agricultural grant policies to be applied to agroforestry systems."

Subsidies to chemical inputs (fertilizers and pesticides) and fossil fuel, and sectoral technical support policies play against the replication and scaling up of IFES systems, especially more complex ones. The uptake of IFES Type 2 options - for example, systems including biogas technologies - is limited in many countries because of insufficient regulatory frameworks and absence of appropriate financial incentives. The wider use of biogas systems depends on the relative price of other energy sources. Usually biogas systems are not competitive in the absence of subsidies, other than in remote locations where electricity and other forms of energy are unavailable or unreliable (FAO 2006). However, the situation might change with the arrival of policies that encourage GHG emission reduction in relation to energy efficiency, land use change and food production.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CHAPTER 6

POSSIBLE WAYS TO OVERCOME BARRIERS

This section outlines a number of practices which could be effective in overcoming the key constraints identified and promote IFES from development and demonstration stages to widespread implementation.

6.1 SUSTAINABLE FARMING PRACTICES TO REDUCE RESIDUE COMPETITION

The use of soil residues for energy production might, in some cases, interfere with the need to maintain and enhance soil quality, or with other residue uses such as animal feed provision. The first issue, trade-offs between maintaining soil-quality versus energy provision, is particularly true for those farming practices that are based on establishing crops in the residues of a previous crop, e.g. conservation tillage.

When livestock is an integral part of the farm, residue use has yet another important function as a feed source. While the competition and necessary trade-offs have been widely discussed for crop-livestock systems (e.g. CGIAR 2007), the use of residues for energy adds yet another complication.

In some cases, although trade-offs can be found, or residues substituted with alternative sources for soil protection and livestock feed, win-win solutions are possible in others. Peters (2009), based on research on residue trade-offs between soil improvement and livestock fodder in Nicaragua, emphasizes that the farmers themselves are aware of these trade-offs and will sometimes aim for a production effect (for cattle), and at other times for an environmental effect (soil improvement), always focusing on the overall maximization of their profits. In cases where they have to decide in favour of one outcome, they will usually choose the one that is most beneficial in the short term.

6.1.1 Trade-offs

The soil organic carbon (SOC) pool in most of the tropics and subtropics, especially in Sub-Saharan Africa and Asia, is below the critical level and often is as low as 2–5 g kg^{-1}. Thus, restoring the SOC pool of such degraded soils would enhance agronomic production and accentuate efficiency of fertilizer use, irrigation and other amendments (Lal 2007). Therefore *in theory*, crop residues in the tropics and subtropics should be used for enhancing soil quality rather than for biofuel or other alternative/competing uses such as feed. However, *in practice*, optimal use of residues depends on several factors, including their degradability, specific environmental circumstances and actual use in farming systems.

Rate of *residue decomposition* varies by climate and crop, leading to varying amounts of erosion protection and organic matter additions to the soil. Due to these and other site-specific effects of residue on soil function, residue removal recommendations need to consider soil type, climate, cropping system and management, in order to protect soil quality, while allowing for residue harvest for other uses, such as bioenergy production (USDA 2006).

Certain *environmental circumstances*, as in the case of the dry savannahs of Africa, can present further constraints to optimal residue use. According to Schulz *et al.* (2001), a substantial amount of the residues left on the field may be lost as a result of bush fires, strong winds, feeding by termites, free roaming animals, or transhumant herds of Fulani cattle.

The *actual* use of residues in different farming systems is yet another issue. Often biomass is wasted or burnt – despite its potential benefits. Rice husks, liquid effluents of palm oil production, or other not easily-degradable residues, for instance, could be used for energy production without compromising, and perhaps even improving, soil conditions.

To be sustainable, residue must only be removed when soil quality will not suffer as a result. In some regions, the combination of crop, management practice, soil, and climate, work together to produce more than is needed to maintain soil health. In this case, excess residues could potentially be used for conversion to biomass energy, however, it is important to discern in what systems residue harvest is possible, or even beneficial, and at what rates (USDA 2006; also see Table 3 below).

TABLE 3

General Guidelines for Sustainable Residue Harvest; Source: USDA 2006

Sustainable harvest amounts will vary by:	Residue harvest rates should decrease with:	Recommendations for sustainable residue harvest:
Management practice	Increased soil disturbance	Use no-till with cover crops
Crop and yield	Lower yield or lower carbon : nitrogen ratio	Harvest high residue crops and only in good yield years
Climate	Warmer, wetter climate	Residue harvest in subtropical and tropical countries can be high-risk
Soil type	Coarser soil texture	Heavy clay, poorly drained soils are good candidates
Topography	Greater slope	Stay off hillsides and eroded knolls

6.1.2 Win-win practices

Sustainable farming practices to enhance soil conservation include manuring (green and animal manure), cover crops, nitrogen-fixing crop rotations, composting, and the application of organic soil amendments, such as biochar (as discussed above). The use of these methods creates win-win situations between soil improvement, fodder provision and energy production.

Manuring is a process which uses both animal and plant materials. *Animal manure* is traditionally a key fertilizer in organic and sustainable soil management. Manure is commonly applied to the field in either a raw (fresh or dried) or composted state, however, some manure may contain contaminants such as pesticides, disease organisms, and other undesirable substances. Many of these undesirable substances can be eliminated through high temperature aerobic *composting* (Kuepper 2003) or *anaerobic digestion* (Sahlstrom 2003). An effective *composting* process converts animal wastes, bedding, and other raw products into humus and reduces many of the drawbacks associated with raw manure use (Kuepper 2003).

Anaerobic digestion (AD) is a biological process that occurs naturally when bacteria break down organic matter in the absence of oxygen. Almost any organic material can be processed with AD, including green crop residues, manure or sewage. AD produces a biogas made up of around 60 percent methane and 40 percent carbon dioxide. The methane can be burnt to generate heat or electricity, which can then power the AD process, or be added to the national grid and provide heat for the farm or home, completing the cycle. The by-product of the digestion is the digestate, also called slurry, which can serve as fertilizer. AD therefore presents a win-win situation where both soil and energy needs are equally addressed. It is a recognized methodology under the Clean Development Mechanism of the UNFCCC, e.g. in Nepal (see Box 5. Carbon finance for small-scale farmers).

Green manuring, involves the soil incorporation of any field or forage crop, while the crop is still green, or soon after it flowers. *Cover crops* are any crops grown to provide soil cover, regardless of whether they are later incorporated or not. Cover crops and green manures can be annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year. In addition to providing ground cover (against soil erosion) and, in the case of a legume, fixing nitrogen, they also help suppress weeds and reduce insect pests and diseases (Sullivan 2003). The contribution of organic matter to soil from a green manure crop is comparable to the addition of 9-13 tons per acre of farmyard manure or 1.8 to 2.2 tons of dry matter per acre (Schmid *et al.* 1984). *Nitrogen-fixing crop rotations* refer to the sequence of crops and cover crops on one site. Crops range between species that fix nitrogen, such as forage legumes, and crops that need a high percentage of nitrogen to grow, such as corn. An interesting example of combined bioenergy green manure production is 'agricultural ponds' developed by the NGO CIPAV in Colombia: liquid residues of biogas production are used to fertilize ponds where aquatic plants are grown - as illustrated below: these are then used as green manure in the IFES farms (Solarte, 2010).

Application of organic soil amendments such as biochar. Biochar has the potential to enhance soil quality and soil carbon sequestration. It is a by-product of biomass-based energy conversion through *pyrolysis,* which is the heating of biomass in the complete or near absence of oxygen. Pyrolysis produces char, oils and gases. While the oils and gases can be used to generate energy, char can be applied to the soil as fertilizer. Biochar has little plant nutrient content itself, but acts as a soil conditioner, by making nutrients more available to plants and improving soil structure. However, practical issues related to how much to apply, cost, availability and possible risks of application are yet to be fully explored, even though research is expanding rapidly (Schahczenski 2010).

The combined production of oil, gases and char from residues through pyrolisis could therefore be a second win-win situation, generating both energy and soil conditioner, making the use of the available resources very efficient. Additionally, this process has also three major economic benefits (Schahczenski 2010): as a soil amendment that could partially replace fertilizer; as a source of heat, bio-oil and gases for farm use; and as potential income as a carbon offset in a future cap-and trade market. However, several economic, institutional and regulatory issues would need to be addressed first. In the US, for instance, a first step in this direction has been taken. The House of Representatives has passed legislation that could lead to the establishment of a carbon offset market, and an amendment to the Senate bill does mention biochar as a potential for carbon offset projects (Schahczenski 2010). However, it needs to be stressed that biochar should be produced from residues, and not from dedicated plantations, in order to avoid competition with other land uses and environmental drawbacks of land conversion. The technical potential of biochar to mitigate climate change is outlined in more detail in Box 9. Furthermore, there can be synergies between gasification and biodigestion, with the combined effects on plant growth of biochar (from gasification) and nutrient–rich effluent (from biodigesters) being greater than the sum of the effects of each component applied separately (Rodriguez *et al.* 2009).

The possible win-win solutions outlined above address the competition between use of residues for energy and those used for soil fertility purposes. However, only the cover-crop practice offers an additional solution in terms of soil protection. The need for soil protection obviously varies according to local circumstances. Likewise, efficiency of residues in protecting soils depends on the type of residues, as well as climate and soil characteristics.

Literature that addresses the trade-offs between these competing uses of crop residues (animal feed included), is relatively scant. Given the importance and the complexity of the topic, it certainly warrants more research and development in the coming years.

A different approach to reduce the possible competition between various uses of residues lies in reducing the need for biomass to produce energy. This can be achieved by replacing or complementing residue-based bioenergy with other types of renewable energy. Such an option was briefly discussed in Section 2.3. of this paper, and the case of the Tosoly farm presented in Box 8 describes an example of a small-scale combination, involving a biodigestor, a gasifier and solar panels. The advantages of reducing competition between different uses of residues must be assessed against the additional complication that complementary energy systems might entail at farm level.

The above example illustrates the need to carry out a comparative analysis of the pros and cons of different types of energy for rural households and communities. In that respect, the SURE DSS (Decision Support System)[5] developed by the Imperial College of London, together with national institutions from Colombia, Peru and Cuba, attempts to define the optimal energy solutions for rural communities that are often under severe resource constraints, and uses a balanced combination of highly technical information,

5 More information on the SURE-DSS is available at http://www.hedon.info/SURE-DSS

BOX 9

CLIMATE CHANGE MITIGATION THROUGH SOIL CARBON SEQUESTRATION: BIOCHAR

When biomass is converted to energy, the carbon originally stored in its organic matter is released back into the air. This process is referred to as "carbon neutral". Through the process of pyrolisis, where oil, gases and char are produced, some of the carbon remains stored, and biomass in this case becomes a "carbon negative" source of energy.

Biomass that is converted to energy releases part of the carbon back into the atmosphere in the form of CO_2. The other part of the biomass is converted into biochar, whose stable properties enable it to sequester a large percentage of the carbon in the soil and, as a result, provide a carbon negative source of energy.

However, the ability of biochar in bioenergy production to offer carbon-negative renewable fuel through its energy co-products is limited by critical points in the process of its production and use. First, it is important that biochar applied as a soil amendment remain sequestered for a very long time. In climate-change jargon, this refers to the issue of permanence. In other words, it would be hard to claim a permanent sequestration of carbon if the biochar carbon that was applied as a soil amendment was immediately released back into the atmosphere through possible soil decomposition processes. Most research to date clearly demonstrates that biochar applied to soil releases carbon back into the environment at a very slow rate, i.e. in excess of several hundreds if not thousands of years (Lehmann and Joseph, 2009).

Second, the carbon-negative potential of biochar is either enhanced or limited by the efficiency of energy production and the ability of the overall production process to limit carbon dioxide and other greenhouse gas (GHG) emissions. To properly understand the potentials for biochar, a life-cycle analysis of biochar needs to be examined to fully account for energy efficiency and GHG emissions. More specifically, one study estimated that the production of biochar was from two to five times more likely to reduce GHG emissions than if the biomass was used solely for the production of energy. But further research is indispensable to analyse both the energetic balances of different cropping systems and the exact potential of biochar to capture and offset carbon dioxide and nitrous oxide emissions.

Third, the fuel versus food issue of first generation biofuel production could also become a biochar issue when biomass for biochar is not produced in a sustainable way. For this reason, among others, there has been an extensive discussion on creating sustainability standards for biochar production.

Source: Schahczenski 2010; Lehmann & Joseph 2009; Gaunt and Lehmann 2008 non-technical criteria, and relevant participatory data. The tool facilitates the planning of energy infrastructure for small communities, enabling the priorities of the users to be considered.

The Delivery Model Tool[6] developed in the context of the DFID-funded PISCES project is another tool that helps with deciding on the right energy mix. By differentiating factors such as needs, users, resources, suppliers, ownership, equipment and financing, the Delivery Models Tool enables project designers and business analysts to position their project against a common framework and successful examples. The tool also connects project design intent with indicative final market systems, via the generation of a representative Market Map for the Delivery Model defined.

6.2 INSTITUTIONAL ARRANGEMENTS

Institutional arrangements concern two different issues, i.e.

- workload and financial constraints through the division of labour and costs (e.g. between farming and energy operations, between different feedstock suppliers, etc.); and
- complexity and technology issues through pluralistic and multi-actor service provision systems.

Often both types of issues are addressed through the vertical integration of the supply chain, with private companies or cooperatives supplying support regarding these aspects, at both input and output levels. Other types of pluralistic arrangements and bottom up decision-making systems have been developed regarding knowledge and technology sharing, but not so much on IFES. These include farmer field schools and other local multi-actor learning approaches.

6.2.1 Division of labour and costs

Productivity increases due to the 'division of labour' - when individuals specialize and work together to achieve end products - rather than work individually (Smith 1776). As already underlined, some of the IFES models can be extremely complex and inter-dependent, especially in the case of Type 2 IFES. The same principles that Adam Smith discovered apply here: it is a rare person that combines the knowledge, skills, experience, entrepreneurial attitude and physical/financial resources required to implement such systems single-handedly. By dividing the labour and allowing specialization, the efficiency of complex IFES can be increased and more easily managed. Rather than one farmer trying to grow multiple crops, keep different livestock types, and purchase and manage anaerobic digesters and gasifiers, it would be simpler and more economical to specialize and collaborate with other farmers with complementary activities. The net result would be a more efficient and productive system, in which the activities of the individual component farms are mutually reinforcing.

6 The Delivery Model Tool can be accessed here: http://practicalaction.org/consulting/pisces/

One basic way of achieving division of labour within IFES lies in having farmers handling what they do best, i.e. farming, and have other people deal with the energy component of IFES. This model would overcome the scale issue, which is so chronic in the more complex Type 2 IFES. Effectively, numerous small-scale farmers would become outgrowers, supplying by-products of their farm products to a centralized energy processing plant. It may be possible for them to own a stake in the processing plant, if desired. The co-products from the processing plant may be fed to livestock on-site, which could be owned by another farmer or group of farmers. If fish were incorporated into the system, one farmer could become a specialist in aquaculture. Hence, economies of scale can be enjoyed by all of the participating farmers who, together, would comprise one highly efficient IFES. An example from the UK is shown in Box 10.

BOX 10

DIVISION OF LABOUR IN A SIMPLE IFES IN THE UK

The east of England is a major wheat-producing region. A key by-product of wheat is straw, which has multiple uses, including combustion for bioenergy production. In Ely, Cambridgeshire, a 38 MW bio-electricity plant was constructed for this purpose, using 200 000 tonnes/year of wheat straw. Ely Power Station is the largest straw-burning power station in the world, producing 270 GWh each year.

The plant was constructed by FLS Miljo who then handed operation over to EPR Ely Ltd in June 2004. Although EPR Ely run the plant, they have created two subsidiaries to complete the supply chain: Anglian Straw Ltd and Anglian Ash Ltd. Anglian Straw is a wholly-owned subsidiary of EPR Ely and was set up to procure the feedstock for the plant, creating a fuel supply chain where none existed before. It currently procures 70 percent of the fuel for the power station, entering into contracts directly with local farmers. The plant can also run on other biomass feedstock and up to 10 percent natural gas, giving increased flexibility.

The farmers are then able to concentrate on what they do best, which is producing wheat. They do this with great skill, achieving some of the highest yields per hectare in the world and supported by tractors and combine harvesters that are specifically designed for the job. In the UK, labour is relatively expensive – as it is in most OECD countries – therefore there is a high degree of mechanization to reduce manual handling and its associated costs. This is made possible by the specialization of the farmers in grain crops that are amenable to harvesting and handling by the mechanized equipment.

Thus, specialists have developed in engineering and plant construction, crop production, straw procurement, electricity production and ash handling. In this way, each link in the supply chain is able to specialize and increase efficiencies through developing skilled labour, scale and, where necessary, investment in equipment to increase speed and reduce costs of production.

Such a system requires coordination, which may come from a company that wishes to market or process the produce, as is often the case with outgrower schemes. In addition to providing access to markets, such a company may also give the farmers access to farm inputs, thus overcoming supply chain issues, both upstream and downstream. They may also give technical support and microfinance – possibly in conjunction with other parties – with the benefit that they operate at the hub of a network of farmers, giving reach and scale that would not otherwise exist. In such a model, many of the critical issues of scale, investment, technology, labour and supply chain are met. However, despite the benefits, commercial drivers alone are not sufficient to ensure widespread adoption. As already mentioned, there is a need for good regulatory frameworks and land rights to facilitate the necessary investments. NGOs may see this as an opportunity to cooperate and meet mutual development goals with governments and private enterprises, working in partnership to create sustainable local enterprise networks (Wheeler et al 2005).

An even further division of labour can be made through area-wide integration, an approach advocated in the case of integrated crop-livestock systems, i.e. crops and livestock do not have to be operationally integrated (within the same management unit) to have functional integration (e.g. feed-manure). This integration can be achieved through supplies from different farmers, all with their specialized contributions and comparative advantages. Combining farm and broader area levels in this way, however, requires collective action and farm-level intensification through technology integration (often outside the farm), for the energy part. This combined division and integration of tasks allows for a reduction of work load at individual farm level and the use of synergies between different types of producers. The "District Biogas Farm" model recently pilot-tested in the Hainan Province of China is an interesting institutional arrangements which combines division of labour and guarantee of benefits to small-scale farmers by involving these as shareholders in the district farm: Instead of raising pigs themselves, small-scale farmers pay the district farm a certain fixed amount of for as many pigs they wish – i.e. their "shares" in the district farm. Thanks to these financial contributions, the district farm, which raises all the pigs, can reach a scale which allows it to invest in more efficient biogas systems that in the vase of household systems. On the other hand, small-scale farmers benefit from a share of the revenue from the sale of the pigs, and often recoup their initial investments break even after 3-4 years – any dividend from the sale of pigs by the district farm is therefore net benefit for small-scale farmers after that period. In addition, not only shareholder farmers but all surrounding small-scale farmers benefit from the biogas and slurry by-product produced by the district farm at a discounted price.

Yet another and rather extreme way of addressing division of labour is to allow farmers who are not keen on IFES, in particular, or farming in general, to leave the farming business altogether and let or sell their land under equitable financial deals. A well-known example in the bioenergy arena – although not IFES – is the fact that about one third of the sugar cane ethanol produced in Brazil comes from land which ex-farmers let to large companies. The planned Thusanang IFES project in South Africa will include an opportunity for farmers to lease their farm in exchange for animal feed (Marx 2010).

6.2.2 Knowledge and technical support services – and how to finance them

As apparent from examples such as the Tosoly farm in Colombia, more efficient IFES rapidly become complex and therefore knowledge intensive. Learning from neighbours may prove to be less effective for complex farm and natural resource management practices, and farmers may not have access to appropriate agricultural extension or training to manage such systems. As in the case of many other farming systems, IFES require better articulation of demand, for support and managing the institutional responses to the demands, in a pluralistic way: this ensures adequate services and accountability to the users of these services.

Exclusive focus on the role of the public sector in policy implementation might lead to ineffective policy reforms. New policies, in fact, not only imply shifts in the structures and rules of public agencies, but also imply new patterns of interaction between the public and the private sector. Whereas policies are ultimately implemented by the government, it is the way the public and the private sector act and interact that matters, and determines the overall outcome of a policy reform. Government, therefore, is only one of the actors in governance. In rural areas, other actors include landowners, farmer organizations, cooperatives, NGOs, research institutes and microfinance institutions.

New agricultural and rural development circumstances and their related new policy requirements, such as those related to the MDGs, increasingly require organizations involved in agricultural and rural development that:

- are more people-centred and participatory to better address the needs and aspirations of rural people, particularly the poor;
- take a holistic perspective and work cross-sectorally, in order to account for the multiple livelihood strategies of rural people;
- work in partnerships to better utilize each other's strengths and compensate for weaknesses, and;
- better link macro- and micro–level activities.

In other words, one needs a *coherent, competent and engaged set of service providers*, which can act as counterpart to the *better-articulated demands* on the farmer's part. This means that a combination of "demand-side approaches" and "supply-side approaches" would be the best way forward, particularly in the case of complex IFES operations. This subject will be discussed further in the coming sections.

This new approach can be illustrated by some recent changes in extension which have encouraged new attitudes and behaviour in extension staff at a number of levels (Pasteur 2001):

- *Incentives towards new behaviour*: Management offered performance-based incentives to high performers.
- *Disincentives towards old behaviour*: Farmers became emboldened to demand a better service from non-performing extension staff.
- *External incentives*: Client farmers appraised extension staff performance.
- *Personal incentives*: Working with farmers led to extension staff regaining cultural identity and pride, thus improving their motivation and dedication.

Demands from different levels (from above and below) and creation of both intrinsic and extrinsic pressures, proved an effective system to motivate extension staff. The pluralistic approach to service delivery in agriculture outlined above applies to IFES, as these are farm-based production systems. In discussing its application to IFES, it is useful to distinguish between simple and more complex IFES.

6.2.2.1 Knowledge management and supporting services in the case of simple IFES
In this case, knowledge and other types of support to IFES producers is usually provided through vertical integration of the supply chain, with private sector companies or cooperatives entering into contracts with small-scale farmers; whereby farmers supply the feedstock while the company or cooperative guarantees the purchase and provides support in the input supply side of the value chain. Box 11 provides two examples of contract farming schemes related to IFES initiatives.

Contract farming often faces implementation constraints. Such constraints, together with possible solutions, have been summarized by Vermeulen and Goad (2006) in the case of oil palm, timber and other crop plantations – see Table 4.

BOX 11

LARGE-SCALE VERTICAL INTEGRATION OF IFES SUPPORT WITH CONTRACT FARMING – EXAMPLES FROM BRAZIL AND INDIA

(i) *The Social Fuel Stamp Program in Brazil*

The Social Fuel Stamp Program was created as part of Brazil's National Program of Biodiesel Production and Use. It attempts to encourage socially sustainable biodiesel production by providing tax incentives for biodiesel producers to purchase feedstock from small family farmers in poorer regions of the country. To receive the stamp, biodiesel companies must agree to:

- purchase a minimum - but importantly not necessarily all – proportion of raw materials from family farmers - ten percent from regions North and Mid-West, 30 percent from the South and Southeast and 50 percent from the Northeast and the Semi-Arid Region; and
- enter into contracts with family farmers, establishing deadlines and conditions of delivery of the raw material and the respective prices, and provide them with technical assistance.

Participating companies may benefit from a partial or total reduction of federal taxes, as defined by the national tax legislation. While this seal is not mandatory, it is now required by the Government for fuel to be counted towards national blending mandates, and to access auctions. It also eases access to loans.

In 2006, five refining companies were accepted in the programme, with a potential production worth 70 million litres of biodiesel. They will buy the feedstock (palm oil, soybean, castor bean) from 65 000 families through their associations or municipalities. By the end of 2007, some 400 000 small farmers had joined the programme. From 2005 to 2008 1 920 000 m^3 of biodiesel were auctioned. More than 80 percent of the biodiesel comes from soybean.

A very interesting feature of this programme lies in its combination between contractual market mechanisms and social concerns. However, as with other innovative programmes, it has faced some implementation challenges:

- Absence of competitiveness of some feedstocks for biodiesel. One example concerns castor oil in the North East Region where pharmaceutical companies pay a higher price for the oil required by the biodiesel refining companies, leading to lack of contract fulfilment regarding supply of feedstock to the biodiesel companies. Another problem relates to limited environmental requirements for small-scale producers. The two main environmental considerations included in the biodiesel policy are: (1)

7 To address several problems with the current scheme, the scenario is most likely to change due to new regulations to obtain the "social fuel seal" (Cesar & Batalha 2010a).

potential CO_2 emission reductions; and (2) production of biodiesel from a variety of feedstocks . The policy fails to promote good farming practices, in particular regarding energy consumption and sustainable land use.

- Small family farmers have been invited to participate in the programme merely as producers of feedstock. There are no incentives for the installation of local small biodiesel processing units. This makes small-scale producers very dependent on the refining companies.
- Small-scale farmers often do not have the necessary conditions to negotiate favourable contracts to sell their raw material, especially where the market is dominated by very few industrial biodiesel plants.

(ii) *The Pravara Nagara sugar-cane cooperative in India*

The Pravara Nagar Sugar Cooperative was organized in the 1950s and concerns 44 villages, corresponding to an area of 12 000 km^2 in Loni Area, Maharashtra State. Its main purpose was to break the monopoly of joint stock companies' discrimination towards Loni farmers in accepting and rejecting their sugar-cane crops. The factory has expanded its operation from sugar to many by-products, including ethanol from sugar molasses (50 000 litres/year), biogas from other residues from sugar and ancillary products (e.g. a paper mill) - used as energy sources for the factory. The Cooperative has become an important source of livelihood opportunities for about 80 000 local people:

- It directly employs 1 444 technicians and villagers.
- About 5 000 rural people find work on sugarcane farms, in crop harvesting and transportation.
- It provides affordable and good quality health (20 centres and 500 paramedical and medical staff) and education services (27 institutions from primary to university levels) for people in the Loni area.
- It pipes biogas to some 200 farmers.
- It also sells compost as residue from the biogas plant to farmers.
- It provides farmers with technical advice (and agricultural research).
- It gives farmers the guarantee of sugar purchase at a decent price.
- It provides loans to some 8 000 families, including poor ones.
- The cooperative has significantly improved water facilities, both for agriculture (37 farm tanks, about 8 200 hectares, of which 6 000 for farmers) and household use (5 village tanks).

The main strengths of the cooperative:

- visionary management;

8 This problem will be addressed in the new "social seal" regulation being issued in 2010/11.The value for the acquisition of raw material is multiplied by 1.5 for the alternative raw materials for soybean in order to encourage diversifying the supply chain (Cesar & Batalha 2010a).

- loyal and dedicated members;
- enlightened membership;
- participatory decisions;
- feedback mechanisms based on bringing about stronger confidence;
- good development of infrastructure;
- strong network of educational and medical facilities promotes awareness and health;
- every activity is participatory and members feel this is their own institution;
- Needs of the members for a better standard of living, and related expectations of energy power from the factory, are met by the cooperative.

Significant weaknesses and challenges of the cooperative include:

- The factory is unable to mobilize capital base funds from financing institutions under the pretext that factory management has political affiliations. The finance for such proposals may not be ploughed back.
- Lack of technical personnel in management, and difficulty in obtaining clearance from management for technical proposals.
- Production of sugar cane is declining due to regular drought, which is adversely affecting its production, capacity utilization and the fulfilment of commitments.
- Government control of levy prices on molasses is too low and causes heavy losses to the sugar factory.
- Fragmented land holding and increased areas under saline conditions (alkaline soils).
- Fluctuating oil prices which become an additional burden on profits.

Pravara is one of the cooperatives in Maharashtra State which has requested authorization to build a cogeneration plant. In order to overcome the shortage of feedstock during increasingly regular droughts, it contemplates the use of sorghum as substitute/complement to sugar cane during the off-season. Farmers involvement will be achieved through the following combined strategy:

- encourage self-help group formation by participation of farmer members and labourers;
- motivate the farmers to rotate between sugar cane and sweet sorghum (every third crop) for improved soil fertility.

Sources: Abramovay and Magalhães 2007; MDA 2006; Garcez and Viana 2009; Cesar and Batalha, 2010; Nalwaya, 2009

TABLE 4

Emerging solutions to key constraints for smallholders in contract farming in the oil palm, timber and other crops;

1. Constraints for both smallholders and companies (or land development agencies)		
Constraint	**Emerging solutions within the palm oil sector**	**Emerging solutions from the timber and other crop sectors**
Land disputes and tenurial uncertainty.	Leading companies go beyond legislation in settling land disputes (Indonesia). Share-based systems can replace individual land holdings, if smallholders agree (PNG, Malaysia, Indonesia).	Strong public policy is essential for resolving long-standing conflicts over land (Canada, South Africa).
Low productivity and quality from smallholders.	Emerging government supported nurseries for high quality seed stock (Indonesia). Upfront cash incentives to encourage use of inputs and overcome cash flow problems (PNG). Acceptance that smallholders have rational priorities other than yield maximization (PNG).	Timber companies diversify into commercial nurseries for high quality seed stock (India). Smallholders empowered to selectively hire services of government extension agencies (India, Vietnam, Canada).
More difficult for smallholders to comply with standards, principles and criteria.	Dedicated Smallholder Task Force of the RSPO exploring options.	Group certification in forestry, to lower costs of compliance for smallholders and community groups (Honduras). Possibility of stepwise or differential standards (Indonesia).
Lack of clear and reliable mechanisms for dispute resolution.	RSPO principles and criteria require companies to set up workable mechanisms.	Government provides both policy context and actual mediation services (China, South Africa).
2. Constraints for smallholders and their communities		
Constraint	**Emerging solutions within the palm oil sector**	**Emerging solutions from the timber and other crops sectors**
Lack of access to capital for investment (and reluctance of smallholders to use land as collateral).	Cross-sectoral government subsidized credit schemes for individuals and cooperatives (Indonesia). Company provides interest-free credit for selected inputs (PNG). Equity through Land Bank mechanism (Konsep Baru, Malaysia).	Small-scale local banks and micro-credit to provide flexible loans (Bangladesh, India). Credit based on government land guarantee rather than actual market value of smallholdings (Vietnam, similar to Land Bank mechanism in Malaysia).
Low access to reliable information.	NGOs provide additional information and help to find and interpret formal documents (Sawitwatch, Indonesia). International agencies write and share practical guidance on palm oil for smallholders (FAO).	Exchange of information through producer groups and associations (commodity groups in India).
Trade-offs between cash crop production and food crop production.	Allow intercropping of young oil palms (PNG, Indonesia). Allow land to be set aside for food production (PNG, Malaysia, Indonesia). Flexible labour schemes (mobile card, PNG).	Intercropping of young trees, or mixed 'forest gardens' (Indonesia).

Long-term crop with volatile world price, hence high risk compared to other land uses.	Intercropping and mixed land use to provide more diverse sources of income and food security, especially in early years (PNG, Indonesia). Income diversification schemes such as livestock (Indonesia).	Government provision of business services such as predictive market information (Thailand). Small-scale insurance badly needed (though few examples). Stepped harvesting to provide early income from small timber (Indonesia).
Monopsony purchase by mills (due to geographic dispersion).	Standardized fair and transparent pricing systems (e.g. FELDA, Malaysia; recently improved formula, Indonesia; minimum price linked to Rotterdam price, Brazil). Government support of expansion of processing facilities causes proliferation of mills (Malaysia, Indonesia).	Competitive, economically efficient chain of buyer intermediaries in the rubber sector (Malaysia).
Low bargaining power: difficult to negotiate terms and prices.	Self-organization into local associations and cooperatives (Brazil). Links with national and international NGOs and trade unions (Indonesia). Schemes to transfer control over at least some decisions (e.g. labour) to smallholders (mobile card scheme, PNG).	Grower contracts with built-in timeframes for renegotiation (Indonesia, South Africa). Support from third parties, such as government agencies and NGOs (Guatemala, Australia).
No share in post-harvest added value.	Emerging cooperative mills (Malaysia, Indonesia). Government job creation policies a useful lever (Indonesia and others).	Associations of growers in wattle tannin industry invest collectively in downstream processing (South Africa).
Lack of broader social development.	Company uses tax breaks to fund local infrastructure (NBPOL, PNG). Free public transport scheme (Agropalma, Brazil).	Land allocation to plantations contingent on social responsibility agreements with communities (Ghana).
Adverse environmental impacts	Mandatory for new plantings to occur on degraded areas only (Agropalma, Brazil). Civil society court cases to tackle illegal burning (Indonesia).	Water-using companies exploring use of tax breaks to fund direct payments to farmers for upstream environmental protection (Indonesia).
3. Constraints for companies and land development agencies		
Constraint	**Emerging solutions within the palm oil sector**	**Emerging solutions from the timber and other tree crops sectors**
Transaction costs of dealing with large number of individual smallholders.	Smallholders organized into legally recognised local cooperatives (Indonesia). Contracts are with associations and cooperatives of smallholders rather than individuals (Brazil). Companies fund shared, centralized rather than individual extension service (PNG). Tax incentives to purchase from smallholders (Brazil social seal system).	Cooperatives and associations to lower costs and improve marketing (Brazil, Guyana). Company contracts neutral go-between (South Africa). Cooperation between buyers, e.g. on information regarding defaulters or joint schemes.

Unreliable rates of supply from smallholders from inaccessible plots.	Company takes full responsibility for collection of fresh fruit bunches, with dispersed collection points (NBPOL, PNG; GOPDC, Ghana; Côte d'Ivoire). Incentive schemes for flexible and efficient labour movement among smallholders' plots (PNG). Outstanding need for regulation of independent buyers, to control theft of fresh fruit bunches (Malaysia).	NGOs provide assistance to small-scale business planning and projections (Brazil).
Smallholders default on loan repayments.	Repayment of loans as a proportion of crop rather than in cash (Nigeria, PNG). Provision of loans and inputs determined by past performance (GOPDC, Ghana). Upfront capital is co-financed by smallholder, rather than from company alone (GOPDC, Ghana).	Shift in forestry away from supported growing to independent growing (India, South Africa). More flexible and renegotiable loan terms (Indonesia). External sources of insurance for smallholders (though few examples). Lending through groups, especially when group has to provide collateral (e.g. Zimbabwe cotton sector). Broad range and good quality of services offered, thus increasing farmers' interests in not breaking the deal. Incentives for repayment, and strict treatment of defaulters (cotton sector in Zimbabwe, tobacco sector in Uganda).

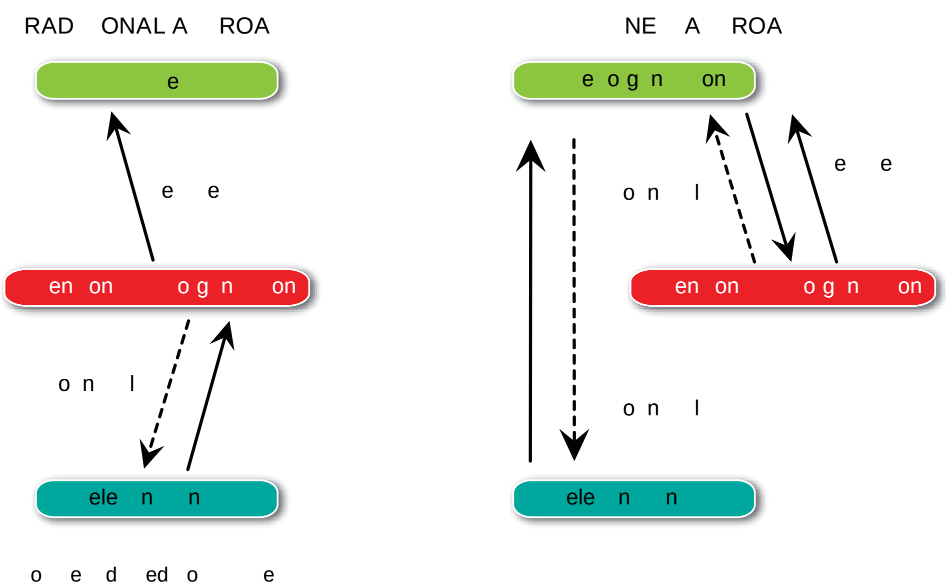
Source: Vermeulen and Goad, 2006

Tenant farming and sharecropping, whereby smallholders farm the land belonging to companies, is another type of agribusiness-smallholder partnership which often includes provision of technical services and sometimes inputs to the farmer. One example relates to irrigated sugar cane schemes in Africa undertaken in the 1970s with support from agencies like the Commonwealth Development Corporation, parastatal organizations or private companies. These organizations developed irrigation infrastructure and undertook costly land leveling. Recovering these costs required high yields – yet it was seen as politically and socially important to involve local farmers. The solution was to divide the farm into blocks (e.g. of 5 ha each) that were farmed by local farmers. Cane planting, mechanical operations and harvesting, were usually undertaken by the management company, while irrigation, fertilizing and weeding were carried out by the farmers, under the strict control of the company. Several of these schemes proved successful, though tenants were effectively more similar to profit-sharing hired labourers than to genuinely independent farmers (Tyler 2008). Moreover, in such partnerships, the negotiating power of the small-scale farmer is weaker than in contract farming because (s)he does not own the land being farmed.

The district model farm developed in Hainan Province, China, briefly described in Section 6.2.1. is an interesting example of small-scale farmer involvement as shareholders in medium-sized biogas IFES.

Accountability and rewards/penalties are essential principles to consider in policy implementation. Farmers have even more influence where they finance a significant share of R&D and extension (in line with more recent thinking on how to finance R&D and extension) while increasing accountability to the intended users of research and support services. This is illustrated in figure 7.

FIGURE 7
Innovative ways to finance R&D and extension and improving accountability to intended users



Such innovative institutional approaches in financing support services have been occasionally developed for renewable energy systems (see discussion on stakeholder involvement in Section 6.3.2.3. iv.), and yet are not common in small-scale bioenergy development, let alone IFES initiatives. However, some interesting financing schemes have been tried in the context of small-scale bioenergy initiatives, and more particularly, regarding the set-up of small-scale businesses. Those presented as examples in Box 12 have been developed for some time and have proven effective.

BOX 12

INTERESTING WELL-ESTABLISHED FINANCING SCHEMES FOR IFES

(i) *Promoting equity in large-scale biofuel development-The sugar cane industry in Mauritius*

The sugar industry is the backbone of the agricultural sector in Mauritius and a significant convertible currency earner, as well as an important source of income to workers and small-scale farmers. The annual cane production in a normal year is around 5.8 million tons of cane. The total amount of bagasse (a by-product of sugar cane production) generated annually is around 1.8 million tons. All sugar-cane factories in Mauritius generate steam from the combustion of bagasse. This steam is used to produce electricity, which in turn powers the electric motors in the factory. Efforts have consistently been made over the past 40 years to exploit cogeneration for energy generation.

In the 1950s, many sugar factories started selling excess power to the national grid, bringing the total amount of electricity exported from the sugar industry to 25 GWh by the late 1970s. However, although electricity exported to the grid from this source represented around 16 percent in the early 1970s, both pricing and supply conditions were not attractive enough to encourage large-scale investments in cogeneration. This prompted the government to develop policies, plans, measures and incentives with respect to bagasse energy in the 1980s. As a result of these government measures, electricity generated from bagasse increased more than three-fold over the 1988-1999 period, and currently covers about 25 percent of national electricity needs. This was achieved without a major increase in sugar cane production – an indication of increased energy efficiency of the sugar industry, which allowed large increases in excess electricity for export.

Mauritius has developed a very interesting revenue-sharing mechanism regarding bagasse-generated electricity. Until the end of the 1970s, all revenue from this export was kept by the millers. In 1982, the millers entered into a contractual agreement with the Central Electricity Board (CEB) to supply continuous power to the national grid. This attracted the interest of the sugar cane growers/planters particularly the small-scale farmers (growing cane on an area of 10 ha or less), who started lobbying for a share of the proceeds from electricity sales with the Mauritius Planters Association. This resulted in a Ministerial Statement in 1985, according to which all planters would get a share of the revenue from electricity sale to the grid. A multi-stakeholder Committee was created and came up with a formula to determine the sharing of revenue from surplus sales of bagasse energy, and the creation of the Bagasse Transfer Price Fund (BTPF), where the proceeds from the sales were placed, to be managed by the Mauritius Sugar Syndicate. The BTPF was divided by the total tonnage of sugar accruing to the planters to obtain the average bagasse accrual per ton of sugar. Each planter was then paid according to their respective individual sugar production. The millers did not benefit from the BTPF, but from the sale of electricity to the grid. The share of BTPF in the total sugar proceeds increased from 0.4 percent in 1985 to 0.98 percent in 2000.

There are different types of beneficiaries of revenues from bagasse-generated electricity:

- *Planters who do not own mills and planters who own mills*: The first group gets 38 percent of the BTPF on the basis of individual sugar production. In addition, they earn dividends from their shares in the Sugar Investment Trust (SIT) set-up in 1994, whose members are all employees of the sugar companies and parastatals in the sugar sector. The second group of planters who own mills are entitled to 12 percent of the BTPF, according to their individual sugar production.
- *Co-generators (Sugar millers and IPPs who generate electricity for sale)*: The co-generators receive all their payments directly from the CEB.
- *Employees and planters in the sugar industry*: All the employees (field and factory) of the sugar companies and state-owned parastatals in the sugar industry are shareholders of the SIT, which owns 20 percent shares in all milling companies. SIT acquired the shares on behalf of its shareholders at a concessionary rate. In addition, SIT owns 20 percent of the seven continuous power plants, and therefore receives 20 percent of the profit from the revenue generated from both the cane-milling and the export of bagasse-generated electricity.

The above revenue sharing is considered a win-win situation for all the stakeholders in the sugar industry. An added advantage of the current system is that the millers receive fiscal incentives for saving energy and do not have to operate, repair and maintain a boiler and turbo-alternator, if they are located next to a power plant.

This is taken care of by the co-generators. In addition, any improvement in exhaust steam consumption that is lower than the usual 450 kg/ton of cane brings extra revenue to the miller.

A major lesson from the Mauritian experience is that the participation of the majority of the stakeholders in the biofuel business is conducive to social stability and peaceful economic development of the sectors that are most relevant to its development (in this case the sugar sector). The Mauritian experience

demonstrates how revenue from biofuel can be shared among stakeholders, in this case through the establishment of a Bagasse Transfer Price Fund (BTPF).
Source: Deepchand, 2004

(ii) *The Green Village Credit (GVC) Project in China*

The Green Village Credit (GVC) Project is a part of UNEP's China Rural Energy Enterprises Development (CREED) project that aims to create a clean energy path in China's Yunnan province and surrounding areas. Supported by the United Nations Foundation (UNF), CREED offers enterprise development services combined with start-up financing, as well as support for consumer credit and income-generation loans. The Nature Conservancy (TNC), China Program is responsible for the consumer credit and income generation component through Green Village Credit in the northwest part of Yunnan Province, China.

GVC provides local villagers with two types of credit: the household credit to purchase higher quality sustainable energy systems (energy efficient and renewable energy systems); and a loan for activities that can generate income using the new and improved energy services, such as vegetable and cash-crop plantations, animal husbandry, tourism services and other activities with sufficient financial returns.

GVC is designed to help local communities generate income that can then be used to purchase better energy services by their own means, instead of simply waiting for grants and subsidies. The project explores a new financing approach, to promote economic development and environmental protection in the remote mountainous communities.

The total project budget (February 2004 -June 2007) was worth US$786 550, consisting of US$400 000 as revolving fund (CREED Green Village Credit) and the rest as operational costs for project personnel, sub-contractors, and local training, to establish efficient and effective project operation. By targeting 500-600 households in the area, the project expected to reduce consumption by 15 000 to 20 000 cubic meters over the 15 to 20-year life of the installed sustainable energy system.

In addition to the environmental benefit, the GVC provided other social benefits, such as enhancing the local capacity to generate income, improving local livelihoods, and providing cleaner indoor air for better health, particularly among women and children.

Based on their larger multi-year Alternative Energy Program, TNC worked in partnership with:

- local government agencies (such as forestry, environmental protection, poverty alleviation, health, and rural energy offices);
- rural financial institutions, such as Rural Credit Cooperatives (RCC);
- rural energy enterprises; and
- local NGOs.

Green Village Credit has also been implemented, in close cooperation with the community-based *Green Village Credit* Associations registered at the local civil affairs bureaus, as specialized rural economic entities.
Source: UNEP, 2007

In many countries there are formal mechanisms in place to provide credit to small-scale farmers and entrepreneurs in rural areas. Examples include the 'village banks' in Thailand and, specifically regarding IFES, the comprehensive micro-credit service developed under the Nepal Biogas Support Programme presented in Box 15. When rural banks are somewhat reluctant to engage in microcredit operations with small-scale operators, small-scale farmer organizations such as cooperatives, are often a way to increase access to microcredit by small-scale producers. This may happen either through:

- cooperatives directly providing credit – for example the zero waste initiatives on jatropha, rice and palm oil in Thailand (Puntasen and Sreshthaputra 2010); or
- cooperatives facilitating access to credit with rural banks, as in the case of the Pravara Nagara sugar cane cooperative in India, described in Box 11.

Microfranchises are an interesting complement to microfinance in addressing financial risks and needs related to IFES financial needs, hence additional explanations on these institutional arrangements are provided in Box 13.

Some simple IFES systems, such as those using biogas, are good candidates for carbon finance, as they have significant potential to reduce GHG emissions, and are relatively easy to monitor. For instance a World Bank-supported project has installed 162 000 quality-controlled, small-sized biogas plants in the Terai, Hill, and Mountain regions of Nepal (Box 5). Each biogas plant is expected to reach a reduction of 4-6 tons equivalent CO_2, which could potentially result in overall carbon credits corresponding to 6.5 t CO_2 during the ten-year crediting period (WB, no date).

Institutional arrangements for financial support require policy instruments to sustain their implementation. These are discussed further in Section 6.3.2.2.

BOX 13

MICROFRANCHISING AS A POSSIBLE BUSINESS MODEL FOR STARTING AND SCALING-UP SUCCESSFUL SMALL-SCALE IFES

Franchises are known throughout the world as a successful business model, enabling local ownership of enterprises with the benefit of a centralized support network. McDonald's and Subway are famous examples, but franchises can exist in almost any sector and have exceptionally low failure rates, because they are replications of a tried-and-tested business. Microfranchising is a scaled-down version of the same thing, which is especially applicable in developing countries. It can be linked with microfinance to provide a complete package for those wishing to start a business. Whereas microfinance is restricted to providing funds, microfranchising can go further and provide a complete support package to enable people to start businesses where the majority would not have the know-how to do it alone from scratch. It is a 'business in a box' model that could also provide solutions to some of the key hindrances to IFES, as identified in this report, both at farm level and beyond.

At farm level, microfranchises provide a vehicle for knowledge exchange between the franchiser and the franchisee through technical support, general business information and advice. Technology can also be transferred, so that the franchisee is able to purchase reliable equipment that has been successfully used elsewhere and is made available at a competitive price due to economies of scale in manufacture and purchasing. The farmer would not need to be a technical expert, nor be familiar with the best suppliers of specialized equipment, avoiding potentially costly mistakes.

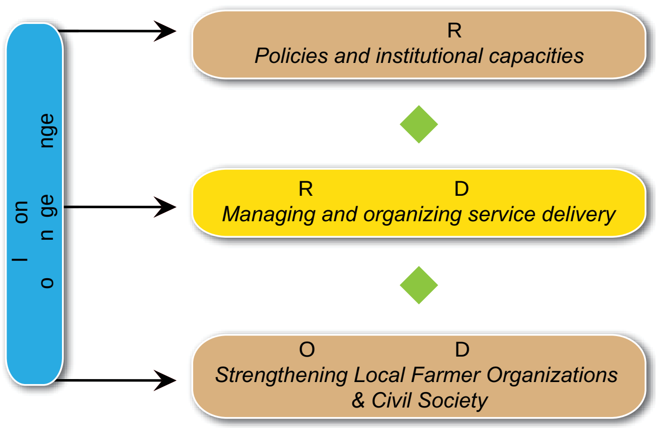
Beyond farm level, microfranchises can provide assistance with supply chain development, both in provision of inputs and access to markets. Where access to finance might not be realistic for stand-alone businesses in remote rural areas, it can be more easily provided through a microfranchise operation. The same is true of access to information and training, because the franchisee would not be left alone without support. When concentrated geographically, clusters of franchisees can create a critical mass and a network that more readily facilitates the above support. Furthermore, such clusters could make possible economies of scale and division of labour that would greatly improve the profitability of each individual enterprise. Thus, microfranchising could be a particularly appropriate business model for small-scale farmers to bring about the spread of IFES, once an optimized system has been developed.

Sources: Fairbourne et al (2007); Magleb (2007); Felder-Kuzu (2009)

6.2.2.2 Knowledge management and supporting services in the case of complex IFES

As apparent from cases like the Tosoly farm in Colombia, more efficient IFES, which involve several uses of residues, rapidly become complex and therefore knowledge-intensive. Learning from neighbours turns out not to be very effective for complex farm and natural resource-management practices, and farmers may not have access to appropriate agricultural extension or training to manage such systems. Complex IFES do not lend themselves easily to vertical integration. Instead, the combination of articulated demand and responsive supply of knowledge and support services would require a more complex web of actors with different roles. Figure 8 below attempts to illustrate this in the generic case of agricultural development; and applies in particular also to IFES.

FIGURE 8
The pluralistic and demand-led R&D and service provision framework



Box 14 illustrates the challenges in adopting decentralized and pluralistic support service systems though the work undertaken by the National Agricultural Innovation Project in India.

BOX 14

INSTITUTIONAL INITIATIVES TO PROMOTE DECENTRALIZED SUPPORT TO INTEGRATED FARMING SYSTEMS IN INDIA

The Indian Council of Agricultural Research (ICAR) has been experimenting with institutional innovations under the World Bank-supported National Agricultural Innovation Project (NATP) for enhancing the livelihood security of rural poor. This will facilitate a dynamic innovation system capable of responding to the present as well as future needs of agricultural research and development. The emphasis is on improving and developing the most suitable integrated farming system models in the less favourable environments, regions and groups through active research so that the livelihood of the rural poor improves through assured food, nutrition, employment and income.

Several technologies refined under the Institute Village Linkage Programme of NATP (such as backyard poultry rearing, integrated farming systems, strategic feed supplementation) are upscaled at state level through the semi-autonomous, registered Agricultural Technology Management Agency (ATMA). In fact, a central feature of NATP was to pilot a decentralized extension model, whereby national funds would be transferred directly to ATMAs. Each Block Technology Team (BTT) developed its annual work plan, in close consultation with, and approval by, the local Farmer Advisory Committee. The proposed work plan was sent directly to the ATMA Management Committee for technical review and then to the ATMA Governing Board for final approval and funding. Once each work plan was approved by the ATMA, programme funds were transferred back to each BTT, so that the front-line extension field staff could implement these location-specific extension programmes. ATMAs could receive both public and private sector funds, including some cost recovery for services from participating farmers. In the pilot phase, most programme and operational funds used at the district and sub-district levels were actually project-financed. Therefore, the more rapid availability of funds by each ATMA had a significant, positive impact on activities. Unfortunately, the availability of these unrestricted programme funds largely disappeared after the project ended. The problem was not lack of funds per se, but that nearly all national funds were still 'earmarked' for specific extension activities.Specifically, the Ministry of Agriculture (MOA) did not follow through with the reform process initiated in NATP by transferring previously earmarked programme funds directly to the ATMAs in each district as a continuing source of unrestricted funds. Instead, the different line departments within the MOA argued against this new policy arrangement and were able to continue transferring earmarked funds directly to individual line departments. The resumption of this top-down funding arrangement severely restricts the capacity of both the ATMAs and the sub-district extension staff in addressing the local needs of different farmer groups within their districts.

Source: FAO, 2010b

Some interesting approaches in knowledge development at farm level are well known and successful. One example concerns the Farmer Field Schools (FFS) approach. FFS is a very well-known experiential or active learning (learning-by-doing) farm-based learning system. The FFS curriculum follows the natural cycle of its subject (crop, animal, soil, or handicrafts). For example, the cycle may be "seed to seed" or "egg to egg". Training subjects are taught in “real time”, for example, rice transplanting in the FFS takes place at the same time as farmers are transplanting their own crops, allowing the lessons learned to be applied immediately. Activities are sometimes season-long experiments - especially those related to soils or plant physiology (for example soil or variety trials, plant compensation trials). Each FFS needs a technically competent facilitator to lead members through the hands-on exercises. The FFS concept has been applied to integrated pest management, livestock husbandry and water and soil management techniques, and also improved household energy (e.g. improved cook stoves in an FFS project in Uganda), and could easily be applied to IFES.

A ‘farmer-to-farmer’ training approach has been developed by ECOTOP[9] on sequential agroforestry systems in Bolivia, which could easily become an example of Type 1 IFES, by adding an energy component to the agroforestry farms. Another example concerns the Colombian indigenous people and farmer organization ASPROINCA, which has included a component on biogas and improved cook stoves in its farmer training programme.

The above-mentioned local knowledge approaches focus on the farmer as an entrepreneur. However, if the division of labour proposed in Section 5.2.2.1. is followed, in which the farmer does what he does best – farming – and other local operators handle the energy part of IFES, then adequate skills need to be provided to these local energy entrepreneurs. Several programmes focusing on these operators have been developed recently by organizations such as SNV, GVEP and UNEP.

UNEP’s Rural Energy Enterprise Development (REED) Programme is a very well designed programme which has worked for many years in Brazil, China and Africa. REED’s services to local energy entrepreneurs are delivered through a country enterprise development partner who builds a relationship with the entrepreneur that extends throughout the entire cycle of enterprise development. Training new entrepreneurs is a multi-stage process illustrated in figure 9 (UNEP/UNF, 2003).

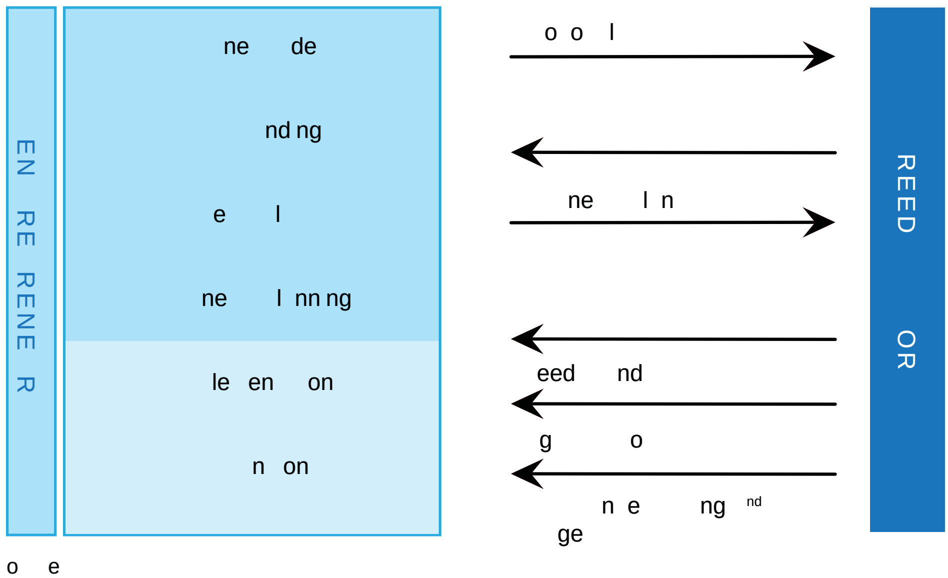
The process begins when an entrepreneur approaches a REED partner with a business idea for utilizing a particular energy resource or technology to satisfy consumers in a specific energy market.

- One of the most crucial stages during the preparatory phase is fact-finding – gathering information about the business idea. Prospective entrepreneurs participate in an initial REED training workshop where they are assisted (as needed) to identify and access the necessary information to test the feasibility of their concept and refine it into a more complete and precise business strategy.

9 http://www.ecotop-consult.de/english/index.htm

FIGURE 9

Training business entrepreneurs



- Entrepreneurs with the most promising and refined business ideas are invited to work with REED partners to define a program of business planning to take them from a core idea to successful implementation when REED seed finance can be made available. Once an enterprise is operating and ready for expansion into a fully commercial operation, second-stage financing from an outside investor can be sourced with REED support.
- Throughout the process of creating the new enterprise, each entrepreneur is able to access customized training and enterprise development services (EDS), such as business feasibility analyses, business plan documentation, business implementation, and growth-oriented business management support.

Regarding skills related to small-scale business development: another approach, which can apply to both farming and energy aspects of IFES, concerns the Success Case Replication (SCR) approach developed in Asia in the late 1990s and applied to a variety of small and medium rural enterprises, including a vegetable marketing cooperative in Nepal, pickled cabbage production in China, and bamboo furniture development in Thailand. It therefore can be easily applied in the replication of successful small-scale bioenergy initiatives, including IFES. SCR is an approach which aims at increasing farmer household income by mobilizing successful farmers and groups to train their peers. It differs from conventional enterprise training because it mobilizes successful farmers or groups to train rural poor. It does not depend upon professional or government trainers to conduct this training (Box 15).

BOX 15

SUCCESS CASE REPLICATION: AN INTERESTING FARMER-BASED TRAINING APPROACH

The SCR methodology follows eleven steps:

- Step 1: Locate success cases;
- Step 2: Ascertain if the success is "replicable";
- Step 3: Assess if successful entrepreneurs - the would-be trainers - are willing to train;
- Step 4: Identify and select trainees;
- Step 5: Match trainer to the trainees;
- Step 6: Establish practical "hands-on" training programme;
- Step 7: Supervise training;
- Step 8: Plan the business with the producers' association;
- Step 9: Access credit;
- Step 10: Arrange follow-up with business development services;
- Step 11: Achieve secondary "multiplications".

Intensive field trials of the methodology were conducted from 1994 to 1998 in eight Asian countries. Eighteen agencies, including government, NGOs and rural banks, joined the project and 16 completed all activities.

In order to evaluate the project, each implementing agency kept cost/benefit records. These included the costs for the time devoted to the project by their field staff and the costs of training the farmers. The benefits were measured as the net income gained by the successful farm families during the first year they marketed their new product. At the end of the four-year field trials, all project evaluations were consolidated to yield the following achievements at the family level:

- Total number of farm families trained using SCR = 3 332
- Number of successful and average success rates = 2 359 = 71 percent
- Average income gain in first year for each family = US$449
- Total increased net income benefits earned by all families = US$1 058 067
- Total agency cost, including staff time and farmer training = US$87 271
- Overall ratio of costs to benefits (C/B ratio) = 1:12

Viet Nam expanded the project to cover four provinces, training 2 605 farm families with an 87 percent success rate. It achieved a cost/benefit ratio of 1:18 in this expansion phase, indicating that the methodology has the full potential for large-scale expansion.

Strengths of the SCR approach include:

- It relies on local strengths and resources, reducing dependency on external actors.
- It is adaptable to local circumstances and comprehensive in that it looks at all important aspects along the value chain (technical, socio, cultural, business, market outlets).
- It is technology and Social Strata-Neutral, which makes it applicable for all kinds of products, technologies and social strata.
- Its implementation is cost effective, mainly because it uses local expertise, without requiring "expensive professional trainers" with often limited knowledge of specific local farm production and enterprise development constraints, and with possibility for follow-up support after the training.

Constraints and weaknesses of the SCR approach include:

- It does not replace conventional training/extension. Technical training and extension are essential to progress. SCR can accelerate technical transfer by "replicating" successes already achieved with conventional technical training.
- It depends on local success cases and the possibility to replicate them.
- Transferring success across barriers is not always obvious, especially given that local circumstances are often important in determining success.
- It requires commitment of the trainee, as the development of an enterprise is not an easy task and requires time.
- It requires honest trainers, to reduce the risk of him/her holding back on business "secrets" to reduce competition from his/her trainees. Trainers might hold back critical secrets fearing market competition from their trainees.
- Over-multiplication of success may result in market oversupply. This should be addressed by a short market study prior to multiplying successful businesses.

Sources: FAO/ESCAP, 2000; Polman and Poudyal, 2009

6.2.3 Collective action through farmer groups

Several of the possible institutional solutions mentioned in this paper allude to the need for some collective action, through farmers' groups. There are arguments in favour of collective action, including easier and cheaper access to inputs, cost reduction in marketing, thanks to economies of scale, and greater bargaining power for the farmers in negotiations with companies. However, experience shows that this is easier said than done, and the record in that respect is mixed, at best. Factors that seem crucial for the success of organizing farmers into groups include (FAO, 2007):

- resources available to farmers, such as land, water, education level and other livelihood assets;
- experience in working together;
- size of the group (small groups work better);
- presence of leadership; and
- most of all, a clear perception of the economic benefits of forming into groups.

The latter factor leads FAO (2007) to recommend that action be taken on the economic performance of a group through both production intensification and marketing improvement, alongside work on institutional and organizational strengthening. This could perhaps be achieved by combining short-term crop production, to demonstrate immediate economic benefit, with longer gestation crops (FAO, 2007).

Given the difficulties in organizing farmers into groups, alternative approaches of farmer organizations have been tried, focusing on those, such as farmer leaders, that are more informal and more organically designed, and entail lower fixed costs (FAO, 2007; Helin *et al.*, 2006).

6.3 SUPPORTING POLICIES

Although there have been isolated success stories of IFES initiatives implemented without *policy support,* in order for IFES to make a substantive impact and move beyond the "island of success" level, policy support is very important.

Policies relevant to IFES concern both the agricultural and energy components of these systems. Constraints in that respect have to do with lack of institutional coordination of concerned government bodies; inadequate links with research; a focus on commodity agriculture and lack of incentives to reward ecosystem stewardship and low carbon agriculture; subsidies to chemical fertilizers; and lack of support for measures favourable to small-scale producer involvement in the local food supply chain. Others are specific to IFES, in particular regarding the energy component. These include incentives for fossil fuel use, lack of measures to promote feed-in tariffs, and lack of evidence to prove to policy-makers that, given IFES advantages, the current agricultural policies need to be changed to encourage their adoption by both small- and large-scale farmers.

6.3.1 Policy support to the agriculture component of IFES

FAO projections (2009d) show that feeding a world population of 9.1 billion people in 2050 would require raising overall food production by some 70 percent between 2005/07 and 2050, with production in the developing countries having to almost double. Ninety percent of the growth in crop production globally (80 percent in developing countries) is expected to come from higher yields and increased cropping intensity, with the remainder coming from land expansion. Similarly, yield increase in biomass production from agriculture and forestry is also seen as crucial for fulfilling the significant increase in bioenergy predicted to be needed in the next decade (IEA Bioenergy 2009)[10], combined with minimal competition and often a positive contribution to food security. It is worth noting that, as far as IFES are concerned, need for yield increase concerns both the energy and food components of Type 1 IFES because their feedstocks are crops in both cases. However, it only applies to the food component of Type 2 IFES, because the energy component uses residues as feedstock.

The emphasis on productivity, be it for food or bioenergy production, will require massive investment in agricultural development[11], and relevant policies. Policies aimed at stimulating investments related to agricultural productivity concern:

- *Research and Development*: In the case of IFES, in addition to R&D specific to crops and livestock yield, the topics of crop-livestock integration and the use of residues also need to be addressed.
- *Improvement of rural infrastructures*, including roads, storage facilities, communication services and market infrastructure.
- *Technology adoption*, which itself includes policy measures related to:
  Input subsidies (e.g. in Malawi);
  Tax incentives, on inputs/investments and on production/revenues: this type of instrument is discussed in Section 6.3.2.(iv) as regards the energy component of IFES.
  Loans/micro-credit: the policy aspects regarding energy loans are discussed in 6.3.2. (ii), and Section 6.2.2.1. presents the institutional aspects of some credit schemes.
  Technical support: ways of achieving this in the case of IFES have been discussed in Section 6.2.2.

While the above policies are needed to promote investment in agriculture, they do not guarantee that these investments will be carried out in a sustainable way, or that they will benefit small-scale farmers and rural communities. Meeting these conditions requires additional policies that promote sound environmental management and social equity.

As regards environmental soundness, FAO promotes sustainable crop production intensification through an ecosystem approach (presented in Box 1), as a way to capture efficiencies through ecosystems services and management. This approach includes three key entry points, to which most IFES characteristics subscribe (FAO, 2010d):

- Develop ways to reduce waste of production inputs and improve efficiency in the use of key resources in agriculture, including horticulture.

10 IEA Bioenergy (2009) estimates that biomass could reasonably contribute to between a quarter and a third of the energy mix in 2050, which corresponds to at least four times the current global bioenergy level of supply – with about a third of the feedstock coming from residues.

11 According to FAO (2009d), such net investment would need to be in the order of US80 billion/year (in 2009 US$) – up by about 50 percent compared to 2009 level. They include primary agriculture and downstream services such as storage and processing facilities, but excluding public goods such as roads, large scale irrigation projects, electrification, and feedstock for liquid biofuels

- As a result, increase farmers' net incomes (through lower spending on production inputs), at lower environmental or social cost, hence delivering both private as well as public benefits.
- Reduces wastage in input use with more use of the natural processes supporting plant growth. Examples of these biological processes include: the action of soil-based organisms (that allow plants to access key nutrients; maintain a healthy soil structure which promotes water retention and the recharge of groundwater resources; and sequester carbon); pollination; natural predation for pest control, etc. Farmers that utilize better information and knowledge on the supporting biological processes can help to boost the efficiency of use of conventional inputs.

Approaches and farming systems, such as integrated plant nutrient management, integrated pest management, conservation agriculture, organic agriculture, integrated crop-livestock systems, agro-forestry systems and integrated weed management, as well as pollination management, all target sustainable productivity improvement.

Core policy needs to promote sustainable agriculture, and in particular, crop-livestock integration, at local, national and international scales concern:

- compatibility and coordination of agricultural development and environmental management policies;
- environmental legislation that embraces the potentials and rights of farming communities as conservators of the environment and natural resources; and
- the removal of public subsidies for agricultural systems and investments that harm the environment.

Policy instruments to support these principles would generally aim at applying the *"provider gets–polluter pays"* principle, through market mechanisms that internalize environmental externalities of agricultural production and reward the provision of agro-environmental services. Such mechanisms include payments for environmental services and taxes on carbon and pesticide use, support to low-input/low emission, and incentives for multiple functions of agriculture. Regulations are another type of policy instrument. Regulations aimed at promoting more environmentally-friendly agriculture include waste management and agro-ecological zoning, and management plans. A simple example of zoning concerns the Brazilian COOPERBIO IFES project, where a cooperative plans to install nine ethanol micro-l distilleries involving 20 families each, and also biodiesel production, integrated with family farming. Farmers are not allowed to use more that ten percent of their land to grow the feedstock necessary for liquid biofuel production, and these are used for local needs (Wilkinson and Herrera, 2008). Zoning will only be effective if there are functioning institutions to assign and control land use. More broadly, weak governance is often an impediment to the enforcement of regulations, and the promotion of "laissez faire", and a reason why these should be combined with market mechanisms, and be developed and enforced in a participatory manner (such as through participatory land use planning regarding zoning, to achieve best impact.

There are significant challenges to develop national and international policies to support the wider emergence of more sustainable forms of agricultural production across both industrialized and developing countries. The political conditions for the emergence of supportive policies that promote agriculture environment links are less well established than institutional arrangements, with only a few examples of positive progress in the areas of voluntary certification, industry standards and government policies and regulations. Examples of full support at national level include Cuba's national policy for alternative agriculture, and Switzerland's three tiers of support to encourage environmental services from agriculture and rural development. Other countries have promoted more sustainable agriculture through partial policy reforms, such as China's support to integrated ecological demonstration villages, Kenya's catchment approach to soil conservation, Indonesia's ban on pesticides and programme for farmer field schools, Bolivia's regional integration of agricultural and rural policies, Sweden's support for organic agriculture, and Burkina Faso's land policy (Pretty 2008).

China's agro-ecological engineering programme is an example of a carefully designed programme (Pretty 2008). In March 1994, the government published a White Paper to set out its plan for implementation of Agenda 21 and put forward ecological farming, known as 'Shengtai Nongye' or agroecological engineering, as the approach to achieve sustainability in agriculture. Pilot projects have been established in 2000 townships and villages spread across 150 counties. Policy for these 'eco-counties' is organized through a cross-ministry partnership, which uses a variety of incentives to encourage adoption of diverse production systems to replace monocultures. These include subsidies and loans, technical assistance, tax exemptions and deductions, security of land tenure, marketing services and linkages to research organizations. These eco-counties contain some 12 Mha of land, approximately half of which is cropland, and though only covering a relatively small part of China's total agricultural land, do illustrate what is possible when policy is appropriately coordinated.

Conscious of the challenges to implement ecosystem-oriented agriculture intensification on a large scale, FAO has recently committed to develop a strategy and implement a programme to 2025, based on the following elements: (FAO, 2010d):

- *Technical*: capturing efficiencies, promoting empowerment of farmers' learning and disseminating knowledge on good agricultural practices, approaches and technologies that can be used to produce high crop yields, while maintaining and/or enhancing environmental sustainability.
- *Economic*: creating tools to assess the economic value of ecological dimensions.
- *Governance*: promoting an enabling policy and institutional environment to ensure productivity, while maintaining or improving the natural resource base.
- *Investment*: capital formation (physical and human resources including applied knowledge).

Making sure that small-scale farmers and rural communities are properly involved in decisions and adequately benefit from the investment promotion measures presented at the beginning of this section, would already significantly contribute to social equity. However, they are not sufficient. Indeed, they require land tenure security as a guarantee to adequate and long-term access to, and use of, land and other natural resources. Therefore, a country's land tenure policies and legislation should clarify property rights, recognize customary and traditional rights of indigenous people, establish public land allocation procedures following due process, including free, prior and informed consent and due compensation, and provide effective access to fair adjudication, including the court systems or other dispute resolution processes. Furthermore, land rental and sales contracts, including contracts for temporary use agreements, should be accessible to all. In the absence of such a system, competition for land for any reason (including production of bioenergy) is more likely to result in adverse social consequences.

But, as with all policies, the above-mentioned instruments are of little value if they are not properly implemented and enforced, and this is particularly challenging in the case of land tenure. As De Witte *et al.* (2009) put it: *"The critical factor is that the State must be able to guarantee in practice the rights accorded to all land users by law. Only then can investors – big and small, entrepreneurs and communities – make financial and longer term plans with confidence in the fact that the parameters shaping their long term vision will not change".* Some recent experience on how to address the challenge of moving beyond "policies on paper" include (De Witte et all, 2009):

- Set economic development upon a series of 'higher principles', such as social equity and natural resource sharing, as in the case of Burkina Faso and Mozambique.
- On the basis of the above, rather than creating parallel rural development for large-scale investors – in particular through State taking land and giving it to them – develop institutionalized formal negotiated partnership mechanisms between the local population, organized in forms of common interests, and private operators, with government authorities as 'referee' and guarantor of law enforcement.
- Ensure adequate level of stakeholder participation throughout the policy process – from design to implementation and monitoring, in order to produce both 'legal' and 'legitimate'[12] policy measures that are also feasible and acceptable to all relevant stakeholders.
- Link needed institutional reforms to policy changes.

It is worth mentioning two ongoing important international initiatives that address the issues discussed in this section:

- The preparation of Voluntary Guidelines on the Responsible Governance of Tenure and Other Natural Resources (Voluntary Guidelines), led by FAO in a broad

12 'Legality' of a policy characterizes those land rights acquired through some form of State involvement – using a specific law and related formal administrative procedures and services. On the other hand, the 'legitimacy' of a legally acquired right is strongly influenced by a set of power relations which may be legitimised by formal processes, and backed or opposed through pressures from influential stakeholders. Customary rights illustrate the difference between legality and legitimacy. They are often much weaker from a legal point of view, but have strong 'legitimacy' because they are rooted in long-standing social and cultural consensus.

partnership with member nations, civil society, IFAD and other United Nations agencies.[13]

- The Principles for Responsible Agricultural Investment that Respects Rights, Livelihoods and Resources (RAI Principles) developed by the World Bank, FAO, IFAD and UNCTAD and discussed in numerous policy fora, including most recently at the World Bank rural week, at UNCTAD and at the FAO Committee on Commodity Problems.[14]

6.3.2 Policy support to the energy component of IFES

In this section we will discuss policy issues related to renewable energy (RE) development in general. This is because policy issues related to the energy component of IFES are often similar to those faced in general by the development of renewable energy systems (RES), and as discussed earlier in this paper (see Sections 2.3. and 5.2.1.2.), it is often advisable to combine different types of renewables in IFES. The EU Biomass Action Plan contends that lack of policies or poor policies is the most important barrier to overcome in RE development since, *"It is convincingly proven that whenever appropriate policies are implemented, the market reacts positively and develops the necessary structures and operations systems to deliver results."* (EU, 2005). Renewable energy systems have high up-front costs. In addition, a number of factors contribute to making renewable energy more expensive than conventional energy. Distortions resulting from unequal tax burdens and much higher subsidies for non-renewable energy, and the failure to internalize all costs and benefits of conventional energy production and use, are high barriers to RE. Additional cost barriers range from the cost of technologies themselves (and the need to achieve economies of scale in production), to the lack of access to affordable credit, and the costs of connecting with the grid and transmission charges, which often penalize intermittent energy sources. Import duties on renewable technologies and components also act to make renewable energy more costly.

While policies related to RE have existed for some time, mainly in developed countries, this trend has changed in recent years. Much more active policy development during the past several years culminated in a significant policy milestone in early 2010: more than 100 countries had enacted some type of policy target and/or promotion policy related to renewable energy, up from 55 countries in early 2005. Many new targets enacted in the past three years, call for shares of energy or electricity from renewables in the 15–25 percent range by 2020 (REN 21, 2010). Most countries have adopted more than one promotion policy, and there is a huge diversity of policies in place at national, state/provincial, and local levels. Many recent trends also reflect the increasing significance of developing countries in advancing renewable energy. Collectively, developing countries have more than half of global renewable power capacity (REN 21, 2010).

13 More information on these guidelines available at: http://www.fao.org/nr/tenure/voluntary-guidelines/en/

14 More information on Responsible Investments in Agriculture Initiative available at: http://www.responsibleagroinvestment.org/rai/

The above development is encouraging and provides enough experience in diverse countries to draw lessons on what makes RE development work or not. Experience in countries where RES have been successfully developed, show that a sustained renewable energy market is an essential factor of such successes, and that RE markets can be developed quickly and efficiently, if the right combination of policies is adopted. It is increasingly agreed that policy choices have been far more critical to the development of RE seen to date than RE potentials or technological challenges (WorldWatch Institute, 2009).

Policy support to the energy component of IFES, and more broadly RES, relate to (Sawin, 2006):

- promotion of renewable energy markets;
- financial incentives;
- standards, permitting and building codes;
- capacity building: research, education and information dissemination; and
- stakeholder involvement.

These policy areas are briefly discussed hereafter.

6.3.2.1 Promotion of renewable energy markets

The most common policies are aimed at promoting RE concern quotas, targets and feed-in tariffs.

(i) ***Quotas/Mandates***

Mandate/quota policies aim mainly at guaranteeing markets for RE, and thereby lower investment risk (and cost). The government sets the target and lets the market determine the price. Typically, governments mandate a minimum share of capacity or generation of (usually grid-connected) electricity, or a share of fuel, to come from renewable sources. The mandate can be placed on producers, distributors or consumers.

According to a recent REN 21 (2010), by early 2010, policy targets for renewable energy at the national level existed in at least 85 countries worldwide. Many national targets are for shares of electricity production, typically 5–30 percent. Other targets are for shares of total primary or final energy supply, specific installed capacities of various technologies, or total amounts of energy production from renewables, including heat. Targets also exist for liquid biofuels in many countries. The same report says that mandates for blending biofuels into vehicle fuels have been enacted in at least 24 countries at the national level, including 14 developing countries. Most mandates require blending 10–15 percent ethanol with gasoline or blending 2–5 percent biodiesel.

Quotas tend to provide certainty about future markets at a relatively low cost. On the other hand, they tend to create cycles of stop-and-go development. In the case of liquid biofuels, according to Biggs (2009), blending requirements often face opposition from the fossil fuel supply industry, which in the absence of a strong, independent public sector, can result in project failure. Furthermore, blending requirements require a consistent government commitment. Zimbabwe illustrates this: when government support for blending waned in the late 1990s, its formerly successful biofuel industry shifted to exporting ethanol as a solvent (Biggs, 2009). Another weakness of blending requirements is that they do not necessarily entail domestic bioenergy production. This drawback has generated tough public debate about the importation of low-cost Brazilian ethanol to meet blending requirements in recent years in the EU.

More broadly, quota systems tend to favour large and centralized plants and are not well-suited for small investors. They also tend to concentrate development in best-endowed areas, which can contradict the rural development benefits that RE development can generate.

(ii) ***Feed-in tariffs***

A feed-in tariff (FIT) is simply a guaranteed price over a predetermined length of time to RE producers who sell electricity into the grid. As such, FIT policies act in the reverse way of quotas, i.e. they establish the price and let the market determine the capacity generation.

FIT is currently the most popular financial measure to encourage RE development. By offering a guaranteed price (high enough to ensure profitability of the project) over a long period of time, it assures investors of the stability of their investment. This type of policy instrument has resulted in significant increase in RE in recent years. According to REN 21 (2010), by early 2010, at least 50 countries and 25 states/provinces had adopted feed-in tariffs over the years, more than half of which have been enacted since 2005. They have had the largest effect on wind power but have also influenced solar PV, biomass, and small hydro development.

However, FITs are not without drawbacks:

- One risk associated with FITs lies in the fact that, if tariffs are not adjusted over time, consumers may pay unnecessarily high prices for renewable power.
- Given that FITs need to be high enough to cover costs and encourage development, they often constitute large subsidies, and therefore a drain on national treasuries, which has sometimes prompted resistance from utilities and consumers because of the resultant higher electricity rates (e.g. in Germany).
- FITs obviously require a grid to feed into. As such, they may be only applicable in countries with well-funded treasuries and abundant opportunities for large-scale RE generation (e.g. a pre-existing high-volume sugar-cane or forest products industry in the case of bioenergy).
- Finally, such policies are likely to favour relatively wealthy households who are already grid-connected.

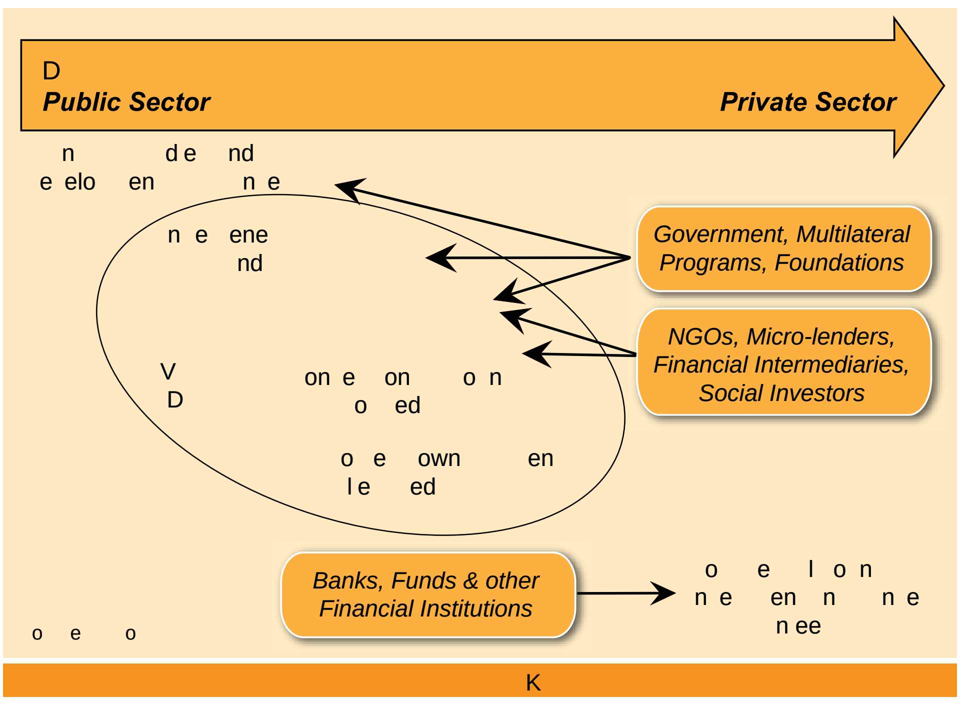
The combination of quotas and feed-in tariffs can sometimes “over promote markets” and thereby lead to debatable developments, such as the recent boom in using crops (in this case corn) instead of residues, to produce biogas in Germany.

An important conclusion of this section on current market-oriented policies for RE development – i.e. quotas and feed-in tariffs – is that these are probably not the most appropriate instruments to promote RE development for small-scale farmers and rural communities in developing countries. They are also more relevant to the operations and maintenance phase of RE initiatives, whereas a lot of the challenges in rural areas of developing countries lie at the start-up phase. Financial incentives can help fill this gap, and are discussed in turn.

6.3.2.2 Financial incentives – Grants, subsidies, micro-credits, carbon finance and tax breaks

There is general agreement that financing instruments will vary according to the development stage of any RE initiative, along a continuum which is presented in Figure 10. This figure also shows the role different types of organizations can play in supporting the needs along the finance continuum. It presents two main stages along this continuum:

FIGURE 10
The Finance Continuum



- A development phase, which corresponds to a technology push through R&D and demonstration activities. The main financing instruments related to this stage are R&D and capital grants.
- A commercial phase, where the technology has reached commercial feasibility and enters a market-pull phase. Financing instruments corresponding to this stage typically include seed capital and loans.

The figure also mentions the “valley of death”, which corresponds to the financing gap between the mid-demonstration and pre-commercialization stages, which currently plagues RE technology development. Financing gaps during that critical phase relate to (UNEP/UNF, 2003):

- too few intermediaries;
- too little seed capital;
- too little reasonably-priced growth capital;
- insufficient customer and micro-enterprise finance.

Financial instruments apply to large-scale operators, small and medium enterprises (SME) and end users. Our discussion will focus on the latter two, because they are the most relevant operators regarding the topic of this paper.

A detailed discussion on the diverse financing instruments available to SMEs and end users of RE technology is beyond the scope of this paper, and can be found for instance in UNE/UNF (2003) and UNEP (2006). Rather, this section focuses on the most commonly used financing instruments for the promotion of RE in rural areas of developing countries, i.e. grants, micro-finance, carbon finance and tax incentives.

(i) *Grants*

One frequent complaint about grant programmes lies in their limitations in terms of flexibility and continuity. Still, in sectors with strong societal externalities, such as those with environmental or health benefits, government R&D grants remain the main financing source in the early development phase. There is agreement that direct subsidies and competitive grants for R&D must be maintained, due to the reluctance of the private sector to invest during this early stage.

Some grants are tailored specifically for developing country conditions (REN 21, 2010):

- One example is the technical assistance grant fund. A variety of output-based aid grant funds is available to finance both technical assistance and part of the costs of delivering rural off-grid energy services. Some initiatives have helped finance innovative pilot projects that have the potential to be scaled up in the future.
- One financing approach used in Latin America has been to include renewable energy options in programmes that provide social and community block grants - as was the case in Guatemala with World Bank funding for improved biomass stoves. Because these social investment funds provide assistance to whole communities, they can lead to very equitable approaches in promoting off-grid renewable energy services.

When developing grant programmes appropriate to a local context, investment culture and technology type, governments should focus on ‘smart subsidy’-style grants that do not create dependence, i.e. a tendency to remain in a research/first demonstration stage, where grants are available. Smart subsidies attempt to grow a new technology area, while minimizing long-term market distortions. Subsidies remain "smart" when they have an 'exit-strategy' as the technology reaches pre-commercialization that will leave a functioning and sustainable sector in place upon their removal.

Contingent grants are one example of "smart" subsidies. This option allows the public sector actor to provide incremental funds without directly subsidizing commercially viable activities, since the support is repaid once the business activity has started providing returns. In the event that the contingent grant is repaid, then the repayment history is useful for demonstration to future investors (UNEP/UNF, 2006).

(ii) ***Micro-credit***

Experience shows that access to modern energy services by the poor is improved when there is convergence between policy objectives related to better access to micro-finance and those focused on energy. But achieving this is not without problems. UNDP (2009a) neatly sums up the situation:

"On the one hand, small-scale finance helps to expand access to modern energy services and promote the productive use of energy, and on the other hand, lending for energy appears to make good business sense for the financial institutions. What is holding back the expansion is the perceived risk that the financial institutions see with regard to the technologies and the delivery models. Energy technologies are not well understood by financial institutions and therefore it is essential to have a reputable energy enterprise supplying a high-quality product that is backed up with reliable service. This is most important in the rural areas, where there is a lack of awareness of different options and misperceptions about technologies appropriate for rural areas."

In the past, the main problem for financing renewable energy has been the relatively small project size, which made loans unattractive to financial institutions. This is less of a problem for grid-based electricity systems because the financing needs tend to be larger and loans can be made directly with a dedicated electricity company. For off-grid electricity projects, rural energy funds have become more and more popular in developing countries – large amounts of financing is provided to local private or public banks that are committed to financing rural energy projects. Typically, such banks or funds develop a portfolio of possible rural and renewable energy projects, although they also can react to requests for new lines of financing by reviewing project proposals. They actually do not provide financing to households directly; rather it is up to the private companies, concessionaires, non-governmental organizations, and microfinance groups to organize the demand for the energy service and to apply for project funding after developing a sound business plan to serve rural consumers. As a result, renewable household systems, improved biomass stoves, and village or community small grid systems can all be serviced by the same financing agency. In practice, many of these funds initially specialize in a single simple technology, but increasingly they are expanding to other renewable as well as non-renewable energy systems.

This successful model has been implemented in many countries, including Bangladesh, Mali, Senegal, and Sri Lanka. (REN 21, 2010 – see Box 16), and is also the scheme used in the UNEP AREED programme[15].

BOX 16

RURAL ENERGY FUNDS IN MALI, SRI LANKA AND TANZANIA

Mali's household energy and rural electrification agency, AMADER, promotes both standard designs and self-initiated forms of rural electrification. The agency has succeeded in attracting local private sector operators to provide electricity services in rural areas, offering these operators services that include direct and indirect grants and advisory assistance on engineering, project management, project feasibility studies, and master plans. AMADER uses a competitive bidding process to serve a small to medium geographic area, specifying the grant per connected household and allowing bidders to bid on the basis of lowest tariff. Self-initiated electrification projects tend to be smaller, spontaneous projects that serve individual villages.

Currently, AMADER will finance up to 80 percent of the capital costs, and it uses a local commercial bank to handle disbursement of its grants. The agency is the de facto regulator for the grant recipients, setting a maximum allowed price as a condition for receiving a grant. This price is based on a cost-of-service financial model developed by AMADER. AMADER also establishes quality of service standards.

In Bangladesh, IDCOL manages a rural energy fund that has been successful in promoting nearly 500 000 solar home systems and now is expanding into other services, such as biogas and improved biomass stoves.

In Tanzania, a new USD$25 million programme for off-grid rural electrification has been established and is now under implementation. A Rural Energy Agency was created to coordinate overall implementation of the rural/renewable energy credit line, with responsibilities that include programme oversight, facilitation of new projects, and monitoring and evaluation.

Source: REN 21, 2010

A recent UNDP report presents examples that show various ways of strengthening the micro-finance-RE links in several countries (UNDP, 2009):

- A micro-hydropower project in Kenya showed that efforts to remove policy, institutional, and technical barriers constraining investment in low-cost, off-grid rural micro-electric- grids are essential. Moreover, when end users had access to

15 Information on UNEP's AREED Programme is available here: http://www.areed.org/

small-scale finance, they were able to pay the upfront costs associated with micro-hydropower.

- In Nepal, there were targeted subsidies for alternative energy programmes integrated with small-scale finance. This involved training energy enterprises and financial institutions (e.g. microfinance institutions and rural savings and credit organizations) on effective delivery, and developing and enforcing technical and service standards for the energy systems.
- The Promotion of Renewable Energy in Tanzania (PRET) programme linked rural energy enterprises with rural financial institutions to get solar home systems, with financing, in the hands of the poor. The Government, through the Ministry of Energy and Minerals, was actively involved in the design of the programme and created crucial institutional incentives and networks to help launch the PRET programme.

Small-scale farmers often face problems in providing collateral as guarantee to get bank loans. Land is often a possibility, but this requires secure tenure, though it may not require an ownership title, as many large-scale investors would claim or wish. Indeed some land titles like the land certificates in Vietnam, or the DUAT land contract in Mozambique, can be used as collateral, on the basis of long-term user rights. Some innovative forms of collateral have been developed recently. One example is a sort of 'integrated energy–food-finance system' developed by the NGO SELCO in India (SELCO 2009): fair trade companies used to providing loans to farmers for their crops, now include a RE component in the loan scheme. The RE credit is refunded as instalments of the crop sales.

(ii) ***Carbon finance***

Carbon finance currently includes regulatory markets and voluntary markets. The regulatory, also called compliance, market is used by companies and governments that by law have to account for their GHG emissions. It is regulated by mandatory national, regional or international carbon reduction regimes. On the voluntary market, the trade of carbon credits is done on a voluntarily basis. The size of the two markets differs considerably. In 2008, on the regulated market US$119 billion were traded, and on the voluntary market US$704 million (FAO, 2010c).

CDM is the best known regulatory carbon market. Examples of bioenergy projects that received CDM funding include the biogas programme in Nepal, presented in Box 5, a methane avoidance, energy and fertilizer enterprise from dumped cattle waste in Pakistan, biogas/methane capture and combustion from poultry manure treatment at Lusakert Plant, Armenia, and biomass production/electricity generation from mustard crop residues in India (FAO, 2010c).

However, small programmes face significant obstacles to receiving carbon funding from the regulatory market/CDM, and it may be necessary to streamline procedures that do not violate some of the basic CDM methodologies.

Although the voluntary market has increased over recent years, it has faced challenges, including lack of credibility and lack of a universal registry, due to the range of different procedures currently applied to projects. In addition, some standards and processes are backed by credible organizations. However, many are not publicly available and could be substantially less rigorous (Harris, 2007).

FAO (2010c) has recently developed simple guidelines aimed at supporting the setting-up of carbon-finance projects which involve small scale farmers.

Interesting financing mechanisms for bioenergy-based IFES and small-scale farmers are briefly presented in this report, in the case of sugar-cane bagasse electricity in Mauritius (Box 12). Given their simplicity, single loop biogas systems lend themselves more easily to large-scale implementation. Perhaps the largest and oldest programme has been developed in China, with more recent programmes developed in Nepal and Vietnam. Box 17 presents the cases of the biogas programme in Nepal.

BOX 17

THE NEPAL BIOGAS SUPPORT PROGRAMME - AN EXAMPLE OF A GOOD COMBINATION OF SUCCESS FACTORS AT DIFFERENT LEVELS

The Nepal Biogas Support Programme (BSP) started in July 1992. It has aimed to provide improved energy service in rural areas through a comprehensive combination of technical support, social integration, financing mechanisms and cost-effective delivery structures. The programme includes key features such as:

- Quality biogas plant construction and assurance of proper operation in rural areas.
- Applied research/analysis for optimized design and operation.
- Comprehensive quality standards and a quality control system.
- Gender mainstreaming and social inclusion.
- Following a first period where the programme was entirely subsidized, current emphasis is on a commercially viable and market-oriented biogas sector. However, there is a differentiation in that remote areas still receive higher subsidies than others, and these target small- and medium-scale farmers.
- In order to achieve the above change, a comprehensive micro-credit facility exists for financing biogas plants in rural Nepal, and gradual entry of the private sector; which currently have equal share as the public sector in biogas plant installation.

From an institutional point of view, the programme is executed by the Alternative Energy Promotion Centre (AEPC). AEPC manages the Biogas Credit Fund, which allocates funds to several microcredit organizations. The Biogas Sector Partnership Nepal (BSP-Nepal) is the implementing agency of Biogas Support Programme (BSP) Phase-IV. BSP-Nepal was established as an NGO in 2003 to take over the implementation responsibility of BSP, which was formerly managed directly by the Netherlands Development Organization (SNV). Additional bodies created through the programme include the private sector representation by several biogas companies, the Nepal Biogas Promotion Association, and a series of NGOs and farmer cooperatives throughout the country.

The programme is now completing its fourth phase. Within the last twenty years it has achieved results on a wide scale:

- Over 200 000 biogas plants installed in 70 percent of Nepalese villages, of which 93-98 percent are in operation;
- 86 private biogas companies and 17 biogas appliance manufacturing workshops;
- Comprehensive quality standards/control - ISO 9001:2000 certification holder;
- 63-69 percent toilets connected with biogas plants;
- 74-89 percent of bio-slurry used as organic compost fertilizer;
- 232 micro finance institutes received wholesale loan from AEPC's biogas Credit Fund;
- As a complementary financing mechanism, BSP has become the first CDM programme in Nepal, with currently two projects concerning about 20 000 plants being registered and approved by the CDM Executive Board, with a potential annual carbon revenue worth about US$600 000.
- More than 1.2 million people have directly benefitted and 13 000 individuals got jobs thanks to the programme.

The above shows that the BSP has contributed directly to the achievement of the Millennium Development Goals (MDGs) in Nepal, due to its comprehensive design that addresses technical, financial, socio-economic, health, and gender aspects. The programme has also developed a thriving economic sector with new technical capacity and linked this to financing options, thereby empowering entrepreneurs and households in their energy and economic choices.

Sources: BSP 2009.

(iv) *Tax breaks*

Tax incentives can be a very powerful instrument to reduce the costs of investing in RE. They can apply to the supply side of RE deployment (i.e. investment and production) and/ or the consumption of RE.

Investment tax credits cover part or all the costs of a RE system. They directly reduce the cost of investing in renewable energy systems and reduce the level of risk, and therefore can encourage their installation in off-grid, remote locations. One risk associated with investment tax breaks lies in that they may encourage fraud and the use of substandard equipment, if they are not associated with technology standards.

Production tax credits provide tax benefits against the amount of energy actually produced and fed into the electric grid, or the amount of biofuels produced, for example. They increase the rate of return and reduce the payback period, while rewarding producers for actual generation of energy.

Supply side tax incentives provide greater benefit to people with higher income levels and tax loads. In addition, they are often used as tax loopholes. As with investment credits, production tax credits should decline over time and eventually be phased out.

Consumption tax incentives apply differentiated taxation to fossil and renewable energy consumption, with the view of favouring the latter. The key to the efficiency of such systems is the existence of an adequate tax differential to encourage both an increase in RE production and consumption, as well as an independent public service that can resist pressures by the fossil fuel industry lobbying against such a move. Consumption incentives may face resistance in countries with low-revenue National Treasuries, as in the case of many developing countries (Biggs, 2009).

A major drawback of tax incentives is their instability: they usually rely on government budgets and are thus subject to frequent political negotiations and annual budget constraints.

UNDP (2009b) proposes the following classification of combination of financing support and RE applications:

- For *social services*, it is likely that subsidies and grants from international donors, in collaboration with relevant government ministries and NGOs, will remain a key mechanism for funding mechanical power installations for basic services.
- For *income generating activities* (for instance grain milling or manufacturing), soft and/or commercial loans, coupled in some instances with small subsidies, are and will continue to be instrumental in creating thriving businesses.
- For *enterprise-based mechanical power initiatives,* there is a range of sources of funding already in existence which are potentially appropriate, based on commercial or semi-commercial loans, including AREED in Africa.
- For *stand-alone mechanical power systems* at farm or household level, financing and micro-lending models have been developed, such as that of the Grameen Bank of Bangladesh.
- For *decentralized mechanical power systems*, such as community water supply or shared milling resources, additional financing options can be considered, drawing from existing experience in revolving funds or loans. Loans are given to institutions involving local government and the community, often with management and operation of schemes by trained local enterprises.

The above discussion on financial instruments leads to the following observations:

- Different policy instruments correspond to different stages of the RE development finance continuum. Understanding financing needs that exist in these various stages is a complex task, as they depend on several different factors, such as regulatory environment, developed or developing country contexts, and clean energy market trends.

- Effective financing mechanisms should fill an existing investment gap, increase private sector involvement and awareness and have the ability to be phased out over time, leaving a long-term private sector financing solution in place. The most effective finance mechanisms do not distort the market, but rather help to build it into a financially viable alternative to conventional energy (UNEP, 2006).
- Another important conclusion relates to the strategy used in financial support to RE initiatives. Recent supporting schemes have focused on the main actors of RE development – entrepreneurs and end users – to provide incentives so that, instead of 'dropping' RE projects on completion, these actors have an interest in their continued success. The big difference between these two approaches lies in the fact that, with the same amount of money, the former scenario produces limited RE installations, while in the latter case, the same amount of money is seen as seed capital to support small RE entrepreneurs and end-users, hence allowing for a much higher multiplier effect, and with better chances of long-term viability.
- This innovative way of promoting RE also favours the business and entrepreneurial dimension of development, as opposed to the 'dole out' approach. The same spirit underpins the success case replication approach to local learning presented in Box 15.

A final point on policy instruments regarding RE market promotion and financing incentives is in order, as these can all be considered as RE subsidies, and energy subsidies is a controversial topic. A recent report (IEA et al, 2010) estimates that global subsidies for RE amount to around US$100 billion per year; whereas subsidies for fossil fuels are worth about US$700 billion – roughly one percent of world GDP. Interestingly the same report states that, on a per energy unit basis, RE is being more subsidized than fossil fuels – US cents 5.0 per KWh[16], compared with US cents 1.7 per KWh for nuclear power, and US cents 0.8 per KWh for fossil fuels. This poses the question: when should energy subsidies be considered good or bad? The basic principle should be to consider sustainability costs, i.e. from an economic, social and environmental point of view.

- With regards to *economics*, subsidies bear the risk of not being very efficient, as they reduce incentives to reduce costs for the producers, and may lead to higher energy use and reduced incentives to conserve or use energy more efficiently. This has led some to suggest replacement of subsidies with 'polluter pays' systems. This principle is not only more economical, as it makes the polluter pay the burden of environmental protection, but can also help to rehabilitate public debts.
- From an *environmental* point of view, again the picture is not black and white. Recent OECD and IEA analyses indicate that phasing-out fossil fuel subsidies could lead to a ten percent reduction in GHG emissions in 2050, compared with

16 This figure amounts to US cents 5.1 per KWh for biofuels in 2007 (GSI, 2009)

business-as-usual (IEA *et al.*, 2010). However, subsidies can sometimes be put to good use. For instance, subsidies that are used to finance R&D, aimed at reducing environmental damage, such as GHG emissions and noxious gases, from all types of energy, including fossil fuels. Subsidies for modern forms of energy can reduce reliance on traditional biomass use, with its risks to forest cover and carbon emissions, not to mention health hazards.

- Regarding social aspects, again the picture is not black and white. Several studies reviewed show that subsidies to fossil fuel use tend to benefit high-income households more than the poor, due to the former's higher consumption levels. The bottom 40 percent of the population in terms of income distribution received only 15-20 percent of the fuel subsidies in developing countries (IEA et al, 2010). But dealing with distributional effects of cuts in energy subsidies is often a major element in overcoming political obstacles to subsidy reform. One route may be to provide more general financial support to the vulnerable, such as through income support, rather than specifically subsidizing energy per se. There could also be a case for maintaining subsidies that result in better access to modern forms of energy in developing countries.

Summing u*p on energy subsidies,* energy markets should incorporate all types of societal costs (economic, social and environmental) in judging energy subsidies, and this depends on country circumstances. In any case, it often makes sense to establish time limits or "sunset clauses" in subsidy schemes right from the outset, and mechanisms to regularly assess their appropriateness of reforming subsidies.

6.3.2.3 Other policy aspects

While market and financing policies are the most important policy mechanisms to promote RE, other aspects also require adequate policies, and are briefly discussed hereafter:

(i) ***Infrastructure***

In many cases, especially for biomass-based cogeneration and power generation, the primary energy resource is scattered, hence creating a dual logistics challenge: collection and transport to the transformation facility and construction of transmission lines to convey the power generated to the market. Meeting this challenge requires appropriate planning of clean-energy and infrastructure development and policy and financing mechanisms. In many developing countries, outside technical assistance is needed to develop such planning capacity.

(ii) ***Standards***

There are several types of standards (Sawin, 2006):

- *Technology standards* can prevent inferior technologies from entering the marketplace and generate greater confidence in a product, thereby reducing risks, which is important for financing. They are also important for the development of quality control mechanisms.

- *Siting and planning requirements* can reduce opposition to renewables if they address other potential issues of concern, such as noise and visual or environmental impacts. They can be very efficient in reducing uncertainties, hence in increasing public acceptance, and in expediting planning. Lack of RE planning regulations can virtually halt the process for obtaining planning and environmental permits, as in the case of wind turbines in the UK (Sawin, 2006).
- *Building codes and standards* can also be designed to promote energy efficiency and renewables such as passive solar (transparent and opaque insulation), solar thermal energy, modern biomass, geothermal and PV, by requiring that these be incorporated into designs and planning processes for residential and commercial buildings.

While standards are necessary, they should be developed in a way that does not become a barrier to large-scale implementation. Ways of reducing such risk include (ECOFYS, 2008):

- *One-stop authorization agency* appointed by the government, to reduce the risk of lack of coordination between different agencies at different administrative levels.
- *Reduced periods and approval rates* through clear guidelines for authorization procedures (e.g. obligatory response periods, setting approval rates as a means for checking the streamlining of authorization procedures).
- *Pre-planning areas for RE deployment* to reduce the time needed to obtain siting authorization. For instance, in Denmark and Germany, municipalities are required to assign locations available to project developers for a targeted level of RES capacity.
- *Account for future RE inputs in grid development or expansion*, especially in the case of large-scale RE systems; grid connection and accounting rules.
- *Transparent grid connection and accounting rules related to grid connection costs*, to reduce the risk of controversies, as has happened in some EU countries.

(iii) ***Capacity-building: Information-dissemination, education and research***

Experience in RE development shows that, even if a government offers generous incentives and low-cost capital, people will not invest in renewable energies if they lack information about them. Education and information dissemination related to renewable energy must include everything from resource studies and education about various renewable technologies, to training and information about available government incentives and support systems.

Government leaders must be the first to be convinced about the inherent values of RE given their coordinating role in organizing information, education and research at national level. In India, the government's Solar Finance Capacity Building Initiative educates Indian bank officials about solar technologies and encourages them to invest in projects.

The Indian government has also used print media, radio, songs, and theatre to educate the public about the benefits of renewable energy and government incentives, and has established training programs (Sawin, 2006).

With regards to information-dissemination, a centralized global clearinghouse might be needed to reduce the likelihood of reinventing wheels in different countries. Participants in the July 2010 FAO Technical Consultation on "How to make integrated food-energy systems work for both small-scale farmers and rural communities in a climate-friendly way" suggested that FAO could play such a clearinghouse role in IFES.

Regarding education and training, some ways to develop local level knowledge for IFES operators have been presented in section 5.2.2.3. Beyond those stakeholders, information and training on RE potential, benefits, state and technologies should also happen in the education system (schools and universities).

Research and development (R&D) on RE has recently gained momentum in both developed and some developing countries, and its results have contributed to cost reduction of some RE technologies (e.g. solar) and technological progress (e.g. advanced liquid biofuels, bioelectricity). Some international funds are becoming available for R&D related to RE, especially in relation to their links to climate change (e.g. GEF). On a domestic scale, revenue from FITs or energy taxes has been funnelled into R&D for bioenergy by some countries. However, Sawin (2006) contends that: *"Ultimately, it is only by creating a market (demand-pull, rather than supply-push) for renewable energy technologies that the technological development, learning and economies of scale in production can come about to further advance renewables and reduce their costs. And as markets expand and industries grow, more private money is drawn into private research and development, which is often more successful than public R&D."*

(iv) ***Public ownership and stakeholder involvement***

As in other development sectors, experience in RE shows that public ownership and stakeholder participation are essential ingredients for acceptance and sustainability of specific projects and also implementation of policies. Germany and Denmark show several examples where local people co-own local RE initiatives. Through cooperatives, people share in the risks and benefits of renewable projects; often avoid the problems associated with obtaining financing and paying interest; play a direct role in the siting, planning, and operation of machines; and gain a sense of pride and community responsibility. The key to the success of some projects in developing countries has been a sense of ownership among local people. For example, local participation and ownership of solar mini-grid projects in Nepal and the Indian islands of Sundarbans, have played a crucial role in the success of projects and have eliminated electricity theft (Sawin, 2006).

When local stakeholders also co-fund the costs of RE systems, and services associated with them, it increases downward accountability (i.e. from service providers to users and beneficiaries), thereby getting closer to innovative ways to fund agricultural extension services, illustrated in Figure 8 (Section 6.2.3.1). Downward accountability can also be enhanced through stakeholder involvement in quality control. This has, for example, been an important feature of the of the Nepal Bioenergy Support Programme described in Box 17, and also of the VACVINA integrated farm management programme developed in Vietnam. In this case, user surveys have been extensively used, allowing them to give their views about different topics, such as quality of the provided energy conversion devices, overall degree of user satisfaction, and environmental and livelihood impacts of the biogas system as a complement to crop-livestock-fish integration (Pham Van Tranh, 2010).

6.4 HOW LOCAL CIRCUMSTANCES, SCALE AND TIME INFLUENCE THE DEVELOPMENT OF IFES AND THEIR SUPPLY CHAINS

IFES vary in types and sizes. They do not happen in a vacuum and are not implemented overnight. IFES development constraints, and possible solutions to overcome them, evolve according to these factors.

If IFES develop organically, i.e. progressively increasing efficiency and complexity, supply chain requirements change with the development. The least supply chain demands are created by farmers who use only on-farm resources for production, and supply already existing markets. In such cases, IFES can contribute only to increased on-farm efficiency and perhaps diversity for higher sustainability. In other cases, increased knowledge of other processes and products can add to diversification of outputs and higher economic and ecological efficiency. Here, input supplies need to be available in the form of *knowledge, biological, technical and perhaps financial and organizational resources*. The higher the output diversification and quantity expectations, the more knowledge and organizational capacities need to be available (see also Table 5). Under most conditions these capacities need to be formed or provided (by government or private institutions). The extent to which this can be done is likely to determine the speed and success of the desired development.

The above described organic type of growth is more likely to occur with small-scale individual farms. In addition, each farm is likely to develop a slightly different approach and mix of crop and energy outputs, very much depending on each farmer's capacities and priorities, even if market conditions favour one or very few crop or energy types. This puts considerable demand on technical assistance, considered a primary supply chain input for all IFES projects.

The time frame of project targets has a significant impact on supply chain design and the needed input and market demands. Some of the interactions are discussed under supply chain processes. First a brief characterization of the different up- and down-farm supply chain needs, including inputs in the widest sense and outlets (demand) for products off-farm. All on-farm produced supplies are not discussed separately, but would mostly fall under, or be produced, with external knowledge inputs and some technology inputs.

6.4.1 Supply chain needs

One can start with the assumption that local farming systems are already integrated to the optimal state of the present system capacities, i.e. are adapted to the prevailing local conditions, such as farmers' capacities and the system abilities to supply inputs and absorb outputs. In the case of some recent destructive impacts, one would have to look at the system existing prior to those destructive influences, plus the changes (new needs) induced by these disruptions. To introduce any additional elements, the gaps that lead farmers to not include self-supply of more efficient energy into their farming systems need to be bridged. These could be falling into any of the following areas*: (i) knowledge; (ii) seed availability; (iiI) production inputs; (iv) needed (essential) technologies; (v) markets.*

6.4.1.1 Knowledge supply

The knowledge supply needs to be evaluated not only for initial decision-making, but also for the later continued investments into production and processing technologies, plus the abilities to market additional production. At all stages, there will be locally specific knowledge requirements and already available experience of attempts at providing similar type of assistance in the past. Unless past barriers can be bridged (financially, institutionally, culturally and technically) the chance of success is highly limited. Means of such knowledge assistance, however, may have evolved also locally through access to new information technologies (mobile phones, interactive radio, internet), which may change investment needs and capacities of personnel. Non-farm educational "supplies" need to be part of the integrated supply chain, to create a benefit of IFES towards poverty reduction and rural development from newly generated income and/or additional time available for different family members.

6.4.1.2 Seed availability

The introduction/acceptance of new varieties of already known crops into traditional or poor farming areas has always been slow, and altogether new crops are even slower to spread, unless strong economic incentives are provided for investment and marketing. The sustainability of such incentives, however, requires careful evaluation and many such even well-meant introductions failed in the long run and sometimes even left farmers with much worse conditions than at the start. Several jatropha schemes, which guaranteed high prices by NGO buyers, failed due to the unstable, new and highly variable market conditions that could not be absorbed by the financially weak buyers.

The introduction of new varieties always needs to be carefully weighed against existing varieties, especially their diversity and their often superior local adaptation, particularly in view of future climate uncertainties. New crops need to fit into local crop rotations or intercropping cycles, in addition to the climatic, soil and pest conditions, preferably without requiring external inputs that reduce cash flow, or cause indebtedness like chemical fertilizers, pesticides and irrigation.

6.4.1.3 Production

New production methods, due to integration of new crops or requirements for higher production intensity, will require successful demonstrations and long-term technical assistance until fully and successfully accepted and locally productive. The different methods available for that (Farmer Field Schools, Farmer-to-farmer trainers, traditional extension services), plus farmer operated demonstration farms, should be considered part of the supply chain and need to be available, accessible and effective over long periods of time. A low input system will require significant knowledge input to improve yields. Such knowledge supply is well worth it, given that these farming systems are capable of producing equal or higher yields more sustainably than industrial input farming under most developing country conditions, while at the same time reducing economic risk due to lower indebtedness and less annual investment needs. The reduction of costly external supplies (money, seeds, agro-chemicals, technology) and increased efforts to enhance natural cycles – fully parallel and complementary, in the spirit of IFES' integrative approaches, makes modern low-input systems more sustainable and empowers choices for rural development in general, and for IFES, in particular.

6.4.1.4 Technologies

The need for, and type of technologies available for IFES, varies much with the objective of the IFES promotion and the local capacities. Small farms usually also mean very limited financial capacities, but not always availability of manual labour to create or substitute technology. Here low input and organic production methods to increase yields may be more suitable than industrial technology (machines). Focus on a combination of faster cash flow generation and improving local (farmers') energy efficiencies that free time for new labour/business and/or education activities, will bring more desirable improvements than most debt creating investments.

6.4.1.5 Output demand/market access

The ability of integrating other (non-biomass based) renewable energies into the farm system is an important option, particularly when farm activities become more mechanized or more processing/value-adding is included on-farm. Also, when market demand for electricity or for other mechanical energy forms exists, the non-polluting transformation of local resources like wind, solar radiation (heat, UV), water, land surface waste can become an important production element of a farm. Since these energy transformations require the importation of technologies to the farm, supply chains need to include the availability of the complete systems, including spare parts, technical assistance and maintenance. Reliability and timely delivery of such services cannot depend on a short-term project, unless local suppliers can be created and a sufficient scale market for those supplies is created (e.g. in Nepal and China biogas programmes).

On-farm energy generation can happen along a wide quantitative and qualitative range, i.e. from partial substitution of imported energy (firewood or kerosene) to selling excess energy locally (liquid or solid fuels), or into existing energy distribution systems (electricity, biodiesel). Modular, small producers will have to choose according to existing and foreseeable market opportunities, while large private and public investments schemes can establish their own market and access to it.

Thus, from worst (basically non-existing) market conditions, where the farmer produces for his own consumption and gains indirect benefits, to high demand for his energy products, where attention needs to be given to avoid a switch to new industrial mono-cropping systems – often at the expense of local food security - the existing markets and affordable market development determine the choice of energy produced by the farmer. They are thus highly determinant for the structure and content of supply chains that either need to be developed or supplemented, both at their input and their output side.

TABLE 5

Simplified supply chain requirements for different IFES scales: the four types of inputs needed for either input or output supplies are shade-coded: the darker the field, the more essential the input is for increasingly complex systems.

	Individual small farms		Large farms or farm networks	
Input supply chain	Knowledge	Money	Knowledge	Money
	Physical inputs	Management	Physical inputs	Management
Output supply chain (market access)	Knowledge	Money	Knowledge	Money
	Internal & ext. output diversity	Management, organization	Internal & ext. output diversity	Management, organization

6.4.2 Strategic considerations

From a strategic point of view, opportunities for progress towards abundance and well-being in rural conditions, i.e. towards and beyond poverty reduction, should be part of an IFES approach, to create opportunities for converting the advantages gained with IFES to better opportunities and living conditions. An integrated production system like IFES needs to be integrated into a yet larger system that can transform the additionally generated energies (fuel, money, motivation, time), into a system that keeps on propagating and multiplying energies for the benefit of the whole nation. Since such systems are frequently lacking in developing countries, or are not well connected among themselves, national policies need to give attention to simple and fair alternatives. This may include appropriate physical, social and economic infrastructures adapted and aimed at the above purpose, not simply copied from other countries or donor models. Detailed discussions on this, and on the type of supply chains, are beyond the purpose of this paper, but are an important element of successful rural development.

In many places, the main strategic motivation for IFES may well be the reduction of destructive energy practices, resulting in deforestation. Available options for reducing such necessities range from better forestry management and fuel price policies, to creating shorter and more advantageous supply chains and use incentives. The transformation into electricity may well have the shortest output chain, but may be the highest cost alternative, while liquid fuel production improves the ability to store energy and solid, mechanical and biogas energy may be the most widely used on-farm energy forms.

6.4.3 Scale

If IFES are planned for larger farms or farm networks, the organization of the supply chain or complete product chain is more demanding in the sense of quantity of inputs – not only knowledge, but also farm supplies, technology and investment needs. If local or "external" markets exist there are likely to be already suppliers with which the new farms need to compete in quantity (consistent availability), quality, and price. If there is no local market, the creation and satisfactory supply of such demand is a great challenge (financially, managerially, and politically), i.e. something that is less likely to be handled by the local farmers alone. This can be truer for energy products as for new food products, since the substitution of existing energy forms often requires changes and investment in technology in addition to changes in user behavior, if not of deeply rooted cultural traditions (e.g. wood fuel cooking, introduction of maize and rice to Africa).

In general, it is noted that simpler IFES can be established faster in a large number of farms. The growth rate of new farms would be expected to slow down, the more complex the adopted IFES systems will be.

Large-scale projects can substitute local gaps with financial investment, and thus decide on the complexity and efficiency of the system they want to create, according to their financial capacities and time frame of investment. The general principle is that increasing complexity requires higher knowledge, high and continuous technical assistance and larger investment in technologies and markets over longer periods of time. Conversely, it appears true that simpler IFES can be established faster in very large numbers of farms (e.g. China biogas). Yet still relying on very high external inputs in all areas (Figure 11A) to establish a large number of farms with IFES, simpler IFES can be more readily established in many farms. If successful, such systems may contribute to local livelihood stability, but the risk of failure is fairly large and very much depending on market and credit conditions external to the production area. Developing approaches that consider scaling up individual farm models do well to start with the simplest acceptable approaches and plan increased complexity as a dynamic process only after integrated systems are well established in an area. Thus supply chains have the chance to develop gradually, with increasing local financial, knowledge and market capacities.

An important element to consider for the success of either approach, is the continuous attention to quality control at all levels of the supply chain, even for the simplest products and services. Bad quality leads to interruptions in the product chain and in market loss, i.e. it is unsustainable. It has been learned that product quality is more the result of an attitude of the producer and user, than a question of knowledge. Thus it needs to be included and demanded at all stages of the product chain, which may require considerable promotional, educational and/or institutional efforts in policy, promotion, control and valuation by the market. Good quality control mechanisms require quality standards – discussed in Section 6.3.2.3. (ii) and stakeholder feedback mechanisms – discussed in Section 6.3.3. (iv).

6.4.4 Time

6.4.4.1 Pace of development

Supply chain requirements are more demanding, the more rapid a development is desired, particularly on the knowledge front (technical input, management capacities), but also for physical supplies. In their absence, less efficient and most likely less complex systems will develop, which in their least developed state and with almost no external supplies (inputs) and low market strength, approach traditional self-sufficient farming systems. Supply chains here depend either completely on locally available inputs (on-farm or in-community) or on the capacities of a few individuals to obtain additional inputs. Under such limited conditions, care needs to be taken by planners, policy-makers or local entities that market conditions do not develop mono-culture, i.e. mono-product demands, as they, under most circumstances, do not lead to sustainable practices and conditions. Too rapid an implementation risks instability of various system elements and requires large funding. Too slow a process is expensive for institutional support, risks supply gaps, due to low volume over time and the loss of (cyclic) market opportunities.

As an indication for time needed, one might look at real projects, although project duration is not necessarily or exclusively a function of building the supply chain: more than 20 years in the case of the China biogas programme and more than 15 years in the case of the Nepal biogas programme; Tosoly single farm seven years, Jatropha Mali >12 years). This is to show that even simple IFES projects should be planned with sufficient long-term capacities.

6.4.4.2 Timing of supply chain development

The presence of existing infrastructure for different energy and food distributions can be a limitation, as well as an advantage, facilitating distribution but facing competition and existing energy and food expectations. Their absence will require higher financial and managerial abilities and longer term resilience, until a certain demand stability or equilibrium is reached.

The ability to build the necessary input supply chain prior to, or parallel with, the IFES projects and to create a consistent demand pull during the capacity development of the farmers, will to a large extent determine the kind of complexity and system of IFES that can be established. However, much of that is likely to be determined when the planning for such a project is done with good local participation, since the practical sense for managing complexity is likely to be well rooted in the farming and village community. This is particularly important when up-scaling or larger projects with many individual farmers are planned. The ability to create the conditions for successful IFES, i.e. a complete up- and down-farm supply chain is critical to project success and speed of implementation.

Figure 11 illustrates indicatively the points of the previous two paragraphs for four scenarios of IFES development, and their respective needs for external inputs over time. The more rapid a development is desired, the steeper the curves become, but they are also likely to shift upwards on the Y-axis, i.e. higher levels of external inputs are required to start. The relative quantitative supply requirements at different times are important for project finances, planning and success and also for policy design and strategy.

FIGURE 11

External supply chain needs for different types of IFES development strategies

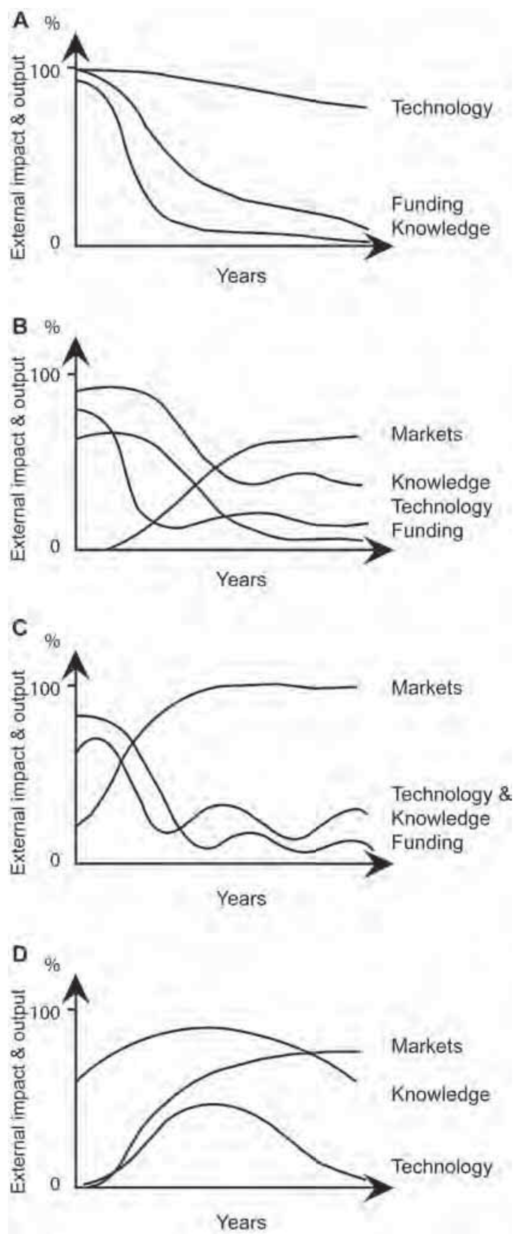


Figure 11A: A simple IFES for rapid upscaling, e.g. small-scale biogas production on many farms. The China and Nepal cases are examples of this (see Box 17); x = moment of self-sufficiency depends on project design and on perceived value created on-farm; *technology* choice defines to which extent technology can be provided on-farm; n*o external market* is indicated since all produced energy is used on-farm and thus only indirectly creates market value by facilitating other production, allowing education or other business and value-adding.

Figure 11B: Small farm IFES of high complexity, i.e. with optimal energy and food production efficiency, least waste and highest self-sufficiency (e.g. complex Type 2 such as Tosoly farm in Colombia, See Box 8).

Figure 11C: IFES with strong emphasis on selling excess energy and food on external markets. Many large-scale Type 2 IFES in developed countries belong to this category: high early demand for external knowledge and technology with regular need for updating and innovation; relatively high upfront investment for technology and rapid establishment of excess production for a market; size of upfront investment determined by urgency to reach the external markets with a product and produce return of investment (pay debts).

Figure 11D: IFES with no upfront financial investment; may switch to B or C type development once sufficient external income has been generated and other supply conditions are favorable.

A number of other factors will eventually influence the starting point, height and shape of the curves, among them also the quality and quantity demands from on-farm and off-farm users. Similarly, the external investment curve would ideally reach zero as soon as possible, to reduce financial risk and dependence.

6.4.5 Collaboration and networking

Such supply chains need to consider that during the first production cycles not all outputs necessary for the next cycle can be produced in time, quantity or quality sufficient to feed the next cycle, thus either alternative sources or substitute processes need to be available to build the overall system. This includes from seeds and nursery outputs, to fertilizer or organic matter inputs, basic technology and spare parts or repair knowledge, to the versatility of mutual support from neighbours, in inputs or output use. In systematically building a supply chain the collaborative factor, i.e. mutual community support, is probably one of the most significant factors. Such collaboration has been substituted in larger systems through pure financial power, i.e. the availability of sufficient funds to buy inputs and market outputs. Varying degrees of the presence of both are likely to be needed.

While the ideal state of an IFES may be the zero-waste, self-sustained system that produces excess energy and food for outside sale, the locally realizable (i.e. ideal) system may be one very well including “wastes” from neighbouring farms and selling/trading “wastes” to a neighbour. Such webbed supply chains require collaboration/communication beyond mere economic benefits and need to be flexible in quantitative terms and in abilities to process material compositions that change over time. Too rigid process requirements require large economic margins, that are for other reasons unfeasible, in order to be maintained under changing conditions.

Thus, actively *managing supply chains* may be a necessity and if so, the desired IFES needs to include elements necessary for creating a locally feasible, sustainable and well functioning supply chain, or be developed on the basis of more self-reliance and flexibility so as not to ’zero waste’ other investments in agro-biodiversity, technology and knowledge.

To summarize, while perhaps over simplifying, the more energy and resource efficient an IFES is to become, the more knowledge and organizational skills are necessary. Lacking these or only being able to build them slowly, simpler IFES are necessary to start with, or will be successful in the short- to medium-term. Progressively, different areas of IFES can be improved, while sustainability in processes (natural and institutional environment) and economy should be a requirement from the beginning. The larger the scale, whether individual farms or farm networks, the more the final desired results have to be part of the project planning, and the more detailed the planning of each phase of input and output supplies needs to be. Considerable flexibility and resilience needs to be built into such a system to allow for delays, additional needs, technology and management adjustments and marketing delays and profitability.

The faster a development is desired, the more financial, knowledge and organizational inputs are required up-front and the more learning/evaluation/adjustments will be necessary, i.e. the more active management is required. At the same time risk of failure is higher due to supply chain dependence for effective implementation. Simplifying the IFES system, i.e. less integration and more single biofuel production, reduces implementation risks. A balance needs to be struck between project time horizon, scale, complexity and local sustainability.

6.4.6 Selection of the most appropriate energy sources and technologies

Technologies for small-scale renewable applications are mature, if one considers that neither one of the technologies needs to supply all or a majority of energy needs, i.e. small water pumps function on slow stream water pressure, in larger streams floating turbines can electrify several households or some agricultural machinery, small wind mills can power water pumps or generators and solar heat can provide heating requirements for cooking, processing or other community needs. The trick is to select the most appropriate energy source (and technology) for the local energy need and combine at least two possible complimentary sources. Always using fossil energy is like going back to the first industrial efficiency models that had to rely on steam power only; total exclusion of fossil energy may equally not be optimal, yet. Technological diversity combined with reasonable simplification can provide more reliable and more flexible solutions that allow IFES to also provide energy needs for modern communities, i.e. electricity, heat and transport energy.

An example may be the use of solar heating to reduce wood fuel needs, which can reduce the size of a wood lot needed, or the opportunity to use wood fuel for agricultural processes. When solar energy is abandoned, the wood resource can be left standing and grow in value for use during a different season or to produce charcoal, fuel gas and biochar, or building material, and other income streams.

Technology choices will vary with energy choices by each community and depend on economic capacities and the kind of comfort desired and affordable, both of them important parameters subject to possibly rapid change.

Flexibility is also needed for larger scale IFES. However a larger system usually has also larger economic means and the option to create flexible alternatives within its own system limits (farm). Less investment limitations allow the deployment of higher efficiency = higher technology options that become feasible only beyond a certain scale. Thus the larger the IFES the more sense it makes to include high tech renewable energy systems and energy management technology. The option of liquid fuel production and excess electricity generation become a feasible part of the system.

At the same time, cost evaluations become more difficult since the inclusion of secondary benefits derived from integrating various energy systems may be difficult to calculate, but necessary to justify the often higher cost of produced energy than that available on the open fossil fuel market.

Supply chain limitations for larger scale renewables may be less, since capacities to pay for locally missing elements are greater. In general, the necessary technology of small- to medium-scale exists. Accessibility varies with the type of energy desired, geographic location and financial power, and larger systems can involve small-scale farmers. One way to achieve this is through the contract farming and tenant contract approaches discussed in Section 6.2.2. Another model concerns the cooperative or community level creation of larger investments that allow processing of "wastes" or products from several farms. This system is relatively flexible, but also requires more management at all levels, i.e. of supplies, operation and marketing. The professional management requirements have been financed in various models by creating commercial enterprises (producer companies) which are farmer-owned but professionally managed, so that in addition to buying, processing and marketing one or more of the farm products, they also provide the farmer-owners with supplies and knowledge. The large difference to the contract farming option is that the primary producers are also in control of the secondary production, i.e. processing and conversion, and value addition, including marketing. This allows for much more integrated planning of needs, capacities and benefit distribution, but also more involvement of small-scale farmers in decisions at the various stages of the supply chain.

CHAPTER 7

CONCLUDING REMARKS AND POSSIBLE WAYS FORWARD

There is great potential for the co-production of food and fuel using existing methods and technologies. The scope of an IFES will depend on local necessities. Ideally, there will be no competition with food production, but where this is not the case and food is scarce, any agricultural energy production will probably be of the kind needed to either produce or process the food, using byproducts with no food value. Where there are severe water restrictions and infrastructure (transport) limitations, again food production emphasis is likely to dominate. Distortions may be created by external stimuli (subsidies, industrial buying, etc.). Where financial resources are available, energy choices may more depend on comfort, social status and knowledge, than the need to be more self-sufficient. Thus any IFES will need to develop according to local needs and preferences and the various limitations discussed in this paper.

Any system and farm is a highly complex system that depends on variable inputs (like weather, pests and little understood processes such as soil fertility, plant nutrition and health). Such systems are highly dependent on management quality and timing, and must be flexible, above all. The art of managing a complex and not completely controllable system to feed an industrial process needs careful and sensitive management. To give more room for mistakes, or allow for variation, process and economic margins need to be wider to compensate for the higher risk. Thus the further away the farm is from the industrial agriculture concept, i.e. the more diverse, complex and interactive the processes become (close to zero-waste, recycling, crop diversity, etc.) the more diversity and margin flexibility is required for each system component. In other words, efficiency and economic performance cannot be calculated as tightly as in industrial economic models. Nature has resolved this problem by designing multiple processes and pathways that can achieve similar or the same results, often requiring considerable sub-systems and operating optimally below maximum potentials. Complex IFES systems that mimic these processes also normally address appropriately the challenge of potential conflicts between different uses of residues, because they integrate all these uses in their recycling pathways, especially those that lead to (close to) zero waste. In such systems, the balance between residue soil management, energy and animal feed is achieved through the trade offs and win-win solutions highlighted in this paper (see Section 6.1.). But this is an area of work that still requires R&D, not least because of the often too optimistic assessment on feedstock available from agricultural residues.

In complex IFES, feedstock alternatives, processing technologies, energy supplies/outputs/technologies and fertility management options all need to be available. Indeed, combining different renewables also reduces pressure on the energy use of biomass, hence on possible residue and food competition. But having all that handled by one farmer is unlikely to be replicable beyond the occasional champion, as in the case of the Tosoly farm. Thus, complex IFES might work best if implemented by several operators, sometimes for feedstock production, but most of all, though a division of labour between the food and energy components of IFES.

The IFES currently implemented on a large scale are: (i) to some extent agroforestry systems where wood residues are used for household energy consumption and some income generation e.g. the DRC example (presented in Box 7); and (ii) more extensively, simple biogas systems e.g. in Nepal (see Box 17), China and Vietnam (see Box 2). They may be less energy and GHG efficient than more complex systems, but are much easier to replicate. Given their scale, on balance, the national biogas systems mentioned in this paper have a greater global positive impact on energy and GHG balances used in agriculture, than the sum of very efficient complex IFES. Reasons for their easy replication include:

- Free or negative value feedstock; little or no competition with the use of crop residue for soil management or animal feed, and sometimes even a positive contribution to it through the use of its compost by-product;
- Simple, low-risk and well known technology; and
- Relatively low upfront costs, especially in the case of polyethylene bags.

The overview presented in this paper shows that other factors are essential for the replication and scaling up of IFES, whatever their type and level of complexity, i.e.

- Quality insurance measures and control;
- Progressive strong involvement of private sector operators, combined with subsidies to poorer sections of the population;
- Accessible micro credit schemes;
- National institutions becoming gradually in charge of the programme[17];
- Multiple benefits related to rural people's livelihoods;
- Stakeholder involvement, for instance, complementing subsidies with loans, and also through user surveys (e.g. VACVINA in Vietnam);
- An inclusive business enterprise orientation to development, avoiding 'dole outs' and 'project dropping' approaches;
- Capacity development at all levels, which in turn;
- Guarantees accessible and good quality technical support at local level;
- Last but not least, long-term government and partners' commitment to support over a sufficient period of time (e.g. 18 years in the case of the national biogas programme in Nepal, more than 20 for the VACVINA programme in Vietnam), for the programme to go through the different hurdles of supply chain development.

17 The DRC agroforestry case presented in Box 6 and the Nepal biogas programme presented in Box 16 illustrate this point about gradual ownership by national bodies.

The above factors do not occur spontaneously. They require supporting policies. Perhaps the most important step governments can take to advance renewables and reduce cost disparities, is to make a comprehensive change in their perspective and approach to energy policy. Governments must eliminate inappropriate, inconsistent, and inadequate policies that favor conventional fuels and technologies and that fail to recognize the social, environmental, and economic advantages of renewable energy.

This overview has shown that the most important IFES policy support areas concern:

- Crop-livestock integration and, more broadly, more environmentally-oriented farming practices regarding the food component of IFES; and
- Market promotion and financial incentive aspects regarding the energy component of IFES, with the provision that most current market promotion instruments – quotas and feed-in tariffs – may not be the most appropriate instruments regarding small-scale IFES in developing countries.

In addition, all of the above will have to be tailored to local circumstances, scale and the stage of development time. Therefore, any support mechanism must be (Sawin 2006):

- *Predictable, long-term and consistent, with clear government intent.* These characteristics are critical to providing certainty in the market, to drawing investors into the industry, and to providing enough lead-time to allow industries and markets to adjust to change.
- *Appropriate.* The right types of support are needed—policies must match objectives and might vary by resource potentials, location, technology type, and timing. It is also important that the level of support not be too high or too low.
- *Flexible.* It is essential to design policies so that adjustments (fine-tuning, but not wholesale changes or elimination of policies) can be made on a regular, pre-determined time schedule if circumstances change. Governments must be able to address existing barriers and new barriers as they arise. Policies also must be designed to allow developers/generators flexibility for meeting government mandates.
- *Credible and enforceable*. If policies are not credible, or are not enforceable (or enforced), there will be little incentive to abide by them.
- *Clear and Simple.* Policies must be easy to implement, understand, and comply with. Procedures of permission and administration, where necessary, must be as clear and simple as possible.
- *Transparent.* Transparency is important for suppliers and consumers of energy and is necessary to avoid abuse. It facilitates enforcement, maximizes confidence in policies, and helps ensure that mechanisms are open and fair.

But policy-makers and supporting partners (donors, private sector, farmers, etc) need to be convinced about the benefits of promoting IFES. Experience shows that policy processes – the way policies are designed, implemented and monitored - significantly influence the outcome of policies, and in particular policy implementation. Indeed, good policy processes that help move from "policies on paper" to "policies on the ground" require (Dubois, O, 2007):

- Effective, evidence-based and multistakeholder policy analysis to identify sound policy objectives and instruments.
- Good synergy between State and citizens to move from policy on paper to policy on the ground.
- Often concomitant institutional change if new policies are significantly different from previous ones; which is often the case in the recent rural energy policies developed around the world.

One first step in that direction would be the development of a critical mass of tangible arguments, to be obtained through documenting IFES experience and being able to show concrete examples of successful IFES. In parallel, one would develop some decision support tools (DSTs) to help policy-makers and investors in IFES to make the right choices, both at strategy and project level. This could build on existing relevant DSTs, such as those developed under the GEF/WB/FAO Livestock Waste Management Project in East Asia (LWMEA)[18], the SURE DSS tool regarding energy type choices mentioned in Section 6.1.2. of this paper, the European Union Biomass Energy Strategy (BEST) Guide for policy makers and energy planners (EU PDF, 2010), and/or the forthcoming FAO-UNEP web-based DST for Sustainable Bioenergy.

The sequence of things that need to happen to promote IFES at international and national levels described above is illustrated in Figure 12. Such a sequence of steps was briefly discussed during the FAO, July 2010, Technical Consultation on "How to make integrated food-energy systems work for both small-scale farmers and rural communities in a climate-friendly way", obviously emphasizing its preliminary steps (step 1 and continuous work).

*Continuous work: A key message from the technical consultation was the need for more information exchange and dissemination on IFES data and other technical information. Several participants suggested that FAO would be well-placed to play the role of *international information platform and repository of knowledge related to IFES.* Besides technical information, the platform would also include Information on policies that support the agricultural (i.e. mixed farming) component and the energy component of IFES.

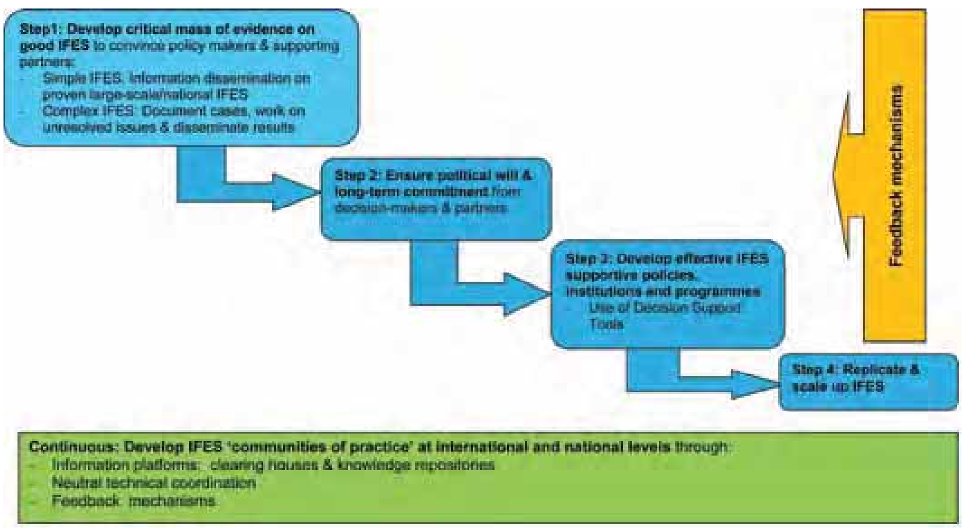
From an operational point of view, to start with, FAO could set up an IFES website within its bioenergy website, and develop a very simple Newsletter to be circulated to the participants to the July meeting, but also other likely interested individuals and organizations.

* Step 1: The following actions could be the starting points regarding the three aspects related to this step:

- Promotion of simple IFES systems: This could happen through collection and dissemination of information related to what has allowed for the scaling up of successful

18 More information on the LWMEA Project available here http://www.lwmea.org/

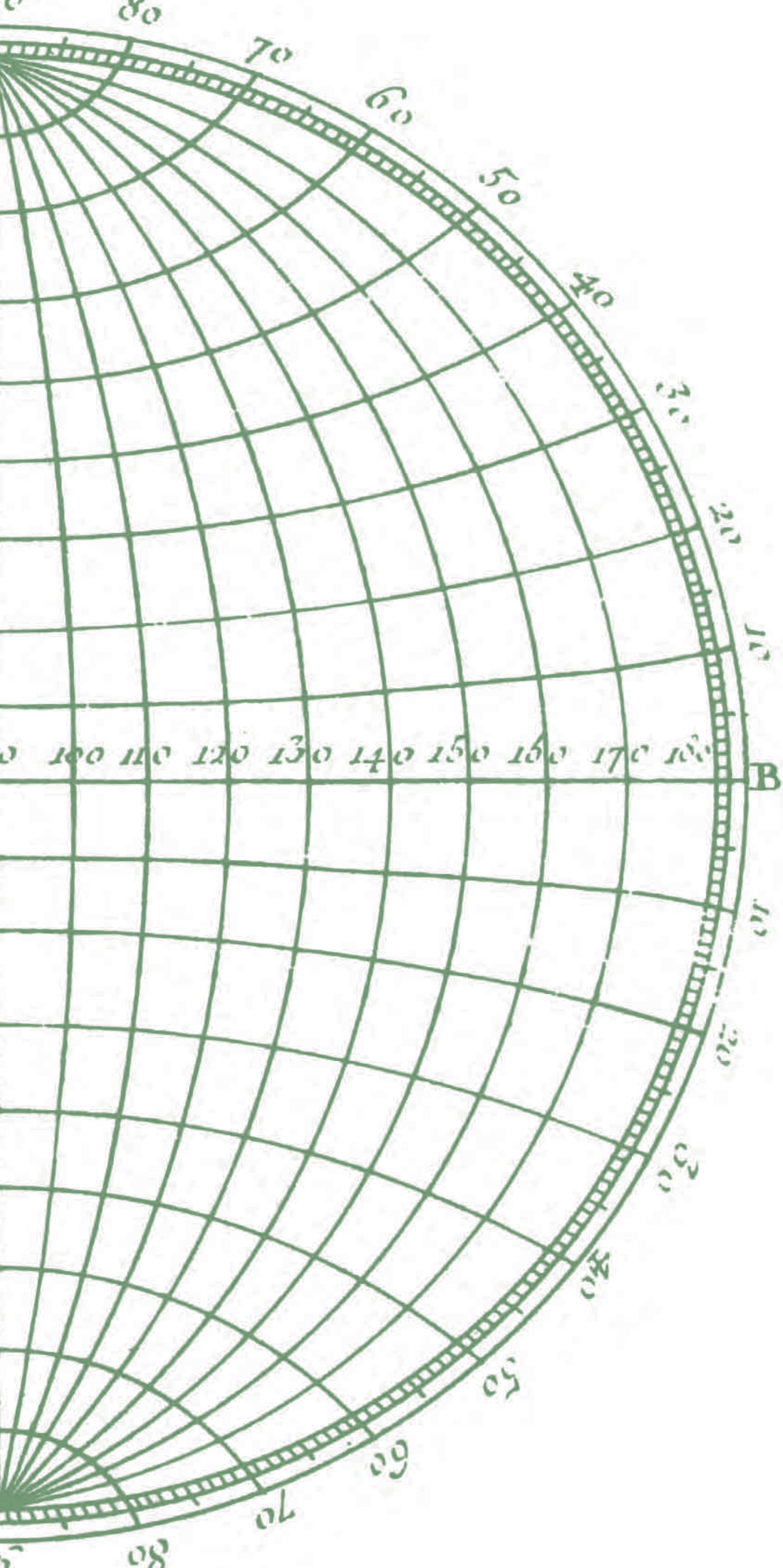
FIGURE 12
Proposed steps to promote IFES



large-scale simple biogas programmes (already in step 4, e.g. from China, Vietnam and Nepal), including policy and institutional aspects. This information would be placed on FAO's IFES website, and shared with FAO's decentralized offices.

- Documenting cases, and more particularly, more complex IFES: In that respect a starting point would be to carry out a comparative assessment of the three Colombian IFES cases that were presented during the July 2010 Technical Consultation, and also a relatively complex system such as Viet Nam's VACVINA. In doing so, one should compare the system with and without an energy component, in order to clearly determine the added value of that component from an economic, environmental and social point of view.
- The previous would require some preliminary work though. Indeed, IFES assessment can be very complex because of the multiplicity of their components, and the fact that one should assess the farm and beyond farm aspects. Therefore, there is a need to develop a sort of rapid assessment methodology regarding IFES, starting with the farm level.
- Work on unresolved issues: Three topics stand out in that respect: (i) the IFES assessment methodology just mentioned above; (ii) residue competition; and (iii) links between IFES and land use changes caused by liquid biofuel development (both direct and indirect land use changes).

Work on the above mentioned activities could become part and parcel of the FAO programme on sustainable crop production intensification through the ecosystem approach described in Box 1.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CHAPTER 8

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Bioenergy can be part of the solution to climate-smart agricultural development. In particular, liquid biofuels for transport, but also other types of biofuels have been promoted as means to reduce greenhouse gas emissions, boost rural development and ensure energy independence. However, increasing evidence clearly shows that this is the case only and if their production is properly managed. Large-scale liquid biofuel development, in particular, may hinder the food security of smallholders and poor rural communities, and enhance climate change through greenhouse gas (GHG) emissions caused by direct and indirect land use change. It is therefore crucial to develop bioenergy operations in ways that mitigate risks and harness benefits.

Safely integrating both food and energy production addresses these issues by simultaneously reducing the risk of food insecurity and GHG emissions, and Integrated Food-Energy Systems (IFES) can achieve these goals on both small- or large-scales. This document shows concrete options of how smallholder farmers and rural communities, as well as private businesses, can benefit from these developments. However, this overview is not restricted to large-scale biofuel operations for transport fuel production alone, but gives a holistic picture of the different types of energy that can be produced from agricultural operations, and how they can be aligned with current food production schemes.

The overview presented in this document is tailored to inform policy-makers, practitioners and entrepreneurs, raising their awareness of different options and showing them concrete examples of how to make IFES work for smallholders and businesses. While examples of long-term implementation and uptake exist for simpler systems like biogas, innovative and more complex systems still face some constraints. Referring to existing and successful IFES and learning from failures, this document suggests practical ways of how to tackle these challenges, and make IFES work at different scales and configurations.

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NRC contact: anne.bogdanski@fao.org

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