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Growing Power:

Exploring energy needs in smallholder agriculture

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Discussion Paper

April 2014

Energy

Keywords:
Access to Energy; Renewable Energy; Agriculture; Smallholders

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Acknowledgements

Several colleagues kindly spared their time to review the draft paper, including Lucius Mayer-Tasch (GIZ), Olivier Dubois (FAO), Bill Vorley (IIED), Barbara Adolph (IIED), Emma Wilson (IIED) and Ben Garside (IIED).   Thanks are also due to those who shared their insights and materials on the topics of energy, agriculture and productive uses, including Emily Haves (Ashden), Mauricio Solano (TTA), Alistair Livesey (Africa Power Ltd), Professor Francis Yumba (Centre for Energy, Environment and Engineering Zambia), Secou Sarr (ENDA), Dr. Yacob Mulugetta (University of Surrey), Andrew Barnett (The Policy Practice) and Craig Jamieson (IRRI).

Produced by IIED's Sustainable Markets Group

The Sustainable Markets Group drives IIED's efforts to ensure that markets contribute to positive social, environmental and economic outcomes. The group brings together IIED's work on market governance, business models, market failure, consumption, investment and the economics of climate change.

Published by IIED, April 2014

Best, S, 2014. *Growing Power: Exploring energy needs in smallholder agriculture*. IIED Discussion Paper. IIED, London.

http://pubs.iied.org/16562IIED

ISBN 978-1-78431-002-8

Printed on recycled paper with vegetable-based inks.

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There is a growing interest in how to deliver energy services to people on a low income, not just for household use but to earn a living: the so-called 'productive uses' of energy. One sector that deserves particular attention is smallholder agriculture. Expanding access to modern energy services and equipment for farmers could help address food security, gender empowerment and rural poverty. But the issues are complex, barriers plentiful and examples sparse of successful delivery at scale. Rural electrification schemes have focused narrowly on supply, rather than use, of energy; joined-up approaches across sectors are lacking; and the private sector is put off by the high risks and low returns. This paper considers the 'why', 'what' and 'how' of energy access for smallholders and related rural enterprises, and invites discussion among experts, practitioners and policy-makers on the key priorities, lessons learned and ways forward.

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Executive summary

Both food and energy are high on the development agenda. Both sectors share similar challenges, such as achieving access to food and energy for everyone, while producing and consuming resources more sustainably. The interconnectedness of food and energy systems is widely recognised.

One area, however, receives less attention than it deserves: the energy needs of smallholder farmers and the enterprises that process, store and distribute farmers' produce. The bulk of food in developing countries is produced by smallholder farms, which are home to two billion people; many smallholders are poor, undernourished and marginalised. There is a huge deficit in access to modern energy services for these farmers. In particular, in sub-Saharan Africa 65 per cent of farm power relies on human effort, 25 per cent on animals, and only 10 per cent on engines (FAO/UNIDO, 2008). Addressing food security requires upgrades throughout the value chain – from food production to retail – which implies more demand for modern energy and equipment.

But the issues are complex, barriers plentiful and the examples of successful delivery at scale, sparse. Rural electrification schemes have tended to focus narrowly on households, and on technology and supply-side issues, rather than ensuring that energy enables people on a low-income to earn a living. Projects founder because the complementary measures – like market access or maintenance – which are needed to ensure interventions are sustainable and lead to real benefits for the user, are not in place. The private sector is put off by the high risks and low returns in smallholder agriculture, as well as low-income energy markets more generally. Energy and agri-food sectors are often not joined up in their approaches.

But what exactly are the energy needs of smallholders and related rural enterprises? What do we know about the impacts of energy access and use on people's livelihoods? What is the experience to date in terms of expanding access to energy for productive uses in rural settings? How have the energy and agriculture sectors approached the issues, and where are the differences and common ground? When are modern energy services and equipment the answer to an energy gap and when should alternatives, like low-input farming, be considered? What role does the private sector play?

These are some of the questions raised in this paper, which reviews the 'why', 'what' and 'how' in addressing smallholder energy needs, and invites discussion among experts, practitioners and policy-makers on the key priorities, lessons learned and ways forward.

Understanding smallholder energy needs

The starting point for any intervention is to understand the energy needs and priorities of farmers and local enterprises, their organisations and communities. These are highly diverse and vary depending on user characteristics, such as the type of farm (subsistence, semi-commercial or small business); the activity in the food chain (farming, processing or distribution); the type of crop or livestock; and people's farming and non-farming activities (such as energy for health or education).

A gender focus is vital: women and girls tend to do many of the back-breaking manual tasks on farms, so modern energy services are an opportunity to reduce drudgery and free up time.

Farms are a distinct type of energy user. As well as consuming energy, such as diesel for tractors, they can provide energy from their own resources (whether plants, waste, solar, hydro or wind) for their own consumption or sale. They also have a particular need for energy solutions that sustain the other natural resources, and ensure efficient use of resources. For instance a farmer may need to choose between using farm waste either to generate energy or to fertilise soil.

'Energy for productive uses' is understood in this paper as energy that directly increases incomes or adds value to goods and services, such as power for a milling machine. While there is crossover with the household energy sector, addressing productive uses also requires:

- a good understanding of agricultural value chains and market opportunities – from field to fork – to identify any bottlenecks, and to ensure that increased production enabled by energy translates into higher incomes
- combining energy with a wide range of complementary interventions to support farmers and rural development, such as seeds, land title, extension services, roads and so on
- farmers, cooperatives and enterprises to access a larger scale of finance to pay for equipment, which is more costly than household products like solar lamps

- major investment in capacity building for users, for instance in business administration, technical operation and maintenance, and sustainable agricultural practices.

Integrating food and energy

A recent evolution in the food–energy discourse is 'nexus thinking', which recognises the interconnections between energy and food, along with other natural resources such as land, water and climate.

Historically, energy and agriculture sectors have different approaches to addressing energy needs in rural contexts. The energy sector has traditionally focused on energy supply, rather than ensuring that energy can be used productively by smallholders. Agriculture focuses on whole farm systems, livelihoods and sustainable resource management, with energy as a sub-component. Yet there is significant common ground. For instance, both sectors now share the recognition that a technology and supply-led approach to addressing users' energy and equipment gaps will not work. Potential ingredients for cross-sector learning include:

- Energy practitioners' experience of pro-poor energy delivery models
- The agriculture sector's experience of mechanisation, conservation agriculture – which seek to manage resources better while reducing external inputs like energy – and integrated food–energy systems, in which food and energy are produced together on the farm.

However, there are barriers to the implementation and wide-scale dissemination of these types of integrated food-energy approaches, including the complexities and increased workload faced by the farmer, access to technical support, and the long-term nature of the benefits to be reaped.

Expert agencies have started to develop tools to design interventions to promote both the productive uses of energy, and 'nexused' approaches to food, energy and water. A key issue is how to design pilots that can be scaled up. While there are some approaches to disseminating energy technologies and equipment that have been replicated – like foot-operated treadle-pumps, or agri-processing industries using farm waste to power their own activities – in the main we are still at pilot stage.

Identifying ways forward and research gaps

We need to build on lessons already learned; there is good experience of the technical options and an understanding of what has gone wrong before. Many of the lessons learned are generic to supplying energy and equipment to poor communities, highlighted by both the energy supply and agriculture approaches. Equally, we know that few off-the-shelf packages are suitable for addressing energy needs. We should instead focus on designing solutions from the local level upwards.

We need to understand what kinds of energy and equipment delivery models might be economically viable for serving productive activities in agricultural contexts. This covers factors such as the management model, maintenance, technology, finance, capacity-building and so on. Examining the role and incentives for the private sector is particularly important given the expectation that serving 'productive uses' could attract in commercial – or semi-commercial – investment.

We need to understand priorities for different contexts. While avoiding blueprints, it would be useful to map out likely energy needs across different types of smallholders and other actors in the agri-food chains they are part of. This would help donors and governments to understand the issues and start discussing priorities.

We need to research the impacts of energy access on smallholder productivity, livelihoods and well-being. More evidence is needed to guide policy-makers and public finance, and this can be tied into new pilots and investments (for example in rural electrification) being developed now.

Building the 'energy literacy' of farmers and their organisations is also vital to help people to articulate their needs and press for high quality services from providers and government.

We need integration. There are some ambitious hopes for what a shift to more integrated approaches in food and energy could achieve. According to the FAO, 'This shift to energy-smart agri-food systems can also improve productivity in the food sector, reduce energy poverty in rural areas and contribute to achieving goals related to national food security, climate change and sustainable development' (FAO, 2012: 3).

However, policy-makers and practitioners can find integrated approaches complex and off-putting. And new guidance and pilots on 'productive uses of energy' on one hand, and 'nexused food–energy approaches' on the other, risk being developed in isolation. Work therefore needs to be done to bring the two together, and make approaches more simple and practicable so they are taken up by decision-makers and practitioners alike.

Introduction

1

Both food and energy are high on the development agenda. The discourse is by now depressingly familiar. We have a food system that is highly inequitable and environmentally unsustainable. There is enough food globally to feed everyone, but hundreds of millions go hungry. A growing world population and changing diets means demand is rising, but the natural resource base on which all food production depends – such as healthy soils, fresh water and a stable climate – is increasingly depleted. Smallholder farming, comprising around 500 million farms that are home to 2 billion people, produce the bulk of food in developing countries. Historically, most advanced economies have relied on growth in their agricultural sector to reduce poverty. Yet at the same time, many smallholder farmers are poor, undernourished and marginalised (IFAD/UNEP, 2013). While many migrate to cities to escape poverty, the transition from agrarian to industrialised economies and consolidation into larger farms is a gradual process; it is also unlikely to affect all smallholder farms everywhere. There is thus a vital need to improve the conditions and productivity of smallholder farms to raise living standards and reduce hunger. This will require significant improvements in production, agro-processing, post-harvest and storage facilities, marketing, retail and infrastructure – all of which imply increased demand for modern energy services and related equipment (Practical Action, 2012).

The energy sector faces similar challenges to the food system: rising demand, an unsustainable resource base (fossil fuels) and gross inequalities in access to energy between rich and poor. The access dimension has gained much greater prominence in the discourses of donors and Southern governments in the last decade, with a multitude of new global reports and initiatives such as the UN Sustainable Energy for All (SE4ALL) platform.[1] Providing modern energy services to the 1.2 billion people worldwide without electricity, the 2.8 billion without modern cooking solutions and the 1 billion with only intermittent power is recognised as a key enabler of economic growth, human development and poverty reduction, and energy is set to feature prominently in the post-2015 agenda (Best, 2013).[2] A common thread in energy debates is the need for a transition that achieves security of supply and access for everyone, while weaning the world off fossil fuels and increasing energy efficiency in order to stay within climate constraints.[3]

A strong focus within the energy and development sector in recent years has been serving poor people's basic energy needs, such as household lighting and cooking. While energy for homes and public services remain vital, the focus is shifting to stimulating energy services that support productive activities – using machinery, irrigating crops or transporting goods.

The 'productive uses' angle is not new: national electrification schemes have aspired to this for decades (ESMAP, 2008). Nor is it uncontentious: is 'productive' energy just about generating income or do services that improve people's education and health count too (Cabraal *et al.*, 2005)? Perhaps what has sharpened interest is the hope of governments and donors that the private sector will help mobilise the billions of dollars of investment needed for achieving universal energy access (Wilson *et al.*, 2014). According to this line of thinking, if energy services help people earn more then they are more willing and able to pay for them, making commercial investment more viable.

Another recent evolution in this discourse is 'nexus thinking',[4] the recognition of the links between energy and food, along with other natural resources such as land, water and climate. This is the idea that a solution for any one problem, like energy, must give equal consideration to others in the nexus, finding interconnected solutions that maximise synergies and manage trade-offs among them. Ideas for 'energy-smart agriculture' and 'integrated food-energy systems' are gaining currency (FAO, 2001; 2011a).

Yet, so far, much of that energy–food debate has focused on *reducing* the energy inputs (and related carbon emissions) in agriculture, and and on options for farmers to *produce energy crops*. There has been less attention on the unmet energy needs of farmers and related small-scale enterprises in smallholder-based food systems (such as processors, distributers and input suppliers) *to increase access to modern energy services* – even though a huge deficit in access exists, particularly in sub-Saharan Africa (see Box 1). This oversight is also apparent in mainstream agriculture debate and policy frameworks. For instance, the Comprehensive Africa Agriculture Development Programme and FAO's annual State of Food and Agriculture reports give little attention to energy *access* even though specific energy issues, such as biofuels, are addressed.[5]

There are, however, some welcome signs of growing awareness of the topic. A handful of development agencies and NGOs have developed projects and tools addressing energy access in agri-food value chains, including the German Society for International Cooperation (GIZ), the UN Food and Agriculture Organization (FAO) and the international development charity Practical Action.[6] USAID has initiated the 'Powering Agriculture' awards,[7] which provides grants to clean energy enterprises addressing agricultural needs in low-income countries. It has also sponsored the well-known Ashden Awards to include an agriculture-focused award in its own 2014 renewable energy awards scheme.[8]

BOX 1: HOW BIG IS THE ENERGY ACCESS GAP IN SMALLHOLDER-BASED FOOD SYSTEMS? EXAMPLES FROM SUB-SAHARAN AFRICA

It seems virtually impossible to quantify energy gaps in smallholder agriculture and related rural enterprises, since energy sources and uses are so diverse and diffuse, scattered across millions of small farms and communities. However, some of the headline statistics give a hint of the scale of the problem. In sub-Saharan Africa:

- Most farm power relies on human effort (65 per cent) or animal power (25 per cent), with a minority from engines (10 per cent). This is much lower than for other developing regions, where engines constitute 50 per cent of farm power (FAO/UNIDO, 2008).
- Just 4 per cent of cropland is irrigated, compared with 39 per cent in South Asia and 29 per cent in East Asia (Practical Action, 2012).
- An estimated 10–20 per cent of grains are lost after they are harvested at an annual cost of US$4bn – equal to the value of cereals imported each year. Lack of appropriate storage, processing and cooling equipment, some of which require energy inputs, are key factors (World Bank, 2011).

One of the big challenges to contend with is the unsustainable nature of mainstream agricultural development models. Since the 1960s, increases in crop productivity across many parts of Asia, Latin America and industrialised countries have been achieved to a large degree through increased use of fossil fuels combined with mechanisation and fertilisers (which themselves are energy-intensive to produce). In the current era of high and volatile oil prices, increasing fossil fuel dependency may be unaffordable – as well as contributing to the sector's greenhouse gas emissions. Low-income countries and poor farmers already struggle to pay for costly energy or fertiliser inputs, while poor consumers may not be able to afford the higher food prices, which are closely linked with global fossil fuel prices (FAO, 2011a).

Yet this constraint could be turned to an advantage. Smallholders using minimal external inputs are not yet locked into a fossil-fuel intensive path, and this offers opportunities for innovation.

This makes it all the more timely to take a step back and ask basic questions around the why, what and how of addressing energy needs in smallholder farming, and identify key knowledge gaps. As well as raising the profile of an under-researched issue, this paper seeks to:

- inform people who are new to the topic and want to understand better the links between energy access and smallholder-based food systems
- bring together the approaches of the energy and agricultural sectors to understand experience to date and see what each have to offer
- provoke discussion among people working in the area on the key priorities, lessons learned and ways forward for governments, donors, researchers, NGOs and the private sector.

The paper is part of IIED's work on access to energy and pro-poor delivery models. It is a first effort to examine the issues around productive uses and smallholder-based food systems and is based on a brief review of the literature, conversations with practitioners, and reflections on a recent conference on rural energy access hosted by the UN Economic Commission for Africa in December 2013.[9] The findings are preliminary and IIED is in 'learning mode' on this topic. For this reason, we have suggested areas for discussion and further research in the form of questions at the end of each section.

Section 2 defines the remit of the study and key terms, examines what the energy needs in smallholder agriculture and related rural enterprises are, and outlines what is known about the impacts of access to modern energy services. Sections 3 and 4 review different approaches by energy and agri-food sectors, including examples on the ground, key issues and lessons learned. Conclusions are presented in Section 5.

Energy needs and impacts in smallholder-based food systems

2

2.1 Who are we talking about?

This paper is principally interested in smallholder farmers because of their importance for food security and rural poverty. 'Smallholder farmers' are understood here as rural producers using mainly family labour to cultivate crops or raise livestock for their own consumption, or for sale to local markets and processing plants.[10] The analysis takes into account other energy-related activities such as processing and storage, which 'add value' to smallholders' produce. These activities could be carried out by a range of actors: smallholders on their farm, a cooperative, a micro or small rural enterprise, or a larger agro-processing firm. The terms 'agricultural value chains' and 'smallholder-based food systems' are used at times to capture this wider set of activities that take place beyond the field or farm gate.

There are of course other entry points that we could use to examine energy needs and access issues in food systems, rather than focusing on smallholders. One could be the OECD typology of five 'rural worlds', which spans from chronically poor rural households to large-scale commercial agricultural enterprises; another would be to examine in detail a specific commodity value chain (OECD, 2006). Such complex mapping is beyond the scope of this paper, but it demonstrates the different types of analytical framing that could be used for different purposes.

2.2 What do we mean by 'access to modern energy services' and 'productive uses' of energy?

There is no single, internationally adopted definition of 'modern energy access'. Traditional measures focus narrowly on whether or not households are connected to the electrical grid and have clean cooking facilities (see SE4ALL, 2013). In this paper, modern energy services for smallholder agriculture and related rural enterprises refers to the use of fossil fuel, renewable and hybrid energy technologies for a range of motive and stationary power applications, and for producing and processing agricultural products. This could include, for example, motorised pumps for irrigation, liquid fuels for tractor engines, and electricity for cool storage, drying and smoking (Utz, 2011). Modern energy services are distinct from human and animal power. The term also includes improved versions of traditional technologies, such as an efficient smoker or cookstove to preserve or process food.

'Meeting energy needs' is about both the supply of energy and, crucially, the equipment that makes energy useful, such as a grain mill or tractor. Energy access is understood here as energy supply and equipment that is affordable, adequate, reliable, safe and targeted at people's actual needs. While recognising the important role of renewable energy, the full energy mix should be considered for poor communities, depending on what is most appropriate.

The definition of productive uses of energy is similarly hard to pin down. The traditional idea was that 'productive = direct impact on gross domestic product' (GDP), and this included an interest in stimulating growth in the agricultural sector. The Millennium Development Goals and Amartya Sen's concept of development as 'freedom' and 'capabilities'[11] prompted a more multidimensional view of poverty, and practitioners started to look more at how energy services could support education, health and gender equality. Some argued for an expanded idea of what 'productive' is. For instance, using a radio or TV could spread knowledge, while improved cookstoves could give women and girls better physical health through less exposure to smoky fumes and potentially more time for income-generating activities if they reduced time spent collecting firewood (Cabraal *et al*., 2005).

However, the pendulum may be swinging back again. There has been huge activity, innovation and progress in the field of household energy in the last decade, and people are talking about income generation again. Focusing on the electricity sector, the World Bank-administered Energy Sector Management Assistance Program (ESMAP) defined 'productive uses' as 'uses of electricity that support any activity that will generate revenue to the user' (ESMAP, 2008: 14). Similarly, a new manual co-authored by GIZ defines productive uses of electricity as 'agricultural, commercial or industrial activities that involve electricity services as a direct input to produce goods and/or provision of services' (EUEI-PDF/GIZ, 2013b: 13).

When this paper refers to 'productive uses' it is in this narrower sense of uses of energy that directly increase incomes or add value to goods and services. However, it supports the view that energy for other uses, such as for health services, is critical for livelihoods.

2.3 What do smallholders need and use energy for?

Across many developing countries, particularly in sub-Saharan Africa, smallholder agriculture is still largely based on human work using simple hand tools for activities like tilling or weeding, and draught animal power, for instance in ploughing or transporting goods. This is quite a different starting point for most energy planners, utilities and investors, who are mainly concerned with large-scale grid expansion to homes and industry. For smallholder farmers, energy inputs might be as much about securing a nutritious family diet or supplying drinking water for animals as it is about electricity supply. The fact that this landscape is so alien to those working in the energy field immediately raises the question of how agriculture and energy sectors work together, and the roles and responsibilities of each to address energy gaps.

The key energy requirements of smallholders and related rural enterprises have been quite well articulated by organisations such as GIZ, the FAO and the non-governmental organisation Practical Action (Utz, 2011; EUEI-PDF/GIZ, 2013a; Practical Action, 2012; FAO, 2011a). They highlight two main types of direct energy requirements for raising productivity**:**

1) **Energy for transport to take goods to market and supply other key services that farmers need.** This encompasses, for instance, the transport fuel (diesel or biofuels), as well as vehicles, road and other transport infrastructure

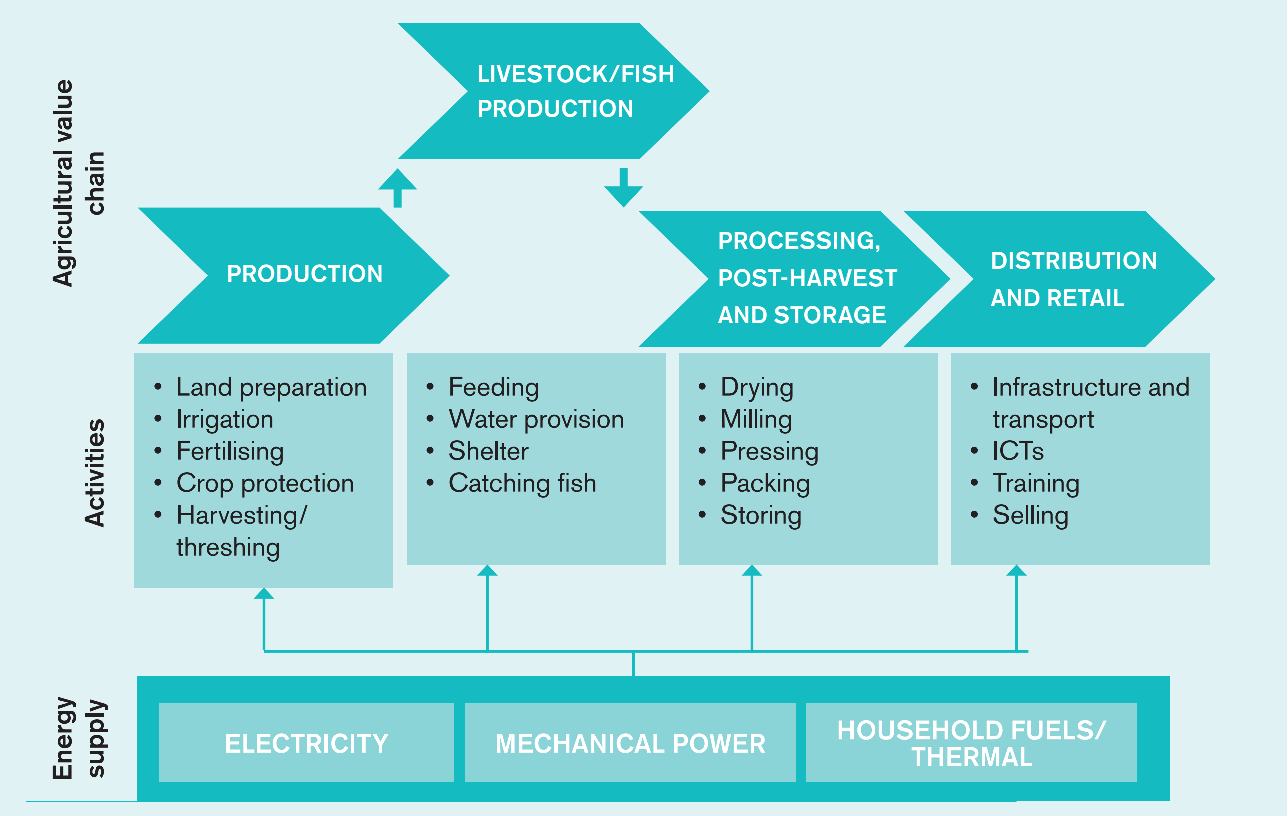
2) **Energy for production, processing and commercialisation of products.** This covers a diverse range of activities, such as pumping water to irrigate crops, drying fruits and vegetables, or charging mobile phones to obtain market price information (see Figure 1).

Much of the literature focuses on type 2 – a bias reflected in this paper. However, transport (type 1) is fundamental, and some practitioners argue this requires far more attention. Lack of quality roads and transport infrastructure, or affordable vehicles and fuel, are real barriers for smallholders to accessing markets and selling their produce at the right time and price (Utz, 2011). They also hinder the development of the non-farm rural economy.

There are two other types of energy input which are important but largely beyond the scope of this paper. One is farmers' **indirect energy inputs** through the use of fertilisers and agro-chemicals, which are energy intensive to make and expensive to buy. (This is touched on in the discussion on sustainable agriculture in Section 4.2.) The other area is **household energy** for cooking to prepare food and boil water, which is critical for food security but is already the subject of an extensive body of literature.

At this point it is worth looking at the energy technologies and sources for powering machinery and equipment, which vary depending on the level of

Figure 1: Energy inputs to enable activities in the agricultural value chain



Source: Practical Action (2012) adapted from FAO (2009) and Utz (2011). See http://practicalaction.org/ppeo2012.

power needed for the task and the resources available locally. For instance, **electrical energy** (from the grid, mini-grids or off-grid technologies) can be used for powering water pumps, milling machines and fridges. **Mechanical energy** is vital for production and processing, for instance to power harvesters or two-wheel tractors (see glossary), while **thermal energy** is needed in a range of value-adding processes, such as cooking, drying, heating, smoking, baking and cooling products. Some energy practitioners argue we need to focus far more on promoting mechanical power and efficient thermal technologies for agriculture and small enterprises, areas that are often overlooked by policy-makers and donors (UNDP, 2009; EUEI-PDF/GIZ, 2013). One simple indication of this gap is in the policy targets countries set. A 2009 UNDP/WHO review on energy access pointed out that among 140 developing countries, 68 had established targets for access to electricity, but only five countries had targets on access to mechanical power (UNDP/WHO, 2009).

The activities requiring energy inputs in smallholder agriculture – both on the farm and beyond – are wide ranging. Figure 1 provides a simple illustration of this.

2.4 Which energy needs take priority?

But which energy needs and gaps in smallholder-based food systems should be prioritised? The literature reviewed for this paper tends to highlight four areas: land preparation, irrigation, processing and storage.

- **Land preparation.** In sub-Saharan Africa, the vast majority of land is tilled, ploughed and weeded by human and animal power. Weeding is critical – more than 30 per cent of crop yields are commonly lost because of weed infestation – and is extremely physically taxing and time consuming to do by hand. A typical farm family reliant on human power alone can cultivate 1.5 hectares per year. This rises to 4 hectares if draught animal power is available, and to 8 hectares with tractor power. However, the inappropriate use of tractors and other heavy machinery also causes soil degradation (FAO, 2006).
- **Irrigation.** Access to water is one of the most important factors for agricultural production; irrigation is crucial to increase yields. Yet most rural, food-insecure communities rely on rain-fed agriculture, particularly in sub-Saharan Africa where just 4 per cent of land is irrigated. During the dry season when little grows, families struggle to feed themselves or produce goods to sell, and face high prices for the food they purchase. Changes in rainfall patterns as a result of climate change have increased people's vulnerability. By irrigating fields, two or more crops can be grown throughout the year, allowing farmers to feed their families and sell crops at a better time and price. At a technical level there are many different options available – though also many challenges, such as the risk of groundwater overexploitation, the salinisation of land through inappropriate irrigation practices, and the need to maintain water storage structures (Utz, 2011).[12]
- **Processing (drying, milling and pressing).** To prepare crops for processing, the chaff has to be separated from the grain, and milling converts grain into flour for food preparation. Using machinery for de-husking, grinding and milling grain saves a considerable amount of manual labour, and is far more efficient. Drying vegetables, fruit and meat helps preserve food, enabling longer storage times, easier transportation and access to some high-value markets. This can be done in the open air but it exposes products to variable temperatures and contamination by dust, vermin or leaves. Using thermal energy technologies, like a solar dryer (see glossary), can improve product quality. Another key process which benefits from energy inputs is pressing nuts and oil palm fruit to extract edible oil (such as groundnut, coconut, palm oil or oil seeds), which is a high value product (Utz, 2011; EUEI-PDF/GIZ, 2013).
- **Storage.** Roughly a third of food produced for human consumption is lost or wasted globally, and in developing countries more than 40 per cent occurs at the post-harvest and processing stages. The data is patchy; rates and causes of losses vary hugely by crop and geography. In sub-Saharan Africa, about 40 to 50 per cent of roots, tubers, fruit and vegetables are lost in the production, storage, and processing/packaging stages.[13] Improving storage – some of which requires energy inputs, such as refrigeration – is one part of the solution for reducing post-harvest losses, as well as helping to maintain quality, create emergency buffers and enable farmers to sell when prices are better (FAO, 2011b).

The above list is helpful in giving a general sense of gaps and needs, but the brushstrokes are too broad to determine priorities at the local level. One of the major lessons learnt from both energy and agricultural mechanisation is that interventions need to be more people-centred, designed in a 'bottom-up' way and far better tailored to local demands and contexts. Projects have often failed because they ignore the fundamental issues of what people want energy for, the types of equipment they use, what they can afford, their capacity to run and maintain systems, and so on.

This points to the need to think holistically about smallholders' energy needs beyond the farm gate. Table 1 gives examples of these, setting agricultural activities alongside energy needs in the home, at a community level and among local rural enterprises. Some of those enterprises might have direct links to farming activities

Table 1. Energy needs in rural development: examples from agriculture, local enterprises, households and community services

AGRICULTURE	RURAL BUSINESS USE	HOUSEHOLD	COMMUNITY
• Land preparation/tillage • Weeding • Harvesting • Drip-feed/sprinkler irrigation • Grain milling • Oil pressing • Drying (fruits, vegetables, coffee, tea, meat, fish, spices) • Smoking (fish, meat, cheese) • Food and drink cooling (e.g. milk chilling/pasteurisation) • Ice-making (fish storage) • Water heating (e.g. textile dying, separating nut kernels) • Sawmilling • Electric fencing • Improved warehousing • Fish hatcheries and fish farms (water circulation and purification) • Lighting (e.g. to increase night growth in nurseries)	• Oven cooking (bakeries) • Cooking and water heating (food kiosks, small restaurants) • Beer brewing • Use of grinders and compressors, welding (vehicle repair) • Drilling & cutting, welding, use of lathes and mills (metal workshops) • Refrigeration, freezing, lighting (shops) • Colour TV, lighting (bars) • Use of electrical cosmetic appliances (barbers) • Charging batteries/cell phones • Cutting and filing (carpentry, crafts) • Use of power looms/sewing machines (clothing outlets) • Use of computers/printers (internet cafés)	• Cooking • Lighting • Charging cell phones • TV & radio • Use of sewing machines • Space heating and cooling • Refrigeration	• Refrigeration of medicines and vaccines • Use of medical equipment • Lighting (medical clinics, especially for night births, religious buildings) • Street lighting • Computing (education) • Drinking water pumps • Sewage pumps

Adapted from ACP-EU Energy Facility (undated) Thematic Fiche No. 2 and extended using material from Practical Action (2013), EUEI-PDF and GIZ (2013a) and unpublished materials provided by Alastair Livesey, Africa Power Ltd.

(such as a metal workshop that repairs farm machinery) and others provide products or services that people value in their daily lives (like bars or hairdressers). The implication is that energy projects promoting 'productive uses' need to take a demand-led approach and be situated within wider rural development needs. In some instances, community members may prioritise power for a local health clinic or school over their farming needs.

Four further points are worth making with respect to energy needs.

a) **Value chain analysis can help pinpoint energy needs and opportunities.** Any 'productive uses' project needs to look at the whole agricultural value chain – from field to fork – to pinpoint exactly where the bottlenecks to productivity lie, where energy and equipment could have the biggest impact on incomes, and what options are most cost-effective. Again, this means looking beyond the farm gate to a wide range of linked cottage and home-based activities, such as bakeries, juice-making or cheese-making; as well as support services, such as tool manufacturers or builders. An ESMAP study on rural electrification for productive uses conducted analyses in Senegal and found that for some commodities and contexts, the greater opportunities for electrification to reduce costs lay in the processing of goods, rather than primary production (ESMAP, 2008: 31).

b) **Needs assessments should place a strong emphasis on gender.** Women make up around 43 per cent of the agricultural workforce in developing countries (FAO, 2011c). Certain tasks are considered women's and girls' work in particular settings, such as weeding, milling or grinding, or collecting water for irrigation and drinking. Women tend to have less access than men to mechanical equipment, yet done manually these are backbreaking tasks.[14] Shifting to mechanical or electrical power (such as for water pumping or operating mills) is often argued to be a way to reduce women's drudgery and free up time for leisure or other activities (Köhlin *et al.*, 2011). The

FAO estimates that if women generally had the same access to productive resources as men – including energy and equipment – they could increase yields on their farms by 20–30 per cent, raising total agricultural output in developing countries by 2.5–4 per cent (FAO, 2011c).

c) **Needs vary hugely across different farming systems**. 'Smallholders' are not a homogenous group and there is huge variety in farming systems, depending on crops, locality, context, culture and agro-ecological zones. There is an equally diverse number of solutions that could be employed. Take the issue of post-harvest losses. For many grains, pulses oilseeds, roots and tuber crops, reducing losses could be achieved without any increased energy inputs – through better handling of the crops during and after harvest, using simple dry storage facilities, and adopting good hygiene practices to avoid insects, rodents or mould. High-value fresh fruits and vegetables, on the other hand, perish easily after harvesting – particularly when cultivated in tropical or sub-tropical climates. A consistent cool chain would help protect quality, extend shelf life and increase incomes; but this generally requires a higher level and reliable supply of energy for fans, ventilators and refrigeration, and is also more expensive (USAID, 2009; Utz, 2011).

d) **'Modern energy services' is not always the answer to a deficit.** This is clear from the storage example above. For a start, energy is clearly just one of many interventions needed to support smallholder livelihoods and raise productivity. Farmers need better and more secure access to a whole range of inputs, infrastructure and resources (land, water, seeds, equipment, credit, markets, roads and extension services),[15] as well fairness in trading relationships and gender relations. Even where modern energy services are desirable, farmers need to weigh up the costs and benefits. The additional income or efficiency gained from using modern energy may exceed the costs of purchasing or running the new equipment. And in some cases, farmers may prefer traditional power systems. Adopting new technology can be an arduous process. Farmers may consider that draught animals support a variety of functions that a single appliance could not – ploughing fields, pounding crops underfoot, transporting goods to market and providing milk or meat. It may also be that significant improvements can be made through the use of low-cost, 'traditional' technology, such as treadle pumps or gravity fed-systems in the case of irrigation.

2.5 What impact does access to energy have on smallholders?

Making the case for a greater focus on smallholders' energy needs is helped by demonstrating that better access to energy leads to better development outcomes. Yet a recent literature review from the PRODUSE initiative[16] found that while energy is widely believed to be fundamental to poverty reduction, the robust empirical evidence to underpin this argument – and particularly policy-makers' claim that energy will enable poor people to earn more – is 'surprisingly scarce' (Attigah and Mayer-Tasch, 2013: 20).

Just a handful of the academic studies identified by the authors covered electrification and agricultural outcomes, and the findings of these were mixed. For instance, one ESMAP study in the Philippines found electrification had little impact on farm incomes – which may have been due to drought and a lack of irrigation infrastructure – while another in India found rural electrification increased agricultural productivity through private investment in electric pumps (ESMAP, 2002; Barnes and Binswanger, 1986). Another issue is that much of the empirical research focuses on Asia or Latin America, and on grid extension by utilities. Far fewer studies look at either sub-Saharan Africa or decentralised energy options such as mini-grids (see glossary) or standalone systems (Kirubi *et al.*, 2009).

There are several possible reasons for this evidence gap: lack of projects targeting productive uses, lack of monitoring or analysis of outcomes, and methodological challenges. Energy is one of many inputs to productive processes, and it is hard to disentangle its impact from other factors, or determine the direction of causality: does more energy use lead to higher incomes, or vice versa?

Another source of information is project-related material, such as evaluations or case studies of donor projects, and these often report positive livelihood outcomes. Some of this material is limited by an anecdotal style and potential in-built bias toward reporting positive outcomes to justify donor spending. Box 2 highlights an interesting case study on community-based electric micro-grids in rural Kenya, where agricultural productivity was helped as a knock-on consequence of electrification among local small and micro-enterprises (Kirubi *et al.*, 2009). Other examples of case study evidence are set out in Annex 1.

BOX 2. COMMUNITY-BASED ELECTRIC MICRO-GRIDS AND RURAL DEVELOPMENT: EVIDENCE FROM KENYA

A review of the Mpeketoni Electricity Project (MEP), a community-based diesel-powered micro-grid in rural Kenya, found that the use of electricity and equipment improved the productivity and incomes of local small and micro-enterprises, contributed to the mechanisation of agriculture, and supported improved village infrastructure such as schools, markets and water pumps.

With access to electricity, productivity per worker among local small and micro-enterprises (like carpenters and tailors) increased by 100–200 per cent, and gross revenues increased by 20–125 per cent depending on the task or product made.

Particularly striking is the link between electrification and increased usage of diesel-powered tractors to clear and cultivate the land. As the mini-grid enabled the local provision of electrical welding services, people in the neighbouring region were more willing to hire out their tractors to farmers in Mpeketoni: they knew tractors and machinery could be repaired in the event of a breakdown. More convenient and timely availability of tractors meant farmers could clear and cultivate more land than was previously possible with hand tools. Electricity also enabled cold storage for farm produce and opportunities for local shops and hotels to buy fruit from farmers and prepare juice for sale.

Source: Kirubi et al. (2009)

A lack of research should not be used as an excuse for failing to prioritise productive energy use in agriculture. Surveys on business in Africa or low-income countries repeatedly point the finger at poor transport, electricity and power infrastructure as key factors holding countries back (see for example Ernst & Young's *Attractiveness Survey*, 2013).

What is required, however, is more micro-level evidence, which can help inform policy decisions and ensure public finance is well targeted. This could examine what types of energy services make the most difference to smallholder livelihoods. Outcomes need to be monitored over time and considered in broader terms than income – including economic dimensions like input costs, waste, incomes, productivity and profitability; social, health and cultural issues such as physical drudgery, air quality, saving time, and the empowerment of women and girls; and environmental outcomes including for soil, water, plants and air quality.[17]

Crucially, as the PRODUSE research points out, evaluations need to examine costs and trade-offs, and how benefits are distributed. Access to modern energy services and equipment is often associated with streamlining production processes and replacing people with machinery. This could be positive – saving time for people to engage in other domestic, social or productive activities – or negative – leading to job losses. There is also a risk that opportunities for increased incomes and value addition are concentrated among a few individuals, firms or localities, at the cost of others in the community or on the periphery (Attigah and Mayer-Tasch, 2013).

The following questions suggest areas for discussion, learning and future research.

Energy needs and impacts in smallholder-based farming systems

What are the main energy needs in smallholder-based food systems? How could these be mapped better?

When is it a priority to expand access to modern energy services for income generation and food security? And for which types of farmers and rural businesses?

What does the evidence show on the impacts of energy access on smallholder productivity, livelihoods and well-being? Is more research needed, and on what?

Meeting smallholder energy needs: the energy sector approach

3

Knowing the 'how' of addressing energy needs in smallholder agriculture starts with understanding what has been tried before. While many interventions have been tried, the scarcity of research in this area makes it hard to get a real purchase on the topic. Published material often focuses on a single aspect, like a particular technology type, and lacks a commonly used analytical framework. Sections 3 and 4 seek to unpick this fuzzy terrain by drawing out key approaches promoted by governments and development actors from both the energy and agri-food sectors. These approaches are summarised below.

3.1 Comparing the energy and agri-food sectors

Energy sector

- Traditionally, energy development has taken a supply-led approach and focused on technical, cost or finance issues. This is now shifting, with more attention given to users' needs, tailoring services to local contexts, and sustainable 'delivery models' (the combination of technology, finance and management needed to supply energy to users; see Section 3.4). The sector is focused particularly on 'modern energy services' and interested in all type of energy sources, including bioenergy. There are two main types of intervention in energy access initiatives which are relevant to our topic:

  i) Large-scale rural electrification programmes led by governments or major utilities, often with donor financing. They are typically focused on electricity grid extension, though they also include mini-grid and off-grid supply.

  ii) Standalone, off-grid energy systems (mechanical, thermal and electrical) and equipment that serves specific functions in agricultural production or processing, such as solar irrigation or 'multi-functional platforms' (see Box 3). These are often small-scale and initiated by donors and NGOs. There is a direct overlap with 'agricultural mechanisation' below.

Agri-food sector

- This sector is focused on improving farmer livelihoods, agricultural productivity and other poverty and sustainability outcomes, with energy as one component. It views energy as both an input and a product of farming, with scope for self-provisioning. This sector is interested in human and animal power, not just modern energy services. It seeks to address power deficits either by increasing the supply of farm power *or* reducing need for it. Relevant approaches include:

  i) Agricultural mechanisation to increase productivity, for instance through the use of tractors, animal and human-powered implements and tools, irrigation systems and energy conversion technologies (such as engines or solar power). This includes a focus on 'appropriate technology' (see glossary).

  ii) Sustainable agriculture, covering a cluster of practices such as 'integrated food–energy systems' and 'conservation agriculture' (see Table 2). It is concerned with efficient resource use, integrated management of natural resources, environmental protection, avoiding fossil fuel inputs and emissions, sustainable bioenergy, and increasing productivity and incomes.

Figure 2 tries to show some of the differences, overlaps and opportunities for collaboration between the two sectors. Ideally this sector-based analysis would also consider approaches in the water sector – shaded in here – given the importance of irrigation, but time limitations excluded it from the scope of this paper.

Figure 2: Mapping sector approaches to smallholder energy needs

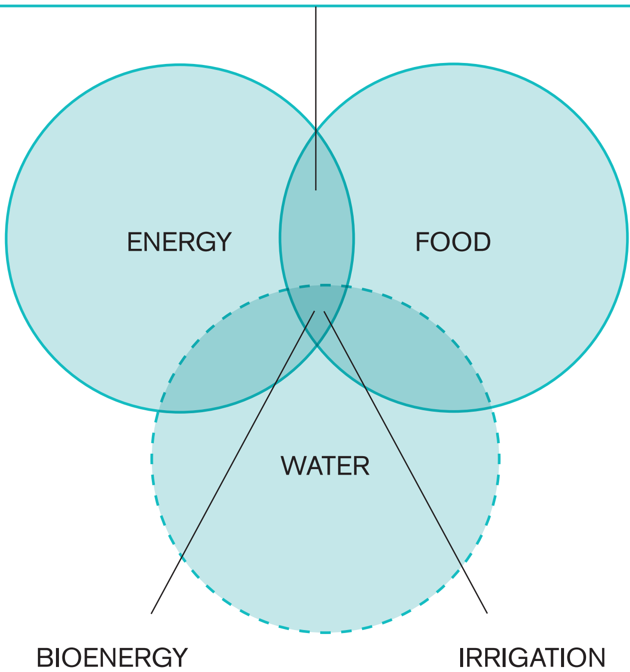
Energy–Food Nexus

Opportunities for cross-sector collaboration on e.g.:

- Mapping energy needs of smallholders and agri-food chains
- Appropriate delivery models for low-cost technology and services specific to smallholder needs and context
- Linking 'productive uses' with sustainable resource management
- Addressing bottlenecks to take-up of new technologies or farming practices (capacity, finance, maintenance and repair services, market access, land rights)
- Promoting energy literacy among farmer organisations

Energy sector

- Was supply-led, now more demand-driven
- Focuses more on 'modern energy services', rather than human/animal power
- Intervention types:
  - **i. Large rural electrification** (governments/ major firms)
  - **ii. Standalone, off-grid energy systems** (e.g. solar irrigation, multi-functional platforms)



Agri-food sector

- Meets energy needs by increasing supply or reducing demand
- Focuses on improving farmer livelihoods/ productivity, interest in all power types
- Intervention types:
  - **i. Mechanisation** e.g. tractors, animals, hand-powered tools, irrigation.
  - **ii. Sustainable agriculture** e.g. efficient resource use, no-till agriculture

3.2 Rural electrification programmes

Rural electrification has been a staple of development interventions over decades, carrying high expectations that these will stimulate local economic and social development. Yet in a key 2008 report by the World Bank-run Energy Sector Management Assistance Programme (ESMAP), the authors conclude that rural electrification programmes – both on- and off-grid – have largely failed to achieve any lasting impact on people's livelihoods in rural areas (ESMAP, 2008). They argue that the failure to address productive uses is principally because rural electrification programmes do not focus any further than the supply of electricity connections and kilowatt-hours, rather than aiming to make a direct impact on rural customers' revenue-generating activities. This passive approach is based on 'waiting for spontaneous positive effects of electrification to trickle down'. The energy sector's interest stops at the electricity meter, overlooking the equipment and activities on the other side that are needed to turn electricity into anything useful (ESMAP, 2008: 1).

These failings sit within a broader set of challenges in rural electrification, such as low population density, the high costs of capital investment and maintenance, the poverty or low demand of customers, and the political economy of subsidy-setting (Barnes, 2007).

Other bottlenecks to catalysing productive uses of energy are identified in the literature. These are relevant to any energy project, not just electrification:

- **Socio-cultural context:** Programmes have traditionally centred on technological aspects without tailoring models according to users' needs and the diverse characteristics, interests and environmental contexts across communities.

- **Institutions:** Energy programmes require clear government policies and complementary programmes to stimulate productive uses in rural areas, such as access to credit and farmer extension services. Yet government policy rarely prioritises productive uses in agriculture, and different ministries and sectors do not collaborate; initiatives are developed in parallel, without exploiting the synergies between them. Policy gaps include, for example, lack of quality standards for equipment, and general lack of support for farmers.
- **Capacity**: There are capacity gaps at all levels, from farmers and rural SMEs to local government and ministry officials. User knowledge gaps include low awareness of technologies; lack of technical skills for the efficient use, maintenance and repair of machinery; and insufficient business skills to take advantage of new energy and machinery inputs. Bigger systems, such as mini-grid systems, have added complexity and involve managing aspects such as load-balancing to avoid conflicts in power needs at peak hours.
- **Finance:** Energy customers on a low income struggle to afford the equipment that makes new electricity connections worthwhile, and lack access to credit facilities. A lack of finance for end-users – as well as for local firms and SMEs that supply energy or equipment – is a long-recognised challenge in the energy access field. Micro-finance may not cover the more expensive technologies such as a grain mill or refrigerated cold storage facilities that make productive activities possible (as opposed to 'Pico' solar home systems, for instance, which provide energy for basic household needs only, such as lighting and battery charging). Because smallholder farming is inherently risky, mainstream financial institutions are already unwilling to lend or invest for their activities, and are often averse to 'new' clean energy technologies where the risks and returns are less well understood.
- **Availability of input products, equipment and services.** This includes affordable and reliable fuel supplies for tractors or generator sets, as well as spare parts, maintenance and repair services for energy technology and equipment.
- **Accessible markets for sale of final products.** Farmers need access to markets if they are going to benefit economically from the increased production or quality of their goods; yet many other supply chain bottlenecks stand in the way, such as poor quality roads (Barnes, 2007; ESMAP, 2008; USAID, 2009; Utz, 2011; USAID/ARE, 2011; FAO, 2011a; FAO 2012; EUEI-PDF/GIZ, 2013b; Bellanca and Garside, 2013).

While the downbeat verdict on rural electrification is quite commonly heard in energy debates, is it the whole story? Several countries have successfully expanded electricity to rural populations in recent decades, such as Costa Rica, Thailand and Tunisia (Barnes, 2007). What do we know about whether and how these have addressed agriculture production and processing?

An historical review of depression-era United States shows how the drive for rural electrification was largely achieved by local, farmer-led cooperatives, advised and financed by a federal government intent on boosting the rural economy and food security. As well as connecting farms, the cooperatives provided support with purchasing household, community and farm appliances and equipment (Wolman, 2007). This hints at a potentially key role for farmers' organisations and agricultural support services in bridging the gap between rural energy and productive uses.

India is often cited as an example of how making subsidised electricity available to smallholder farmers can boost irrigation and food production. We need to understand how inter-sector working was achieved and learn from the ongoing challenges. One of the criticisms of the Indian experience is that it lacked a fully integrated approach to natural resources, with over-pumping for irrigation putting massive pressure on groundwater sources (see Box 3).

Another area that merits further scrutiny is **mini-grids.** Many are in operation across sub-Saharan Africa and South Asia,[18] and there is increasing support for them among some donors and governments. There is particular interest in hybrid and renewables options, given the limits of centralised grid extension, the growing cost of diesel, and recent advances in technology that make mini-grids more viable. Developers implicitly expect mini-grids to stimulate productive activities in rural areas because they provide more power than standalone technologies such as solar home systems. Indeed, mini-grids are designed for the larger loads required for productive activities and community services; in poor communities, households alone would not provide an adequate revenue base to cover the costs of installing and operating a mini-grid (USAID/ARE, 2011).

There is a growing body of literature on lessons learned by developers about what to consider when designing a sustainable, replicable mini-grid model, yet many knowledge gaps remain (USAID/ARE, 2011). For instance, we know little about how – or whether – mini-grids currently serve smallholders' and agro-processors' needs, and lack examples of developers working with local stakeholders to stimulate productive uses, or an assessment of livelihood impacts resulting

BOX 3. ENERGY, FOOD AND WATER IN CONFLICT: ELECTRICITY FOR IRRIGATION IN INDIA

Rural electrification policy in India since the 1960s has focused on promoting diesel and electric pumps. This was part of an aggressive agricultural development programme (the 'green revolution') to increase crop yields, including access to seeds, fertiliser, credit – and subsidised electricity for irrigation. While the policy boosted productivity, it put pressure on groundwater resources. India has just 4 per cent of the world's freshwater resources, but 17 per cent of the world's population. Agriculture is responsible for 90 per cent of water withdrawals nationally.

As well as heavy subsidies, electricity customers enjoy flat rates regardless of use. This has encouraged massive water over-extraction for irrigation and created financial losses for the energy sector. An unreliable electricity supply encourages farmers to use oversized pumps to maximise extraction during periods when electricity is available, and automatic pump switches that pump water whenever the electricity is turned on.

Several Indian states have experimented with alternative irrigation methods, such as drip irrigation. They now face the challenge of reforming subsidies that farmers have relied on for decades, and a gradual phase-out will be needed to ease the adjustment costs.

Based on Cabraal et al., 2005; Barnes, 2007; FAO, 2012; Casey, 2013.

from electrification. The current increasing investment in mini-grids by donors and governments provides the ideal opportunity to prioritise the productive uses angle in project design, and include a research element to document the experience and outcomes.

3.3 Off-grid, standalone energy solutions

A different approach to the more 'top-down' large-scale rural electrification programmes initiated by national governments are decentralised interventions focused on standalone, off-grid systems. These tend to be for particular activities in smallholder food production or processing, such as solar water pumps and crop dryers. Many donor and NGO-led initiatives fall into this category, often as part of agricultural livelihoods projects. There is also a strong overlap in literature and practice between off-grid energy technologies and agricultural mechanisation.

Off-grid energy technologies inevitably play an important role in serving smallholder needs – again, because of the challenges of grid extension to more remote and dispersed rural areas. In fact much of current provisioning is 'off-grid', in the form of the diesel generator sets which are common throughout much of the developing world.

The technical options are very diverse – from foot-operated water pumps to electricity generated from food waste – reflecting the variety of energy needs within and between crops and agri-food chains, as well as the usual context-specific factors such as local regulation, business environment, local energy resources and human capacity (USAID, 2009; Utz, 2011; EUEI-PDF/GIZ, 2013a). In fact, one of the features of the literature on off-grid technology for agricultural production and processing is a tendency to focus on technical aspects, such as the energy source, power output and operational requirements. Compared to the literature on the household energy sector, less attention is given to the nuts and bolts of supplying technology to customers on a sustainable basis – the 'delivery model' – in terms of how it will be managed, maintained and financed (USAID, 2009; Utz, 2011). And, compared to the household energy sector, very little has been written about the role and activity of the private sector, from large firms and agri-businesses to local energy service SMEs or social enterprises.

Renewable energy technologies

There has been growing interest recently, particularly in donor-funded projects, in promoting renewable energy technologies for development purposes. For instance, USAID's Powering Agriculture awards are exclusively for 'clean energy technologies' in the agricultural sector. This donor preference is at least partly influenced by the global politics of climate change, as developed country governments use development aid to meet their climate financing commitments and to demonstrate the viability of low-carbon pathways in developing countries.

Practitioners highlight some of the technical challenges here. Machinery for productive activities, like a milling machine, often requires more power than can be provided by the types of standalone renewable energy technologies widely available now, such as photovoltaic (PV) solar home systems. Many of these off-grid systems based on renewables cannot manage the surge current required for machinery start-up. The fluctuation in renewable energy resources over the day or seasons creates an additional challenge – for instance, where the output of hydropower lowers during the dry season (EUEI-PDF/GIZ, 2013b).

That said, renewable energy will play an important role in off-grid as well as grid-based solutions. Rural communities often have abundant renewable resources, such as solar, wind, hydro and bioenergy (see glossary). Some technologies have been used for decades (including mini-hydro) and the technical and economic performance of others has improved significantly; for example the costs of solar power have fallen steadily. There are some productive activities that can be supported by a relatively low level of power, including solar lighting for poultry farmers to increase egg-laying, and mobile phone charging. Larger renewable energy generators may be an option for higher-power productive uses, provided the financing constraints can be addressed (EUEI-PDF, 2013b). The point is that the most effective interventions are those that take a 'technology neutral' approach, giving preference to neither renewables or non-renewables but having an objective view of what works best in a particular context.

There are some examples of successful take-up by farmers of standalone energy technologies and equipment such as two-wheel tractors and treadle pumps (see Section 4.1). However, the bigger story seems to be that energy technologies and equipment targeted at smallholder farming and small-scale processing have often struggled to be sustained over time, to achieve commercialisation, or be taken up on a large scale. One example is the 'multi-functional platforms' in West Africa. Much heralded in the 2000s as a wonder technology that could empower women and serve multiple energy needs, results on the ground have fallen short of expectations (see Box 4). Also, a scan of the market place shows that most products on offer for poor rural consumers are in small-scale solar lighting, for household purposes rather than for productive activities (UN Foundation, 2013). However, there is probably more activity going on under the radar to design and pilot energy products serving productive uses; USAID's Powering Agriculture 2013 prize scheme had applications from 475 organisations across 80 countries.[19]

3.4 Towards sustainable 'delivery models' for serving productive uses

The experience in rural electrification and standalone energy technologies has generated many lessons. There is widespread recognition that the traditional approach, centred on technical and cost issues, will not work. Instead, energy projects need to be designed so they are more focused on end-users' needs and

BOX 4. THE MULTI-FUNCTIONAL PLATFORM: EMPOWERING WOMEN THROUGH DECENTRALISED ENERGY?

Multifunctional platforms (MFPs) were promoted by the United Nations Development Programme (UNDP) and other donors in West Africa from the mid-1990s as a technology solution which specifically targets the farming and family tasks done by women (as well as girls and boys), like post-harvest food processing. It consists of a small diesel engine mounted on a platform which can drive different types of equipment also installed on the platform. This includes mechanical equipment like grinding mills, oil presses and hullers, and alternators for electricity to provide lighting, battery charging, refrigeration, water pumping, welding and power carpentry tools.

To ensure a focus on women, the MFP projects in countries like Mali made female management and ownership a condition of financing, usually via the local village women's association. In Mali, 450 platforms had been installed by the end of 2004 covering about 10 per cent of the rural population, and early evaluations reported highly positive results. These included the freeing up of women's time, saving 2–6 hours daily, and better educational outcomes as more girls had time to attend primary school.

However, subsequent reviews were less positive. Around a third of installed platforms in Mali were not in operation at the end of 2005. The multiple technical functions did not always work well in practice and having a pre-determined organisational set-up (based on women's groups) proved difficult. Organisational problems and social conflicts were cited as a key reason for platforms falling into disuse – or being turned over to others to run, such as local millers.

Based on: UNDP (2004); Nygard (2010)

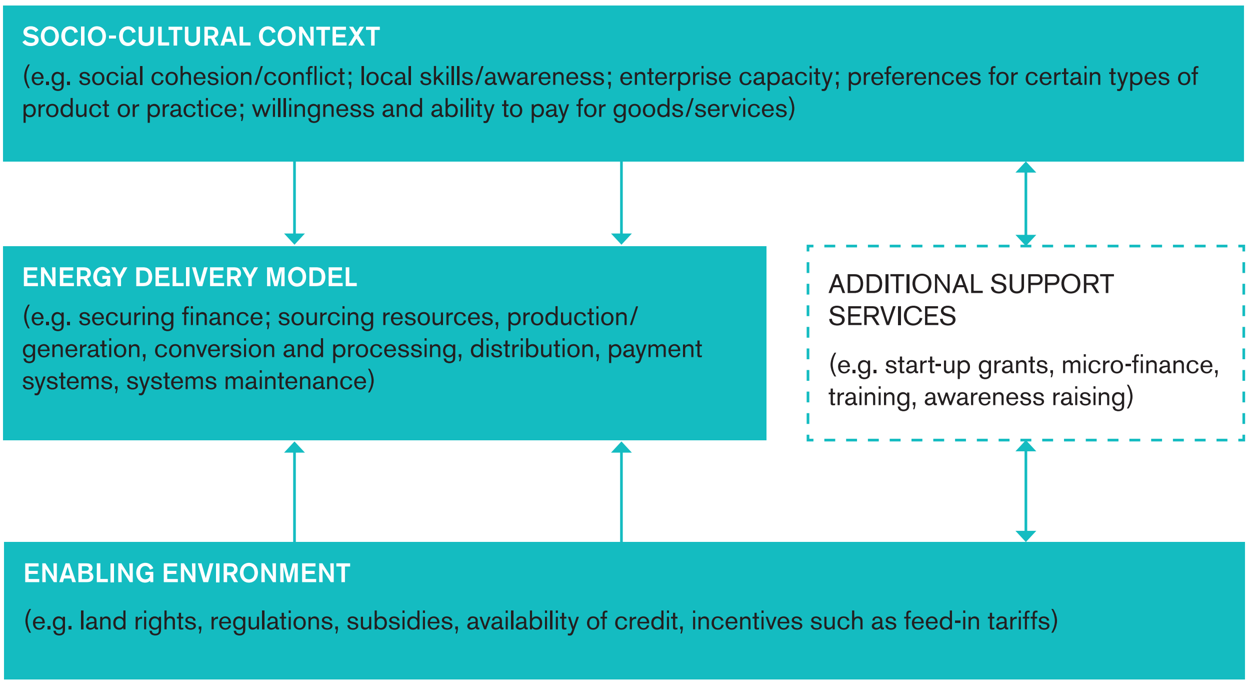
involvement; and to consider the full range of capacity building, policies, financing, operation and maintenance measures that ensure equipment and services are sustained over time (Wilson *et al.*, 2012; Bellanca and Garside, 2013; USAID/ARE, 2011).

Another big lesson is that there is no single 'master plan' or model of ownership that works (USAID/ARE, 2011). Particularly useful is the concept of 'energy delivery models'[20] increasingly used by practitioners to describe the combination of technology, finance and management needed to supply energy to users (see Figure 3). A successful delivery model depends on the wider enabling environment, including government policy and tax regimes; the socio-cultural context, such as the local skills base and social cohesion; and additional support services, like grants and business development skills training for suppliers and users of energy (Wilson *et al.*, 2012).

The World Bank and GIZ have also developed practical guidance on how rural energy projects could be better designed to address the main barriers and stimulate productive uses (ESMAP, 2008; EUEI-PDF, 2013b). These guidance measures (and the delivery models approach) emphasise the following priorities:

- **Involve people, raising awareness and demand**. This requires an outreach effort to local users and businesses, to identify and educate people on opportunities, understand needs, work together to identify options, build capacity and address barriers that might inhibit take-up. Barriers may include risk aversion, lack of awareness of credit facilities and lack of technical skills to operate new machinery. Participatory approaches are all the more important where a community-ownership model is adopted. Schemes have often failed where people lack the skills or social cohesion to maintain a service; a participatory design approach can help identify these types of issues and potential solutions.
- **Promote cross-sector collaboration**, particularly for big ticket, government-sponsored rural electrification programmes. Government departments such as energy, food, water and local government should work together in order to target investments and policy that can increase the productivity of existing activities in agri-food chains, or stimulate new ones.
- **Identify productive use opportunities in the target area** by mapping needs in rural SMEs and agricultural producers, engaging stakeholders,

Figure 3. Map of the pro-poor energy delivery system



Source: Wilson *et al.* (2012)

identifying bottlenecks, and assessing the costs and benefits of electricity use. Drawing on experience in Senegal, the ESMAP guide suggests how this analysis could be done either in a very systematic way or through a more pragmatic approach. A pragmatic approach would mean looking at existing projects led by other sectors – such as a food security project – and identifying where access to electricity would provide rapid gains.

- **Build capacity and provide business development services** for new start-ups and established producers/firms. This could include training in business administration skills to help people manage the higher production volumes enabled by modern energy services, or to market their products.
- **Facilitate access to efficient and high-quality end-use equipment** through advice, demonstrating how equipment works, improving local technical expertise in repair and maintenance, and improving access to credit so equipment is affordable for users. The latter could involve working with banks and micro-finance institutions to educate them on technologies, providing risk guarantees for investment loans (ESMAP, 2008; EUEI-PDF, 2013b).

Delivery models for expanding electricity and off-grid technologies for smallholder farming

Are there successful, scaled-up examples of delivery models for energy access for smallholders and local agri-food chains?

Are the barriers identified, and proposed approaches to addressing these in designing projects and investments the right ones?

What role, if any, is the private sector playing – from large utilities to small equipment providers – or is this primarily a space for not-for-profits and social enterprise-based models?

Meeting smallholder energy needs: the agri-food sector approach

4

While the energy sector has traditionally focused on energy supply, the starting point for the agricultural sector is the farm. Energy for mechanisation and productivity is one concern among a range of concerns and drivers including food security, livelihoods, sustainable resource management and climate change. The agricultural sector considers the use, costs and revenues of energy as it flows through the farm system, both as an input and product of farming in the form of bioenergy (see Figure 4).

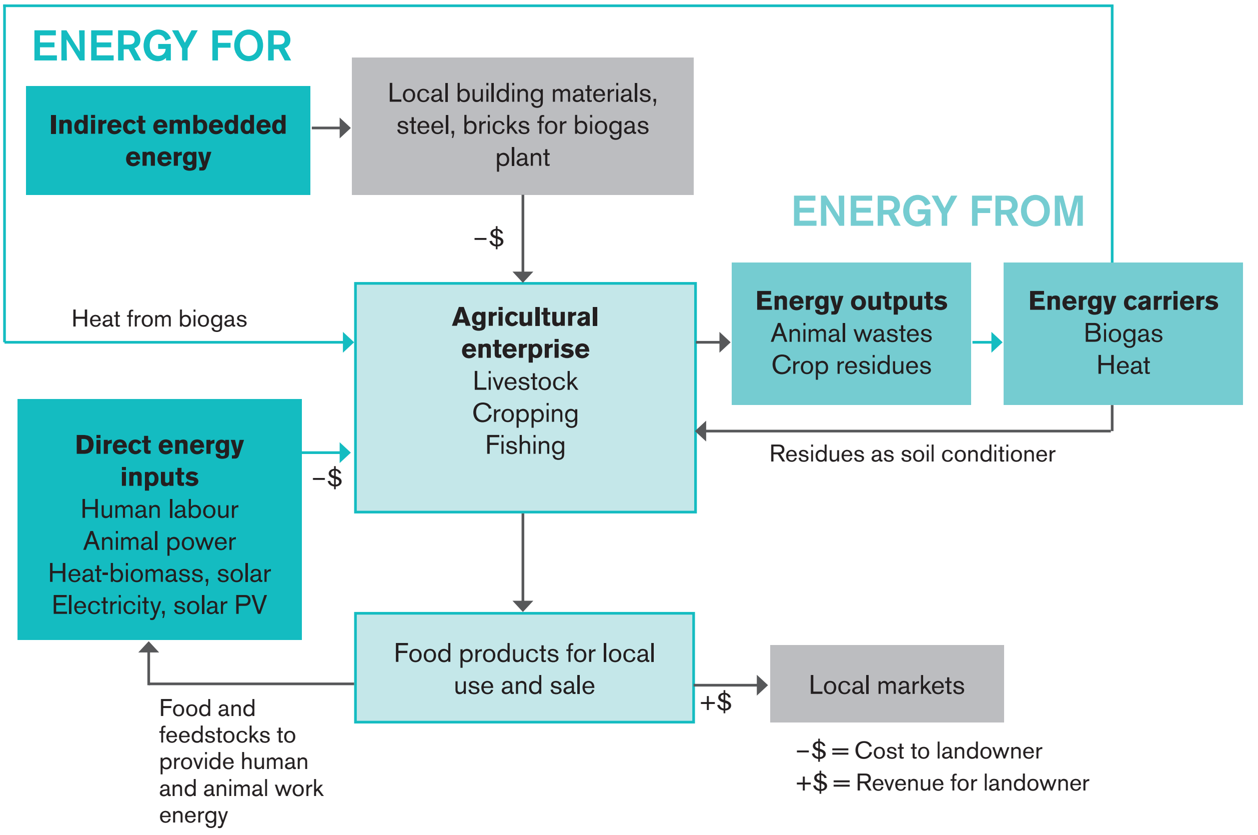
This section looks at key ideas and experience within agricultural mechanisation and sustainable agriculture, including integrated food–energy approaches. Although it finds examples of simple tools and integrated approaches that have achieved take-up at scale, many of the same barriers already identified in the energy field have caused mechanisation or sustainable agricultural projects to founder – particularly in sub-Saharan Africa. And outside the larger-scale agro-processors there appear to be few strong examples of farms producing energy for their own productive purposes, rather than for household needs.

Figure 4 below helps frame the analysis which follows by mapping energy flows at the farm level. It depicts a hypothetical small-scale farm with its direct and indirect energy inputs, including a household biogas digester to produce energy from animal waste and residues (see Box 6 for more on biogas digesters). It reinforces the point about the agriculture sector's interest in energy *from* as well as *for* the farm.

4.1 Agricultural mechanisation

Agricultural mechanisation has been a major focus of agricultural development for decades and is considered vital for increasing the amount of land in production, making farm operations more efficient, reducing physical drudgery, improving yields and quality, and stimulating rural economic growth. The term refers to 'tools, implements and machinery applied to improving the productivity of farm labour and of land; it may use either human, animal or motorized power,

Figure 4 Energy flows in a small-scale farm



Note: Example of a small-scale, low-input, family managed farming enterprise showing energy flows through the system. Outputs are primarily fresh food for local consumption, although they may also be delivered to local processing companies. Along with human and animal power, some direct energy inputs can be obtained from other sources, such as solar thermal and solar PV systems and biogas produced using a simple anaerobic digester.
Source: FAO (2011a: 6)

or a combination of these' (FAO, 2006: xii). While mechanisation directly overlaps with the energy access field, some of its features are distinct. For instance, it focuses on:

- simple hand-power tools and draught power, as well as modern energy and equipment
- promoting the agricultural machinery industry as well as regulating safety standards
- tractors, as well as irrigation and small-scale processing
- alternative crop practices, such as 'no-till' agriculture (see glossary). This more recent development recognises that a farm power deficit can be addressed both by *increasing* energy inputs and *reducing* energy demand.[21]

The approach to agricultural mechanisation and its success has varied considerably over time and across regions. On the one hand, for example, government-run tractor schemes adopted in some African countries 'failed miserably' due to problems such as poor management, training and planning. On the other hand, widespread uptake of machinery in Asia in the 1970s and 1980s was a feature of the 'green revolution' and the expansion of commercial agriculture in the region. This transition involved increased power outputs via tractors and diesel engines, and huge investments in irrigation, fertilisers and high yielding crop varieties (FAO/UNIDO, 2008: 8).

Some of the innovations with the greatest impact are low-cost machinery, often in conjunction with subsidised fuel (FAO, 2011a). In Bangladesh, for instance, the introduction of small, mobile diesel engines is said to have revolutionised food production in the country. These engines can be used to power a range of farm machinery, such as two-wheel tractors, threshers and water pumps. Public policy changes allowed the Chinese-made diesel engines to be imported, while their low cost and simplicity meant they were affordable and easily repaired by local mechanics (FAO, 2011a).

Other frequently cited success stories are simple technologies like treadle or ram pumps, which avoid the need for modern fuels or power sources altogether (see glossary, and Box 5). While these use 'traditional' energy sources, they are nevertheless important as examples of affordable technologies disseminated at scale and which have a concrete impact on farmers' productivity. Some studies have shown that treadle pumps may increase crop yields on small plots of land by 50–80 per cent, doubling farmers' income (UNDP/PAC, 2009).

Sub-Saharan Africa has faced particular challenges in mechanising agriculture. Many of the barriers are, unsurprisingly, similar to those previously identified for the energy field: insufficient focus on user needs, no after-service support or repairs, farmers' poverty, lack of credit, and the absence of government coordination. Additional problems are a lack of land titles, denying farmers collateral to access loans; rising fuel costs; and the inappropriate use of tractors and other heavy machinery degrading the soil (FAO/UNIDO, 2008; FAO, 2006).

More recent recommendations on mechanisation in sub-Saharan Africa bear a strong resemblance to insights from the energy sector, especially the 'energy delivery models' approach and 'productive uses of energy' toolkits (see Section 3). In 2008 the FAO and United Nations International Development Organization (UNIDO) published an expert workshop report with the following recommendations for agricultural mechanisation:

- take a participatory approach to technology development and mechanisation planning, working more directly with farmers and farmers' groups
- build user capacity, including farming, machine management, entrepreneurial and marketing skills
- work with the financial sector to promote medium-scale finance for farmers and farmers' groups
- make use of alternative energy sources such as biomass, solar, wind, micro-hydropower and biodiesel
- secure access to related inputs such as seeds, fertiliser, electricity, water and fuels
- promote the development and dissemination of appropriate technology better suited to local conditions – including more efficient use of manual and animal-powered machinery and transport as an interim step (FAO/UNIDO, 2008; FAO, 2008).

However, some emphases in the mechanisation literature differ from those of the energy sector literature. First, it recommends 'conservation agriculture' (using methods such as no-till; see Section 4.2) to reduce the power demands in agriculture, as well as to reverse soil degradation and increase fertility. Second, the importance of land-ownership and titling is not often highlighted in energy access initiatives, because the scant work on 'productive uses' tend to focus more on SMEs and industry.

Another issue is the question of public–private roles. The tenor of the expert workshop report on mechanisation is that government's role should be to create an enabling environment – investing in education and training, promoting entrepreneurship, regulating standards, establishing attractive fiscal regimes – while the job of importing, distributing and maintaining machinery is best done by business (FAO/UNIDO, 2008). However, within the energy access field the broad consensus is that a diverse set of ownership and management arrangements for energy services (public,

BOX 5. TREADLE PUMPS: LOW COST IRRIGATION IN INDIA

Treadle pumps allow smallholder farmers to irrigate their land very cheaply, and are widely used in South Asia and sub-Saharan Africa.

First developed by the NGO International Development Enterprises (IDE) in the 1980s, International Development Enterprises India (IDEI) has won two Ashden Awards (in 2006 and 2009) in recognition for its achievements in commercialising treadle pumps in India. A pump, tube well and installation cost around $US30 to US$42 (2009 data). Most farmers pay the full cost outright, but some dealers offer part credit. IDEI has established local supply chains to manufacture, distribute, sell and install the pumps, and developed innovative marketing and branding techniques to promote it, including Bollywood-style films.

By February 2009, 750,000 treadle pumps and 295,000 drip irrigation systems had been manufactured and sold, bringing benefits to 3.9 million people. Over half of these replaced diesel pumps, often hired, and the rest provided irrigation for the first time. Case study research suggests farming families have a better diet and surplus produce to sell, and that farm incomes can double or treble as result of using a treadle pump.

Source: Ashden Awards, 2009b

private and hybrid) will come into play, and to reach people on a very low income, public finance is vital. This may include start-up grants for business or social enterprises, subsidised electricity tariffs, and social protection (Best, 2013; Wilson *et al*., 2014).

4.2 Sustainability-led approaches to energy and food in agriculture

For several years now the FAO and other organisations have been promoting the idea that policy-makers need to better integrate the energy and agriculture sectors, and the concept is now gaining wider currency (FAO, 2001; 2011a). Relatively new terms in the discourse such as 'energy-smart agri-food systems' and 'climate-smart agriculture' describe an overall approach to addressing energy, food and climate issues. 'Integrated food–energy systems' (IFES) and 'conservation agriculture' have been around longer and describe specific practices and activities that achieve those approaches (see Table 2). Within the FAO world, all this falls within the paradigm of 'save and grow' or sustainable crop production intensification (Dubois, 2014).[22]

Many energy policy-makers and practitioners will be unfamiliar with the world and language of sustainable agriculture, and yet this world is closely concerned with energy use and conservation. While the precise meaning of terms differ, broadly these types of integrated food-energy approaches seek to:

- use energy more efficiently while retaining productivity and quality
- increase farmers' self-sufficiency in energy, thereby reducing production costs
- reduce the use of fossil fuels and increase the role of renewable and low-carbon energy
- produce bioenergy sustainably from the land, which farmers can sell or use for self-sufficiency
- increase food security and raise farmer incomes
- achieve more efficient management of natural resources (land, water and soil) and external inputs (fertilisers and machinery) through an ecosystem approach
- reduce or remove greenhouse gas emissions where possible
- help adapt and build resilience to climate change impacts (Bogdanski *et al*., 2010; FAO 2011a; FAO 2012; FAO, 2013a).

Discussions about 'energy-smart' and 'climate-smart' agriculture appear to be more focused on addressing the energy-intensity of the food system – how much energy is used to produce food – than on the specifics of productive energy in smallholder farming. Globally, the food system accounts for around 30 per cent of the world's energy consumption. Energy intensity is rising due to mechanisation, increased use of fertilisers, and improved food processing and transportation. A significant issue highlighted by the FAO is that the need to increase food productivity to address food security could be severely constrained by the shrinking availability of cheap fossil fuels:

> 'Modernizing food and agriculture systems by increasing the use of fossil fuels as was done in the past may no longer be an affordable option. We need to rethink the role of energy when considering options for improving food systems' (FAO, 2012: 6)

The use of fossil fuels in agriculture also contributes to the sector's emissions footprint; globally the food

Table 2. Disentangling the energy-food nexus: 'IFES' and 'CA'

INTEGRATED ENERGY-FOOD SYSTEMS (IFES)	CONSERVATION AGRICULTURE (CA)
IFES consists of food and energy produced together on the farm for sustainable crop intensification, energy self-sufficiency and/or selling energy crops. Operates at various scales and configurations.	CA improves resource use for sustainable food production through integrated management of soil, water and biological resources, combined with limited external inputs.
• Type 1 IFES combines production of feedstock for food and energy on the same land, through multiple cropping patterns or agro-forestry systems.	• Promotes practices such as low tillage, better use of fertilisers, integrated pest management, varied crop rotation.
• Type 2 IFES promotes synergies between food crops, livestock, fish production and renewable energy. Involves using technology (e.g. anaerobic digestion) to recycle farming products or residues to produce bioenergy and/or organic fertiliser.	• Reduced energy inputs is a co-benefit (e.g. no-till methods could reduce fuel consumption in tractor use).

Sources: Bogdanski et al., 2010; FAO 2011a; FAO 2012; FAO, 2013a

system accounts for 20 per cent of greenhouse gas emissions. However, this is more relevant to energy-intensive industrial agriculture and food systems than to smallholders who have very low energy inputs.

The types of solutions advocated in sustainable agriculture literature are wide-ranging. Many fall under the ambit of 'integrated food-energy systems' (IFES) and 'conservation agriculture' (CA), which are described briefly in Table 2. Some of the classic energy-related interventions have already been discussed, such as the use of off-grid renewable energy technologies (Section 3). Two new areas worth highlighting are energy efficiency and bioenergy.

Literature on energy efficiency recognises that, for smallholders, the aim should be to reduce costs rather than emissions; there should be no reduction in energy inputs if this lowers productivity (FAO, 2011a). The types of low-cost options relevant to smallholders include more efficient water pumps or conservation agriculture practices such as zero or minimum tillage. Mechanical tilling of the soil is the most energy consuming operation in the crop cycle, and in some contexts 'no-till' methods can reduce fuel consumption for cultivation by 60–70 per cent, as well as reducing losses of soil carbon (FAO, 2011a). Scaling-up agricultural practices based on more efficient use of energy and other natural resources requires a huge shift in policy, practice and behaviour, as well as the development of new types of mechanical technologies appropriate to low-energy inputs (FAO, 2012).

Producing bioenergy from farming epitomises both the challenging trade-offs between different resources, and the positive synergies. Much of the public debate has focused on meeting clean transport fuel targets in North America and Europe, and is often associated with negative impacts – such as diverting food crops like corn to biofuel markets, and competing with food crops for essential inputs – potentially contributing to food shortages and spiking food prices (FAO and OECD, 2011). Yet advocates of bioenergy, and of IFES in general, emphasise that many types and models of bioenergy can be efficient, sustainable and provide genuine development opportunities for poor communities and countries (Bogdanski *et al*., 2010).

The relevant question for this paper is: What do we know about bioenergy – and IFES more generally – supplying heat, power and fuel for productive uses in smallholder agriculture and related agri-food enterprises? In fact, little has been written about the productive angle of IFES, but a few points can be inferred from the practical experience to date.

First, proven examples of modern bioenergy achieving access to energy at any scale tend to be relatively simple systems serving domestic energy needs, particularly for heating and cooking. These are widespread in countries like Vietnam, Nepal and China (Bogdanski *et al*., 2010; see Box 6 on biogas in China).

Second, initiatives promoting bioenergy to serve smallholders' own productive needs or to generate an income are still at the pilot phase. For example, the JatroREF project in West Africa (from 2008 to 2015) is piloting short biofuel supply chains, intending to produce jatropha on 2000 family farms to supply pure vegetable oil. The oil could be used by 650 micro-enterprises for motorised services such as mills and decorticating machines (used to remove bark from wood, rind from nuts and so on), oil presses, battery chargers and multifunctional platforms.[23] A 2009 FAO

BOX 6. BIOGAS IN CHINA: USING WASTE TO POWER HOMES, FARMING AND AGRO-INDUSTRY

China has supported household biogas installations since the 1970s, with a major drive in government investment from 2003 onwards. This technology allows households to convert manure into clean cooking fuel ('biogas') and organic fertiliser, providing an alternative to fossil fuels, firewood and chemical fertiliser. Its domestic biogas programme has now reached 100 million people, supplying a quarter of rural households.

A simple version provides a biogas digester fed by a pigpen and toilet ('three-in-one' model). More complex ones add on a solar greenhouse ('four-in-one'), which is used for vegetable or fruit production, particularly in cold weather conditions in the north of China; or solar-powered barns to rear livestock, water-saving irrigation schemes and a water cellar (the 'five in one' model), adopted in the arid areas of northwest China, where water shortages and long cold winters restrict agricultural production. By the end of 2011, around 40 million household units had been installed; added to these are a further 24,000 small biogas plants and 3690 medium and large plants, which deliver biogas to an additional 1.7 million households.

However, there are questions about the sustainability of the current design model. Fewer animals are kept as livestock in rural households today, meaning less manure to feed digesters, and migration to the city means less labour available to operate them. Other difficulties include inadequate maintenance and repair services and mixed results on the level of savings accruing to households.

One institutional innovation that could reduce the burden on smallholders to raise livestock themselves is the 'District Biogas Farm' model piloted in Hainan. Small-scale farmers pay a larger district farm to rear pigs, and in return receive biogas and slurry at a discounted price, as well as revenue from the sale of the pigs.

There are also large-scale industrial systems that integrate biogas technologies. Fushan farm in Hangzhou is a large livestock and poultry farm that produces 15 tonnes of solid waste and 70 tonnes of wastewater every day. By using biogas digesters to deal with pig and poultry waste, biogas is made available for processing the tea crop, heating the chicken coop and providing fertiliser for tea plants and paddy fields.

Based on: Bogdanski et al. (2010); Zhuzhang (2014)

review of 15 small-scale bioenergy operations – of which three served productive purposes – highlighted that many of these were at an early stage. The reviewers also felt it was premature to identify a particular delivery model that might be economically sustainable (FAO, 2009).

Third, some of the promising opportunities for generating energy for productive uses in rural areas may lie with **larger-scale farms and the food processing industry**, rather than smallholder farmers individually producing energy for their own self-sufficiency. There are many examples of agribusinesses producing energy from waste as a spin-off from their core activity. A history of electrification in Costa Rica cites a sugar plant in the 1920s converting bagasse[24] to electricity, and supplying local households for half the year (Foley, 2007). A more contemporary example is the Tanzanian sisal growing company, Katani Limited, which has developed a biogas plant to convert sisal residue into electricity. This powers the company's factory, and the excess is used by sisal farmers living on the estate for domestic lighting and cooking (FAO, 2009).[25] This example underlines again the need to examine energy needs and solutions across the agricultural and food value chain, and not just within smallholder farms.

4.3 Key insights and barriers to integrated food-energy approaches

As we have seen, the agriculture literature shares plenty of common ground with the energy literature. This is particularly true of the shared recognition that a technology- and supply-led approach to addressing energy gaps in smallholder systems will not work. Solutions require a greater focus on users' needs and involvement; the delivery model for supplying and servicing energy and equipment (management, technology and maintenance); a supportive enabling environment; and complementary support packages (such as farmer credit, extension services and enterprise skills training).

Seeing the agriculture and food literature side by side also brings new perspectives. It forces us to widen our horizons beyond the questions of access to energy, and what is required to design energy services for productive uses. It provokes us to think about the wider challenges affecting smallholders' prospects in coming decades, which directly shape their energy needs and choices: climate change, food security, local environmental degradation, water availability, input prices (such as pesticides and fuel supplies), land rights and so on. It is critical to understand the farm as provider as well as user of energy; the flow of energy throughout the whole system; and how its use interacts with other natural resources like soil and water. Looking at both sectors in tandem has also widened the range of possible solutions to energy needs on the farm, highlighting the importance of improving human and animal-powered tools and reducing the demand for energy through changes to agricultural practices such as conservation agriculture and IFES.

However, there are also challenges and limitations. Practitioners have identified many barriers to the implementation and wide-scale dissemination of the types of integrated food-energy approaches flagged here, and many schemes are still at the pilot stage. As well as the usual technology, finance, policy and market access gaps, these barriers include:

- The complexity of some schemes, which require a high level of knowledge and skills. Highly integrated farm systems implicitly require farmers to be experts in many crops, activities and processes. Complex schemes also hit problems of scale, limiting the number of crops or livestock that a smallholder farm could take on.
- The increased workload often experienced with IFES makes the system less attractive to farmers. Where multiple crops are grown on one piece of land, or where there is a diverse array of interconnected crops and livestock, there tends to be less scope for specialisation and mechanisation, therefore often requiring significant manual input.
- The need to manage competition and trade-offs between different residues and resources – for instance, ensuring that crop and animal waste used for energy production does not prevent their use for soil fertility and/or for feeding animals.
- Access to technical support, information, communication and learning mechanisms is crucial for knowledge intensive schemes but not always available for poor communities in rural areas.
- A disconnect in time horizons, as the benefits of low-input agriculture or food-energy integrated schemes are often only seen over the medium to long term, but people want to maintain and improve their livelihoods in the short term (Bogdanski *et al.*, 2010).

Integrated approaches are clearly needed, but the complexity of 'systems thinking' is a real challenge – and a turn-off – to policy-makers and practitioners. The FAO is currently developing a rapid assessment approach for the 'water–energy–food (WEF)' nexus to help governments and investors prioritise issues, and is preparing a comparative analysis of the main WEF nexus tools and approaches available (due in 2014). One practical next step would be to examine how far these nexus tools address the 'productive uses' question in smallholder systems, and set them alongside the types of energy access toolkits referenced earlier to see what each has to offer and how they might inform each other.

An integrated food-energy approach for the energy access agenda

What's required to make joined-up approaches between sectors work at a local and national level?

How do we make complex 'systems thinking' simple and practicable? What does 'nexus thinking' and tools for the food-energy links add to our understanding?

Do we need to build 'energy literacy' among local people? What can we learn from farmers' organisations and the agricultural sector more broadly about the best way to do that?

Conclusion

5

5.1 Concluding remarks

This paper opened by stating that the food and energy sector share similar broad challenges: achieving access to energy for everyone; de-coupling from 'dirty' or expensive fossil fossils; and producing and consuming energy much more efficiently, to avoid costly waste and to help preserve a pressured natural resource base.

Nested within these dizzyingly complex challenges is one specific issue: how to expand access to modern energy services for smallholders and related rural enterprises in developing countries, who are among the most food insecure and, in many regions, highly dependent on manual and animal power. While we cannot put precise numbers on the energy deficit for smallholders, we know there is a direct link between higher energy inputs, mechanisation and productivity in agriculture and agri-food chains more widely. So at first glance, it is hard to disagree that lack of access to modern energy services is a major problem for families surviving off the land.

Equally, we can see that it is not a simple question of just more energy. Take the single issue of fossil fuels, like diesel fuel for tractors: more fuel and equipment inputs may mean increased food production, but also incurs new costs for farmers and exacerbates their vulnerability to volatile fossil fuel prices. Yet farmers may be deterred from adopting the alternatives. Adopting unfamiliar renewable energy technology or low-input agricultural practices may seem risky, require new knowledge or lack policy support.

This paper has attempted to shed light on some of the uncertainty and complexity around the why, what and how of addressing smallholders' energy needs. As this is a new area for IIED's energy access work, the analysis is tentative and raises many doubts, quandaries and appeals for expert opinion. While the key points and questions do not need repeating in full, it is worth making a few concluding remarks.

We can build on the lessons already learned

First, we're not starting from scratch. There seems to be good experience on the technical options, an understanding of what has gone wrong before, and potential ingredients for success. Many of the lessons learned are generic to supplying energy and equipment to poor communities. This includes things like the importance of capacity building and addressing end-user finance constraints. Equally, we know that serving agricultural and processing activities will require tailored approaches, different from the household energy sector. For instance, energy services and equipment could be combined with training in business and management skills, and we could think holistically about how to solve bottlenecks in local agri-food chains: ('is the solution an electricity connection, conservation agriculture, or better roads?').

Another key insight was the need to involve users closely in project design and ensuring a needs-based approach. Given the generally low levels of knowledge of energy issues, perhaps there is a need for an 'energy literacy' campaign among farmers, rural enterprises and their organisations in order to help people understand opportunities, articulate their needs and press for high quality services from providers and government.

We need to research delivery models and impacts

On the other hand, we're rather in the dark when it comes to understanding what kinds of delivery models might be economically viable for serving different energy and equipment needs in farming. We also know little about the role of the private sector in supplying energy services for smallholder agriculture and related processing activities. This is a critical issue, especially given the expectation that serving 'productive uses' could attract in commercial – or semi-commercial – investment. We need more analysis on this, and particularly about whether there are successful examples that this paper has overlooked and could be learned from. The lack of good empirical evidence on the impacts of energy access on smallholder productivity, livelihoods and well-being is another gap. This can be addressed by factoring in research and monitoring elements into new pilots and investments being developed now.

We need integration

Finally, there is a pressing need for integration and 'joined-up' approaches. One of the main aims of the paper is to distil and bring together the approaches and experience of the energy and the agri-food sector in addressing energy issues in smallholder farming. Now is the time to grapple with integration as 'nexus-thinking' is riding high in the development discourse.

This idea of integration is hardly new; it's a fundamental tenet of sustainable development. At the level of an individual or even a farm, people do not think about energy and food in isolation. Even at a local government level, it might be as simple as a few officials who already know each other working more closely together. But at higher levels and between different stakeholders, like a private utility and a farmers' cooperative, it gets more complex and contested. People and institutions have very different perspectives, languages, incentives, knowledge, political viewpoints and priorities. If we are to make real inroads into the dual problems of increasing access to modern energy for smallholder farmers – while supporting a transition to more environmentally sustainable and equitable food and energy systems – we need to think pragmatically about what kind of interventions stimulate integration.

IIED invites partners around the world to share their views, research and experience on some of the key issues and questions arising from this paper. Please contact Sarah Best at sarah.best@iied.org

Annex 1

Examples of case study evidence on the impacts of energy inputs in smallholder agriculture and processing

SOURCE	COUNTRY/ REGION	ACTIVITY	ENERGY INTERVENTION/ ACTIVITY	IMPACTS/ CONCLUSIONS
UNDP/PAC, 2009	Southern Africa	*Production*	Treadle pumps for irrigation	**Productivity/yields:** Crop yields increase by 50–80% and double incomes
Burney *et al*., 2010	Benin	*Production*	Solar power drip irrigation	**Income/food security:** Significant increase in household income and nutritional intake, particularly during the dry season, and was cost effective compared to other technologies
Ashden Awards, 2009a (GERES)	India	*Production*	Improved greenhouses to absorb and retain thermal energy from the sun	**Production/incomes:** Enables people living in cold areas to grow fresh fruit and vegetables throughout the year. Evidence of better diet/ health for local population, improved status for women who operate greenhouses and sell produce, lower market prices through local production, 30% increase in family income (allowing payback in 4 years)
USAID, 2009	Lebanon	*Post harvest and storage*	Packinghouse and cold storage facilities for citrus growers	**Product losses/ input costs:** Reduced input costs as improved storage eliminated use of pesticide spray (to prevent insect damage), reduced postharvest losses, improved quality and market value.

SOURCE	COUNTRY/ REGION	ACTIVITY	ENERGY INTERVENTION/ ACTIVITY	IMPACTS/ CONCLUSIONS
USAID, 2009	Bali	*Post harvest and storage*	Strawberry growers given access to pre-cooling unit at local packing house	**Product losses/quality/ incomes:** Post harvest losses reduced from 30 to 5%. Increased profits as supermarkets paid higher farm gate prices for better quality strawberries.
EUEI-PDF/ GIZ, 2013a	Bolivia	*Post harvest and storage*	Solar dryers to preserve and dry fruit	**Incomes/market access:** Sales price of dried peaches tripled (from BOB 8/kg to BOB 24/kg). Producer association increased income by over 60% in three years. Improved quality/quantity produce secured position in local and regional market
EUEI-PDF/ GIZ, 2013a	Benin	*Processing*	Efficient cooking technologies (rocket stoves) for shea butter producers	**Costs/incomes/ gender/product quality:** Shea butter production involves thermal energy using firewood. With improved stove, women-run enterprise reports 50% fuel saving, increase daily profit of CFA 350 (USD 0.70), extended working hours, tripled production and doubled company revenues
Ashden Awards, 2007	Nepal	*Processing*	Improved design of watermills to provide mechanical power for grinding wheat	**Efficiency/income:** Reduced waiting time for customers from 3–4 to 1–2 hours and 25% increased income for watermill owners
UNDP, 2004	Mali	*Processing*	Multi-functional platforms for agro-processing	**Labour/gender equality:** Women customers saved on average 2–6 hours a day (by mechanising agro-processing); 4 of 12 studies reported time saved was use for income-generating activities

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Notes

1 See www.se4all.org.

2 The development framework due to follow on from the Millennium Development Goals (MDGs), which conclude in 2015.

3 See for example the objectives of Sustainable Energy for All (http://www.se4all.org/our-vision/our-objectives/)

4 See for example the Water, Energy, Food Nexus Conference and platform, launched by the German government in the run up to Rio+20: www.water-energy-food.org.

5 See www.nepad-caadp.net and www.fao.org/publications/sofa/2013/en.

6 See http://practicalaction.org.

7 See www.poweringag.org.

8 See www.ashden.org/news/usaid-partners-ashden-launch-new-energy-agriculture-award.

9 'Rural Energy Access: A Nexus Approach to Sustainable Development and Poverty Eradication', held in Addis Ababa, 4–6 December 2014. For conference information and presentations see http://sustainabledevelopment.un.org/index.php?page=view&nr=489&type=13&menu=1634.

10 Definitions vary between countries and between agro-ecological zones. A shorthand definition is farmers operating less than two hectares of agricultural land, but size may vary considerably depending on landscapes and population densities.

11 Sen, Indian economist and Nobel laureate, outlined these concepts in his book *Development as Freedom*, 1999. Oxford: Oxford University Press.

12 This section also benefitted from unpublished materials provided by Alastair Livesey, Africa Power Ltd.

13 Estimates for waste percentages by commodity and region by each step of the food supply chain are provided in Annex 4 of FAO (2011b).

14 Note the useful figure in the executive summary of SOFA 2010-11 report on women's access to mechanical equipment: www.fao.org/docrep/013/i2050e/i2082e00.pdf.

15 'Extension' is an educational process which works with rural people to improve their livelihoods, often involving helping farmers to improve the productivity of their agriculture. See www.fao.org/docrep/t0060e/T0060E03.htm.

16 The study was completed as part of Productive Use of Energy (PRODUSE), a joint initiative of the Energy Sector Management Assistance Program (ESMAP), the Africa Electrification Initiative (AEI), the EUEI Partnership Dialogue Facility (EUEI PDF) and the German Society for International Cooperation (GIZ). PRODUSE aims to build understanding on how energy and productive activities intersect and provide practical guidance on this for energy projects and planning; see www.produse.org/index.php?lang=eng&page=3.

17 An example of different livelihood impact categories relevant to energy access is provided in UNDP (2009: 10, Table 10)

18 For instance, Mali has more than 150 isolated mini-grids in operation, which are mainly privately run small, diesel-generated units (Tenebaum and Knuckles, 2013)

19 See http://poweringag.org/2013-winners.

20 There is still no agreed definition of the term 'energy delivery model', despite its increasing use in international development and public service delivery. The term has evolved out of research and practical work on access to energy, which has focused on market mapping and business model design, and explored models of public service delivery.

21 See www.fao.org/ag/ags/agricultural-mechanisation/en and FAO/UNIDO, 2008.

22 See www.fao.org/ag/save-and-grow.

23 See http://jatroref.org.

24 'Bagasse' is the fibrous remnants of sugarcane or sorghum stalks after juice extraction.

25 See also the company website: www.katanitz.com/index.html.

Abbreviations and Acronyms

CA	conservation agriculture
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization of the United Nations
GIZ	Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation)
IFES	integrated food energy systems
SE4ALL	Sustainable Energy For All

Glossary

Appropriate technology is technology that is appropriate to the social and economic conditions of the local area; environmentally sustainable; and cost effective.

Bioenergy is the energy generated from biomass, wood, and energy crops, as well as organic wastes and residues from agriculture, forestry and industrial activities (sawdust, husks, shells and so on). Traditional bioenergy includes fuel wood, charcoal and dung, and is widely used for domestic energy use in the developing world.

Mini-grids or micro-grids are power systems that feed the electricity produced into a small distribution network to provide a number of end users with electricity on their premises. They are typically off-grid, less than 1MW (mini-grid) in capacity and use diesel, renewable or hybrid (combined) fuel sources to produce power.

Mini-hydro or micro-hydro typically produces up to 500kW (mini-hydro) or 100kW (micro-hydro) of electricity using the power of flowing water; this often consists of a small dam, several hundred metres of piping and a generator.

No till is a system for planting crops without mechanical tillage or ploughing, using herbicides to control weeds, with the aim of reducing soil erosion and preserving soil nutrients.

Ram pumps, or hydraulic pumps, are powered by falling water. They can pump water uphill to a significant height above the water source. While they are more expensive than treadle pumps, they can supply water for a large number of people.

Solar dryers use the sun's energy to dry food substances. Sunlight passes through glass onto a black surface at the base of the dryer, heating the air, which draws moisture off the food either directly or indirectly.

Treadle pumps are foot-powered suction pumps to draw water from depths of up to seven metres. They are very cheap, and widely used by poor farmers in South Asia and sub-Saharan Africa.

Two-wheel tractors are single-axle tractors which are self-powered and self-propelled. They can be fitted with a range of implements including a trailer or a plough. The operator usually walks behind it or rides the implement being towed.

There is a growing interest in how to deliver energy services to people on a low income, not just for household use but to earn a living: the so-called 'productive uses' of energy. One sector that deserves particular attention is smallholder agriculture. Expanding access to modern energy services and equipment for farmers could help address food security, gender empowerment and rural poverty. But the issues are complex, barriers plentiful and examples sparse of successful delivery at scale. Rural electrification schemes have focused narrowly on supply, rather than use, of energy; joined-up approaches across sectors are lacking; and the private sector is put off by the high risks and low returns. This paper considers the 'why', 'what' and 'how' of energy access for smallholders and related rural enterprises, and invites discussion among experts, practitioners and policy-makers on the key priorities, lessons learned and ways forward.

IIED is a policy and action research organisation. We promote sustainable development to improve livelihoods and protect the environments on which these livelihoods are built. We specialise in linking local priorities to global challenges. IIED is based in London and works in Africa, Asia, Latin America, the Middle East and the Pacific, with some of the world's most vulnerable people. We work with them to strengthen their voice in the decision-making arenas that affect them – from village councils to international conventions.

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Funded by:

This research was part-funded by UK aid from the UK Government, however the views expressed do not necessarily reflect the views of the UK Government.

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