



Livestock and renewable energy



Enabling poor rural people to overcome poverty

Livestock Thematic Papers
Tools for project design

Livestock and renewable energy



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Abstract

The International Fund for Agricultural Development (IFAD) is an international financial institution and a specialized United Nations agency dedicated to eradicating poverty and hunger in rural areas of developing countries. The 'Livestock and Renewable Energy' Thematic Paper is part of a toolkit for development practitioners, created to support the design of appropriate livestock development interventions. It has been developed to assess existing synergies between livestock and the renewable energy sector and consider the potential benefits that could arise from their interactions, such as mitigation of greenhouse gas emissions, environmental preservation (soil restoration), and availability of clean, affordable and reliable energy sources (e.g. biogas). The paper is divided into two sections. The first part looks at livestock's potential as a renewable energy source. For example, through the use of cost-effective technologies such as biogas systems that can stem methane emissions from livestock manure by recovering the gas and using it as an energy source as an alternative to wood/charcoal or fossil fuel. The second part, given the climate change scenario, considers viable applications of renewable energy technologies (RETs) addressed for small-scale farmers and livestock keepers at different levels of the value chain that can provide multifunctional benefits for households, community and environment.

Drawing on knowledge gained from IFAD-supported projects and from experiences and lessons learned by other IFAD partners, the paper provides recommendations for project design and possible actions to encourage the use of RETs that will enhance a sustainable livestock sector, preserve the environment and facilitate access to a renewable and sustainable energy sector. The paper thus seeks to identify the direct benefits from combining policy measures and innovation technologies for poor small-scale farmers and their production systems.

Background

Energy services are a key input in eradicating poverty and ensuring food security. Today, 2.5 billion people rely on traditional biomass fuels (wood, charcoal and dung) as their principal source of energy for cooking and heating, and almost 1.6 billion people have no access to electricity (UNDP, 2008). About 85 per cent of the global population using biomass for cooking lives in rural areas and more than 70 per cent of this population – over 1.7 billion people – are located in South-East Asia and sub-Saharan Africa (USAID, 2007).

Access to modern energy services can be crucial for sustainable development and for the achievement of the Millennium Development Goals. Such access is essential to meet basic human needs (i.e. health, education, safe water and sanitation services) and to enhance social and economic development. Indeed, many researchers are of the view that one of the main challenges that humanity will face over the coming decades is how to supply sustainable and reliable energy services to poor rural communities.

Recent high oil and coal prices, as well as an intensified debate about climate change, have led many analysts to suggest that renewable energy development could mitigate the negative impacts of unstable fossil fuel prices on the one hand, and the continued reliance on inefficient and unhealthy traditional biomass energy options on the other, as well as contribute to reducing greenhouse gas emissions.

Although the impact of smallholder farmers on global anthropogenic greenhouse gas emissions is minimal, the impact of climate-change-related effects (in terms of heat stress, dwindling water and land resources, spread of diseases and vectors, and loss of biodiversity) on small-scale farmers and livestock keepers is enormous (Thornton et al., 2009).

Within this scenario, waste manure and other organic materials from livestock farms could be an important source of energy production. A host of tested and successful technical options are available to mitigate the environmental impacts of agricultural activities while improving soil fertility and income levels. These can be used in resource management, in crop and livestock production, and in the reduction of post-harvest losses (FAO, 2009b).

The objective of this thematic paper is to synthesize available knowledge on the livestock and renewable energy sector, analyse livestock-renewable energy interactions (both in terms of the livestock sector's energy needs as well as its potential as a renewable energy source) and identify strategies and technological interventions for improved livestock productivity. Drawing on knowledge gained from IFAD-supported projects and from experiences and lessons learned by other IFAD partners, the paper provides recommendations for project design and possible actions to encourage the use of renewable energy technologies (RETs) that will enhance a sustainable livestock sector, preserve the environment and facilitate access to a renewable and sustainable energy sector.

The first part of the paper shows the livestock sector's huge potential for contributing to the supply of sustainable and reliable energy services (such as for cooking, lighting and space heating). This section recommends the use of animal manure and other organic-based waste products such as bioenergy¹ feedstocks for waste-to-bioenergy conversion processes that would allow farmers to take advantage of the availability of local materials to enhance the quality of their lives and – subject to availability of distribution mechanisms – even develop new markets for energy products. The second part considers viable applications within the climate change scenario of RETs for small-scale farmers and livestock keepers at different stages of the value chain. The purpose of this section is to promote the use of RETs that can provide multifunctional benefits for households, the community and the environment. This section discusses the potential synergies and efficiencies available when renewable energy sources are considered within the broader framework of development and poverty alleviation.

Overview of the livestock sector

Livestock is a very important sector, contributing about 40 per cent of the value of agricultural output globally (FAO, 2009a). The sector provides a source of livelihood and food security for about 1.3 billion people who are wholly or partially dependent on livestock, and 800 million people living in marginal, rural and peri-urban areas of developing countries (IFAD, 2010).

Livestock plays an important role in the livelihoods of many rural dwellers in Africa. This is particularly true in semi-arid areas, where livestock provides marketable products such as meat, milk and eggs, which are generally less vulnerable to critical harvest timing than many crops (Mariara, 2009). Livestock are also used as a store of wealth or as insurance against droughts. Domestic animals in rural communities are especially important, where they act as a “savings bank”, provide draft for farming and transportation, produce fuel, and yield non-food goods, such as leather and wool (ILRI, 2009). Hence, beyond nutrition, livestock offer further societal benefits, highly diverse and not easily quantifiable.

The livestock sector has expanded rapidly over recent years, especially in developing countries. This expansion has been driven by a number of factors, ranging from growth in incomes and population to urbanization and changing diets that include an increasing proportion of protein. Livestock-raising can take many forms. Depending on the context, it can serve quite different functions, play different roles in people's livelihoods, vary in herd structure and breed composition, and be managed in different ways (FAO, 2011).

Despite the importance of the sector to poor rural people, however, livestock production has failed to achieve sustainable returns for poor livestock raisers owing to several key constraints. Chief among these are the lack of modern energy services that can improve crop and livestock productivity simultaneously.

¹ Bioenergy is renewable energy produced from materials derived from biological sources or biomass, including plant materials and animal waste. It is the result of a solar driven process that converts these organic products into chemical energy.

It must be realized that expanding the capacity for livestock production and marketing can be a potent catalyst for rural poverty alleviation and an important contributor to sustainable rural development. The introduction of storage and processing methods could substantially improve the welfare of smallholder farmers. For example, progress could be made on the use of solar-powered refrigerators for dairy, fish and meat processing and for storing vaccines for veterinary and extension services (Van Campen, 2000). In general, interventions aimed at reducing livestock mortality and improving animal nutrition and management would allow for greater use of renewable energy throughout the traditional agricultural system.

Overview of the energy access situation in rural areas

Rural poor people tend to rely on human and animal power for mechanical tasks such as agricultural activities and transport, and on the direct combustion of biomass for activities that require cooking, space heating, heating water for bathing, and for some industrial needs. Rural poor people account for only 1 per cent of consumers that can afford diesel fuel and electricity (UNDP, 2008).

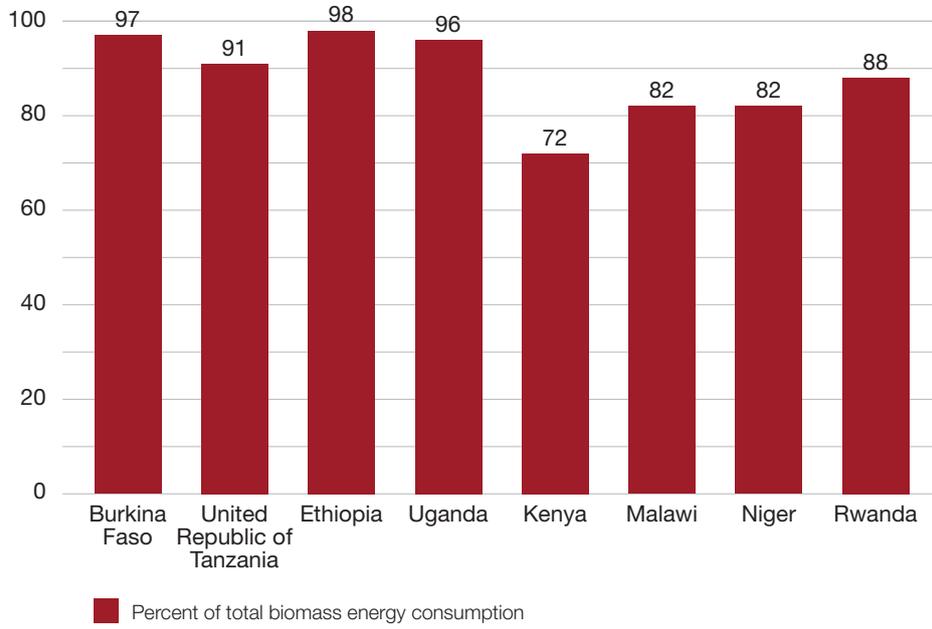
At present, expenditure on low-quality energy sources is surprisingly high in terms of cost, time and labour. Most estimates suggest that families in rural areas of developing countries spend on average approximately US\$10 per month on poor quality and unreliable energy services (USAID, 2007).

Hence, although the use of traditional biomass for cooking is not a problem in itself, the unsustainable harvest of biomass resources and inefficient combustion on open fires indoors (and outdoors) cause significant damage both to the environment and to human health. In addition, large amounts of human energy are expended for daily chores, and the burden tends to fall more heavily on women and children.

As figure 1 shows, in Africa, more than 80 per cent of the rural population relies on traditional biomass for their domestic needs, and 20 per cent or more is spent on wood and charcoal. In 2002, in sub-Saharan Africa, it was estimated that 393,000 people died as a result of inhaling pollution from the combustion of traditional biomass fuels (Karthi and Leach, 2001). Globally, about 1.5 million deaths per year are caused by smoke inhaled from health-damaging fuelwood (WHO, 2008).

For these reasons, coupled with the fact that traditional biomass is free in terms of immediate financial costs, the consumption of biomass in rural areas (mainly for space heating, lighting and cooking) is remarkably high and equals 82 per cent of total energy consumption (UNDP, 2008). Thus, for millions of smallholder farmers, animal draught power and nutrient recycling through manure compensate for lack of access to modern inputs such as tractors and fertilizers.

Figure 1
Biomass energy consumption in sub-Saharan Africa



Source: FAO, 2009a



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Livestock as a potential renewable energy source

Energy problems must be seen in the wider perspective of agricultural and ecological development (Keri et al., 2008). In developing countries, livestock-raising provides a mode to take advantage of otherwise non-exploitable areas for agriculture, making resourceful and sustainable use of natural resources and contributing to local economic development. Hence, viewing farming systems in an integrated manner, and the use and availability of livestock as an energy source can play a major part in improving agricultural productivity.

Within this context, the greatest potential for using livestock as a renewable energy source lies in small-scale mixed farm systems² where farmers can create synergies, for example by feeding animals crop residues and using animal manure to fertilize crops.

The use of animal manure and crop residues as bioenergy feedstock allows farmers to take advantage of new markets for traditional waste products. In effect, transforming livestock waste into bioenergy has the potential to convert the treatment of livestock waste from a liability or cost component into a profit centre that can generate annual revenue, moderate the impacts of commodity prices and diversify farm income (Kothari et al., 2010).

Renewable energy sources are increasingly gaining attention as a sustainable energy resource that may help cope with:

1. Increasing demand for energy by increasing the global energy supply.
2. Rising fuel prices by providing import substitutions for expensive fossil fuels.
3. Concerns about climate change by reducing global greenhouse gas emissions.
4. Energy security by promoting domestic supply of renewable energy.
5. Desire to expand agricultural commodity markets in the face of world trade forecasts.³

Biogas from livestock waste and residues

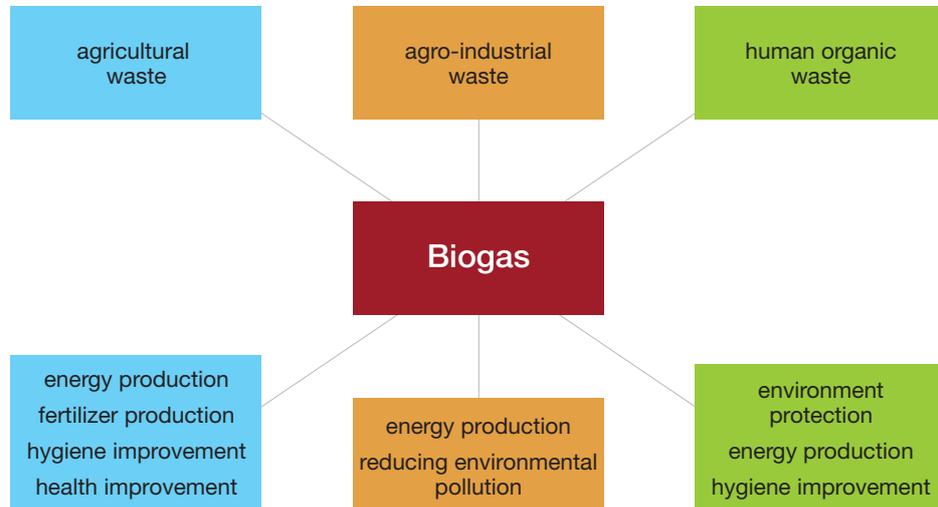
Biogas provides a renewable and environmentally friendly process that supports sustainable agriculture. It is one of the simplest sources of renewable energy and can be derived from sewage; liquid manure from hens, cattle and pigs; and organic waste from agriculture or food processing. Additionally, the by-products of the 'digesters' provide organic waste of superior quality (Arthur and Baidoo, 2011).

Biogas is particularly well suited to household energy needs in sub-Saharan Africa, as it improves both soil conditions and household sanitation. Manure-based biogas

² Mixed farms are estimated to produce the bulk of the global meat and milk supply (48 per cent of beef production, 53 per cent of milk production and 33 per cent of mutton from rain-fed mixed systems) (FAO, 2011).

³ Global Scenarios for Biofuels: Impacts and Implications. Presented by Siwa Msangi, Timothy Sulser, Mark Rosegrant, Rowena Valmonte-Santos on the Tenth Annual Conference on Global Economic Analysis Special Session on "CGE Modeling of Climate, Land Use, and Water: Challenges and Applications," Purdue University, Indiana, United States, 7 June 2007.

Figure 2
Multiple benefits from integrating waste flows for energy production⁴



digester systems are considered ecological since the technology captures and utilizes methane directly, thereby limiting total greenhouse gas emissions from livestock.⁵ According to technical specifications for pollution treatment projects involving livestock, biogas systems are the most commonly used at the household level because they are a readily available primary resource.

Figure 2 shows the significant health, sanitation and environmental benefits that could be obtained by filtering manure into a biogas plant and converting the waste into safe fertilizer. By using renewable resources and non-polluting technology, biogas generation serves a triple function: waste removal, environmental management and energy production. Biogas is now widely integrated with animal husbandry and can become a major means of manure treatment in the agricultural sector, thus advancing other environmental goals, namely, habitat preservation, soil restoration and watershed protection.

Harnessing the potential of biomass from livestock

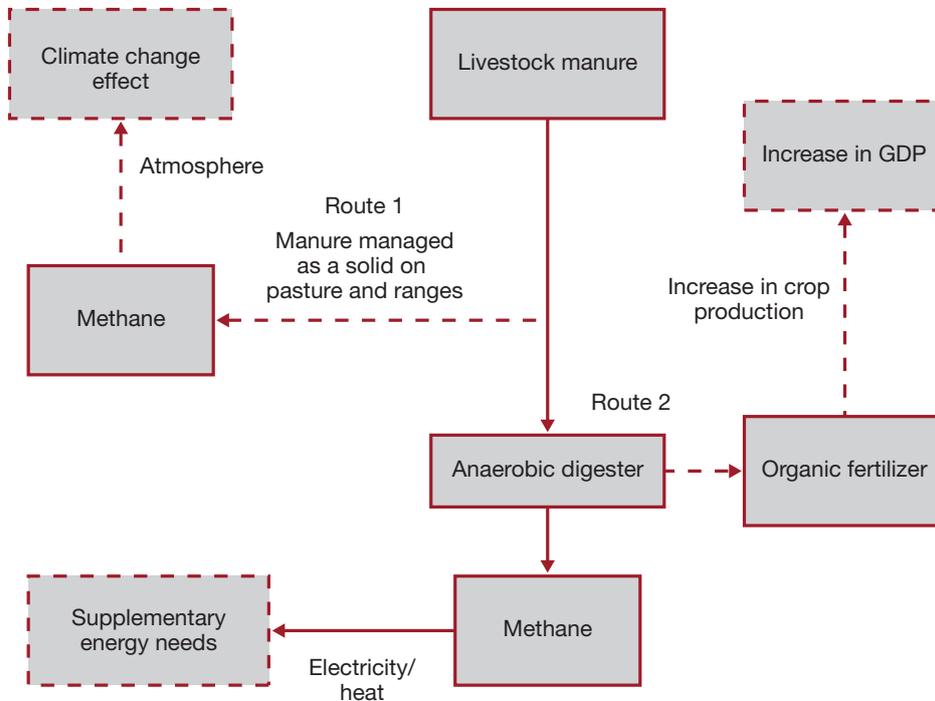
The conversion of animal waste, ashes and other minerals into biogas encourages on-site energy production and brings the production of bioenergy⁶ to the farm level, thus providing a way of reducing the agricultural sector's reliance on the combustion of traditional biomass while improving the soil,⁷ air quality and human health. Generating methane from manure produced by livestock under controlled conditions

4 FAO/GBEP (2009) Bioenergy – A Sustainable and Reliable Energy Source – a review of the status and prospects. Rotorua, 2009. Available online: www.ieabioenergy.com.

5 Livestock manure is collected, concentrated and treated in anaerobic digesters which can protect against methane and nitrous oxide emissions, and substantially reduce the amount of nutrients that potentially would rush into the groundwater, resulting in aquatic system eutrophication (Lin, 1998).

7 There is widespread evidence of the enormous impact of bio-slurry compost on crop yields. Given that other agro-ecological parameters are constant, crop yields have increased by 15-70 per cent (Garnett, 2009).

Figure 3
Mechanism for controlling direct methane emissions⁸



could supplement energy needs and, consequently, reduce the direct contribution of methane to climate change; essentially mitigating the use of firewood by relying on a more sustainable energy source.

The multiple benefits of anaerobic digestion are making it an increasingly attractive manure management technology. Other than being adopted at the household level, the system can efficiently be used in medium and large livestock farms. Such larger-scale energy production could provide electrification to entire rural communities for local use or for sale to small-scale industries via mini-grids.

In figure 3, the livestock manure management shown by route 1 results in the manure being applied as a solid on pastures and ranges. This results in the generation and release of methane into the atmosphere, contributing to greenhouse gas emissions. At the same time, most rural areas depend heavily on firewood as their primary energy source. If livestock production methods are modified such that a high proportion of the manure generated can be harnessed and fed to an anaerobic digester (route 2), methane can be generated under controlled conditions.⁹

In the case of livestock-dependent societies where production systems are based on grazing land, the use of the system requires concise logistical and management systems. A key constraint in the development of renewable waste substrates as energy

⁸ Arthur and Baidoo, 2011.

⁹ Manure from livestock dung is a source of methane, which is about 22 times more damaging than carbon dioxide. Turning animal and other waste into a mixture of methane and carbon dioxide can provide a cheap source of energy for lighting and cooking.

Table 1
Daily required input and fuelwood equivalent per plant volume

Bio digester size (m ³)	Daily dung feeding (kg)	Use of biogas stove (hour)	Use of biogas lamp (hour)	Wood value replaced (kg)
4	20 - 40	2 - 4	8 - 16	4 - 8
6	40 - 60	4 - 6	16- 24	8 - 12
8	60 - 80	6 - 8	24 - 32	12 - 16
10	80 - 100	8 - 10	32 - 40	16 - 20
15	100 - 150	10 - 15	40 - 60	20 - 30

Source: ITDG, 2009

Box 1
The IFAD biogas support mission in Rwanda

The IFAD-supported Kirehe Community-based Watershed Management Project (2009-2016), implemented by the Ministry of Agriculture and Animal Resources, aims to develop sustainable and profitable small-scale commercial agriculture in Kirehe District. The project will have approximately 22,500 direct and 10,000 indirect beneficiaries.

One expected output is more efficient livestock production through the use of biogas, which will reduce firewood consumption. To date, the project has installed approximately 1,500 bio digester systems.

Biogas was introduced in Kirehe District through the National Domestic Biogas Programme (NDBP) implemented by the energy sector of the Ministry of Infrastructure, with technical assistance from the Netherlands Development Organisation (SNV) and funding from the German Agency for Technical Cooperation (GTZ). An initial target of the construction of 15,000 brick digesters by 2011 was suggested.

The NDBP focuses on the promotion of biogas, training for farmers and other users, quality control and the provision of subsidies with the collaboration of the Banque Populaire du Rwanda. The average price per digester is RWF 700,000, towards which the NDBP provides an investment subsidy of RWF 300,000 and the Banque Populaire du Rwanda a loan of RWF 300,000.

Following the SNV experience in some Asian countries, the project is working to take advantage of the reduction in carbon emissions. The project has also implemented integrated biogas systems in Kirehe and Ngoma by constructing 76 fiberglass bio digesters, made in China, in order to reduce the construction time and minimize quality assurance issues.

Source: IFAD, 2010

resources is their dispersed nature. Large sources of waste substrates are often located some distance from potential energy production sites. In addition, a significant amount of livestock manure (as much as 25-35 per cent) of total residues may remain unrecoverable (Kothari, 2010).

The collection, transport and processing of renewable waste also poses significant challenges to their use in energy production. For these and other reasons, the technology is best suited to integrated crop-livestock systems at the household level, where families own up to four pigs, heads of cattle and/or poultry animals.

Biogas digesters are generally sized on the basis of local energy requirements and the manure production of the farm. Two main types of technologies exist – the brick bio digester and the tubular plastic one. The brick bio digester consists of a fixed dome placed underground. The plant is constructed with local materials: bricks, sand and cement and has an estimated lifetime of 20 years. The total size ranges from 4 to 10 cubic metres, depending on the resources available. The average cost of each plant is approximately US\$450.

The tubular plastic digester is relatively simple and cheap. The average cost of materials is currently around US\$150, starting from 3 to 8 cubic metres per bio digester. The plastic tube is generally installed in a pit in the ground. The waste inlet is installed higher than the outlet and a plastic tank is connected by a PVC tube with a diameter of 21 millimetres linking the gas reservoir to the gas burner. The waste is mixed with water, which drains into a plastic barrel dug into the ground.

Advantages presented by the use of biomass

Renewable biomass energy occupies an important position and plays a decisive role in the present world energy structure. It has the potential to supply about 14 per cent of global energy consumption, however only 1 per cent of its total energy capacity has been used to date (World Bank, 2009).

Given the recognition of biomass energy as a viable alternative resource, greater efficiency should be sought in its production and use. Future prospects for RETs are also good, with growing acknowledgement of their potential for the environment, price stability, local job creation and energy security. Manure collection is efficient where the livestock are kept in a pen (stalled) and provided with food and water. This system allows for manual collection. Alternatively, purpose-built pens allow manure to be swept into a drain connected to a biogas digester. Biomass resources have attracted much interest and enthusiasm because of five key advantages they hold over fossil fuels and/or other renewable energy sources:

Widely available resource. Biomass resources are diverse, widespread and often found in large volumes. In principle, biomass residues exist wherever trees and crops are grown and wherever food and fiber are processed.

Available on demand. Biomass is a form of stored energy and can therefore provide energy at all times, without the need for expensive storage devices. In this respect, biomass resources are like fossil fuels and differ markedly from intermittent renewable energy sources such as solar, wind and hydropower, with their nightly, seasonal or sporadic supply shutdowns.

Convertible into convenient forms. Biomass can be provided in all the major energy carriers: electricity, gases and liquid fuels for transportation and space heating. Biomass can therefore be used to substitute fossil fuels or other energy

Box 2

Biogas project turns waste into energy, Guangxi Province, China

The IFAD-supported West Guangxi Poverty Alleviation Project has provided nearly 23,000 biogas tanks to about 30,000 poor households, saving 56,000 tons of firewood annually, which is equivalent to the recovery of 7,470 hectares of forest. If this trend prevails in the long term, it could lower forest depletion rates and hence reduce deforestation. Each household involved in the project channels waste through their own plants from nearby animal shelters – usually for pigs – and from domestic toilets into a sealed tank. The waste ferments and is naturally converted into gas and compost.

As a result of the project, greenhouse gas emissions from the livestock sector have dropped, and the local environment has improved as a consequence of improved household sanitation. Average income in the village has quadrupled to just over a dollar per day.

Living conditions have generally improved. “We used to cook with wood,” says Liu Chun Xian, a farmer involved in the project. “The smoke made my eyes tear and burn and I always coughed. The children, too, were often sick...now that we’re cooking with biogas, things are much better.”

supplies needed to underpin poverty reduction, development and growth strategies for the 2 billion people who currently lack access to modern forms of energy, and thereby help reduce forest depletion rates and deforestation.

Potential to contribute to greenhouse gas reductions and other environmental objectives. The use of waste resources as an energy source is climate-friendly. In sharp contrast to fossil fuels, their production and use emit little or no carbon dioxide. Instead, the carbon dioxide released when biomass resources are burned will be reabsorbed from the atmosphere during biomass regrowth. Modern bioenergy technologies can serve similar ends by replacing traditional cooking fuels with clean, smokeless, efficient and easily controlled liquid and gas alternatives based on renewable biomass.¹⁰

Source of rural livelihoods. Much of the value added and income generation offered by bioenergy systems are retained locally and can help to reduce rural poverty – in sharp contrast to fossil fuel or central electricity production and distribution systems. Indeed, modern bioenergy is widely thought to be a key means of promoting rural development. When biomass is produced in a sustainable manner, it is considered as a renewable energy source that can generate power and heat by combustion or anaerobic digestion. All things considered, the economics of biogas digesters suggest that it is a perfect micro-level solution to macro-level issues of climate change, social empowerment and agricultural productivity.

¹⁰ This paper focuses only on issues of the energy access situation at the household level for poor rural smallholder farmers; therefore it does not look at the potential of biomass resources as liquid fuels for transportation. The paper looks at one convertible form of energy through the process of anaerobic digestion.



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Livestock – renewable energy interactions

Energy-related development interventions and livestock development are both recognized as crucial to poverty reduction efforts and sustainable development. These elements have been independently recognized, but the case for livestock and energy as a nexus in poverty alleviation is less developed and has only recently gained substantial attention (Steinfeld et al., 2006).

The livestock sector affects a vast range of natural resources and must be carefully managed given the increasing scarcity of land, soil, water and biodiversity. Given the prevalence of mixed crop-livestock systems in sub-Saharan Africa, crop and livestock farming cannot be considered independently of one another. Livestock and crops – and the related soil, air and water resources need to be viewed as an integrated system.

In the varied contexts of the livestock sector, this section looks at the direct benefits from combining policy measures and innovation technologies for poor livestock keepers and their production systems. The interactions between livestock and renewable energy are of potential benefit to both sectors. Careful management of these interactions can lead to:¹¹

1. A sustainable livestock sector that takes advantage of, as well as strengthens the renewable energy sector.
2. A larger global primary energy supply through the production of biogas and minerals from livestock residue.
3. Reduced greenhouse gas emissions achieved by converting livestock waste into biogas, which will help mitigate possible greenhouse gases that would have been emitted by unmanaged livestock waste, and thus have a positive impact on the environment.
4. Greater local energy security and improved trade balance by substituting imported fossil fuels with locally produced biomass.
5. New economic and social development opportunities in rural communities by enhancing on-farm and non-farm livelihood activities that drive the development of infrastructure and create new markets in rural communities.
6. Enhanced management of natural resources such as land and water.
7. Improved waste management by recycling livestock waste for biogas production.

Linking livestock and renewable energy technologies (RETs)

Wind power is an abundant energy resource that can be exploited for pumping water in remote locations. The use of this renewable energy source dates back to the nineteenth century, when more than 30,000 windmills were already operating in Western Europe.

11 IEA Bioenergy: ExCo: 2009:06 and FAO/GBEP 2009 – Website of Global Bioenergy Partnership. <http://www.globalbioenergy.org/bioenergyinfo/background/detail/en/news/39205/icode/>.

The use of wind energy to pump livestock water can have a comparative advantage for poor livestock keepers who have difficulties in accessing water resources. The power generated by utility-scale turbines ranges from 100 kilowatts to as much as 5 megawatts.

Hydro power can be used by a small community of people, especially if there is a small running body of water nearby. At present, about 13 per cent of the world's hydropower is found in Africa, but only 5 per cent of this potential is being used (UNDP, 2008). Although the region has some of the world's largest water systems, this resource, hampered by low demand and dispersed populations, remains barely exploited.

Since investments have been historically concentrated on large dams (because of easier finance mechanisms and lower unit costs of generation), scaling down hydropower units from 10 to 1 megawatts increases specific costs of installed capacity by 40 per cent, and scaling down from 1 megawatt to 100 kilowatts by another 70 per cent (ITDG, 2009). This situation is a source of much controversy since the most suitable plants for smallholder farmers are micro-hydro (up to 100 kilowatts) or pico-hydro (up to 5 kilowatts) plants.

The main micro-hydro programmes in the developing world are in mountainous countries and countries in the Himalayas. Experience in China, India, Nepal and Sri Lanka has shown successful results with hydropower-based mini-grid systems that distribute power locally. Moreover, small-scale individual end-use activities such as battery charging and freezing of produce have proved to be more viable projects than large community-owned end-use activities such as rice milling (Canadian International Development Agency, 2005).

Solar energy can broadly be categorized into solar photovoltaic (PV) technologies, which convert the sun's energy into electrical energy, and solar thermal technologies, which use the sun's energy directly for heating, cooking and drying (Karekezi and Ranja, 1997). For centuries, solar energy has been used for drying animal skins and clothes, preserving meat, drying crops and evaporating seawater to extract salt. Solar energy is utilized at various levels. On the small scale, it is used at the household level for lighting, cooking, water heaters and solar architecture houses; medium-scale applications include water heating and irrigation. At the community level, solar energy is used for vaccine refrigeration, water pumping and purification, and rural electrification (Karekezi and Ranja, 1997; Ecosystems, 2002).

Solar-powered refrigerators and freezers

Solar-powered refrigerators and freezers are widely used by health clinics because of their high reliability and low-maintenance requirements and the importance of a reliable conservation method for vaccines. Cost-wise, PV refrigerators are still not competitive with other off-grid alternatives like propane or kerosene fridges (Van Campen, 2000). A major problem is that most electric refrigerators are not designed to be powered by PV systems and have high energy consumption. The few refrigerators that are made for PV use are expensive, partly because of the low volume of sales. In some countries like Brazil, attempts are being made to developing PV refrigerators for off-grid use.

Dairy, fish and meat processing generally require larger refrigerators with high energy consumption, meaning that PV systems lose their competitive edge. However,

examples exist of hybrid PV/diesel and PV/wind systems that power larger refrigeration systems, for instance in Indonesia and Mexico.

Another application of PV refrigeration in the agricultural sector is the cooling of vaccines for veterinary use where reliability and low maintenance are important criteria. Many examples of this type of application exist, such as in the FAO-managed project on rangeland management in the Syrian Steppes (FAO, 1999).

Poultry lighting

Several scattered cases have been identified in which solar systems were used to provide light for poultry (for both meat and egg production). Use of artificial light extends the day and increases the growth of poultry and the production of eggs. Another important factor for poultry farms in some areas is heat to reduce the mortality rate of chicks. In conventional poultry farms 'heat lights' are used to provide both heat and light. In hot areas, ventilation is needed, which can more easily be supplied with PV-powered electric fans. More investigation is needed to ascertain the actual potential of modern RETs in the livestock sector.

Solar pumping for livestock watering

As livestock operations improve, the need for watering places and natural water sources increases. Effective watering systems are also needed to protect watercourses and to improve the availability of good quality water. Given the prevalence of rain-fed systems in Africa and South-East Asia, PV pumping for livestock watering is one of the alternatives that is gaining prominence in off-grid areas.

PV systems are mobile, low maintenance and need no supervision or fuel supply. A specific characteristic of solar-powered pumping systems is that they generally do not require a battery for energy storage since energy is stored in the form of water in a water reservoir, which reduces maintenance and increases system reliability.

However, investment costs in PV systems are still high, which makes them mainly attractive for large herds. PV pumps for livestock watering are widely commercially available and mature markets exist in countries such as Australia, Brazil, Mexico, the United States and Western Europe.

The Mexico Renewable Energy Programme has been promoting the use of PV pumping for livestock watering in Mexico as one of the most attractive PV applications. The Mexican market for these systems is estimated at US\$297 million (Van Campen, 2000). The advantage of the system for the livestock sector in countries such as Mexico is that the many large-scale cattle owners manage their cattle over a wide area, thereby requiring several small pumping systems to make continuous rotation of their cattle possible. The main direct impacts are increased production on existing lands (of both milk and meat) and improved natural resource management. Uncontrolled access to a watercourse has significant potential effects:

- Impact on the watercourse itself, including damage to vegetation and water banks;
- Faecal contamination introducing pathogens and excessive nutrients into the water; and
- Damage to herd health, including reduced water intake, injuries to legs and hooves and increased water transmittable diseases (Van Campen, 2000).



Barriers to the adoption of RETs

To achieve the desired growth in rural areas, decentralized RETs have emerged in some circumstances as a more affordable and practical means of providing essential energy services, and more importantly, as a prerequisite for equitable socio-economic development.

While RETs cannot solve all the energy problems of rural communities, they are still seen as having significant unexploited potential to enable developing countries to meet their growing energy requirements. Renewable energy is already the dominant source of energy for the household subsector (biomass energy).

However, despite the recognition of RETs as important sources of energy for developing countries, these technologies have attracted neither the requisite level of investment nor tangible policy commitment. Although national and international resources allocated to developing, adapting and disseminating RETs in the past two decades may appear substantial, the total amount dedicated to livestock productivity is still insignificant compared with the amount allocated to the conventional energy sector.

The success of RETs has been limited by a combination of factors: poor institutional framework and infrastructure; inadequate RET planning policies; lack of coordination and linkages in RET programmes; pricing distortions that have placed renewable energy at a disadvantage; high initial capital costs; weak dissemination strategies; lack of skilled human resources; and weak maintenance, services and infrastructure.

Key issues for project design

Linking rural energy systems with the activities of other sectors of the national economy, and with local culture and use patterns requires an integration of policies, plans and programmes of various sectors in rural areas with energy sector programmes. Such an understanding serves as a basis for strengthening IFAD's capacity to engage in both the rural energy and the livestock sector, and for identifying actions that it can take, in collaboration with its Member States at the national and local level.

Where access to energy is lacking, other urgent human and societal needs also are often not met (i.e. tackling diseases, water scarcity, etc.), implying that energy must compete with rather than complement other priorities. In rural areas, it is important to consider that accessing modern energy services is also complicated by habitual use of traditional methods, which are perceived as inexpensive.

Therefore, the immediate obstacle to access to modern energy services for many poor households and governments in developing countries is the lack of financial resources. Because the ability of the rural poor to pay is low, and because long-term, off-grid service costs are not known, entry into rural off-grid markets was, and to an extent still is, considered a high-risk, low-return proposition (World Development Report, 2010).

The previous sections of this paper have explored some of the key interactions between livestock and the renewable energy sector. Project designers should consider these interactions and design livestock projects that benefit from as well as strengthen local renewable energy production. The following elements are essential in this regard:

1. Educating and sharing knowledge about the benefits that can be derived from harnessing the synergies between the livestock, crop and energy sectors for local rural communities.
2. On their own, poor livestock keepers may not achieve the efficient production systems needed to benefit from livestock-renewable energy interactions. Project design should aim at developing and/or strengthening existing livestock keepers' cooperative groups as well as facilitating credit and microfinance¹² to support other income-generating activities.
3. Project design should promote the transfer of technologies that enhance the conversion of livestock waste to biogas to rural communities. This will not only support waste management but facilitate the opening of new markets for livestock by-products which livestock keepers can benefit from. Essentially, this should be linked to on-farm productivity and profitability.

¹² IFAD Thematic Paper on Livestock and Rural Finance provides insight on how to facilitate credit and microfinance.

4. Project design should aim at reducing the competition between livestock and other natural resources (mainly land and water). This can be done by developing a framework for collaborative management of natural resources¹³ using participatory methodologies that involve all stakeholders. Using this platform, stakeholders can be properly informed and educated on how to maximize the benefits of linking livestock production and marketing with RETs.
5. Project design should promote RETs that can reduce post-harvest losses.

¹³ IFAD Thematic Paper on Livestock and Land (Case study 3) provides insight on developing a framework for collaborative management of natural resources.

Lessons learned and recommendations

The characteristics of rural energy systems – supply sources, energy mix patterns, problems and potential for development – vary from place to place, depending on numerous factors such as availability, accessibility, affordability, alternatives, income level, sociocultural practices and climate. Hence, it is difficult to generalize about rural energy systems by explaining only one of the different traditional energy sources that are commonly used in rural areas or by approaching them purely from the point of view of wood energy alone. The same applies when identifying strategies for its development. A holistic approach is required that takes account of the following factors:

1. The livestock industry is important for the sustainability of many energy operations. This is because the residues from the livestock sector can become a resource in the energy sector, making both sectors more economically viable.
2. Likewise, the renewable energy sector is important for the livestock sector as it can reduce the risks associated with livestock production and create a new pathway for income generation through the sale of waste.
3. The need to develop the renewable energy sector from livestock residues may drive expansion of extensive systems of livestock production which are more efficient at mitigating some negative externalities associated with livestock production such as loss of biodiversity due to overgrazing, land degradation and social conflicts along pastoral corridors.
4. Biogas and mineral production from animal waste provide a pathway for recovering energy and improving waste management. This not only favours the livestock and energy sector, but also fosters sustainable development by addressing local energy needs of poor rural communities.
5. Recycling of animal waste or conversion of waste to biogas can mitigate greenhouse gases emitted by the accumulation of manure (i.e. animal waste). This will reduce the contribution of the livestock sector to climate change.¹⁴
6. Good management of livestock waste through conversion to biogas fosters good public health and improves the capital assets (such as soil and water) of rural poor farmers. This is because it reduces the rate at which ground and surface water is contaminated by animal waste and discourages the growth of certain pathogens that adversely affect human health.

¹⁴ IFAD's strategic framework should aim to minimize agriculture's contribution to greenhouse gas emissions while maximizing its potential to mitigate climate change. Although it is recognized that the greatest reductions in emissions are realizable in intensive industries in developed economies, IFAD should take into consideration its target group – small-scale farmers, pastoralists and livestock-keepers.

7. A policy framework that encourages livestock-energy interactions is recommended. Such policies should focus on:
 - i. Technology development programmes in order to transfer cheap and relevant technologies for converting livestock waste to biogas.
 - ii. Providing credit and microfinance for bioenergy projects that intend to use livestock waste as feedstocks, thereby enhancing growth in the livestock sector.
 - iii. Establishing other income-generating opportunities from livestock-renewable energy-related microenterprises.

Recommendations for project design

Project design should take into consideration various principles, lessons and recommendations to promote a stronger and more sustainable livestock sector while preserving the environment and facilitating access to a renewable and sustainable energy source. In this overall framework, key recommendations for project design are as follows:

1. Ensure multistakeholder dialogue to ensure that relevant sectors and stakeholders of the local economy are effectively interlinked (i.e. producers, suppliers and consumers) so as to promote production and consumption of bioenergy and foster collaboration in support of efficient and sustainable bioenergy chains.
2. Undertake an analysis of (strengths, weaknesses, opportunities and threats [SWOT]) to help reveal any potential for conflict that could arise from renewable energy promotion and identify fields of action.
3. Aim for more sustainable outcomes in relation to ecosystems and livelihoods. All the stakeholders engaged in the renewable energy agenda (governments, businesses, communities, landowners and individuals) should be involved in project activities. Sustainability goals should take into account recurrent issues such as management of cooperatives, access to finance and affordability and rural communities' ability to pay for the energy produced.
4. Develop and/or strengthen existing livestock-keepers' cooperative groups and facilitate credit and microfinance to support enterprises.
5. Promote the transfer of relevant technologies that enhance the conversion of livestock waste to biogas to rural communities. This will not only support waste management but facilitate the opening of new markets for livestock by-products that can benefit livestock-keepers.
6. Support the development of business models and financing concepts which increase added value for livestock/RETs and innovative practices. Project planners should ensure equitable inclusion and participation of indigenous peoples in the planning process.

Recommendations on biogas digester systems

Cost-effective technologies are available that can stem this emission growth by recovering methane and using it as an energy source. These technologies, commonly referred to as anaerobic digesters, decompose manure in a controlled environment and recover methane produced from the manure. Digesters also reduce foul odour and can reduce the risk of ground and surface water pollution. In addition, digesters are

practical and often cost-effective for small-scale dairy cattle and pig farms, especially those located in warm climates.

This does not mean that every smallholder farmer should be equipped with a digester. However, given the correct agro-ecological environment, the right climate and most importantly, an abundance of manure, crop residues and other wastes, biogas digesters can be a viable option. Hence, the technology serves as a multifunctional platform where waste resources from the livestock sector become a resource for generating lighting, cooking and heating needs at the household level. Obstacles to the dissemination of bio digesters at the household level and possible solutions are as follows:

- **Initial costs barrier:** provision of a subsidy to lower the initial investment costs (possibly in combination with microfinance services).
- **Technological barrier:** adaptation of bio digester to the needs of the participants; imposition of standards and provision of training for operating RETs.
- **Information/behaviour barrier:** provision of information, awareness-raising and promotion regarding the benefits of RETs. Consistently high quality is quite a decisive factor since the implementation period is long. Quality standards should also be defined for cooking stoves and/or biogas digester systems.

The technical, economic and social issues confronted by farmers in adopting biogas systems at the farm level are summarized below:

- Dung collection proved more problematic than anticipated, particularly for farmers who did not keep their livestock penned in one location.
- Small-scale farmers with small herds were not able to get sufficient feedstock to feed the bio digester unit and ensure a steady generation of energy for lighting and cooking.
- Investment costs of even the smallest biogas unit proved prohibitive for most poor African rural households. Though evidence from many African countries is still limited, the general consensus is that the larger combined septic tank/biogas units that are run by institutions such as schools and hospitals are more viable than small-scale biogas digesters.

These factors have contributed to the low dissemination levels of the technology. There is some anecdotal evidence, however, that biogas technology can be successfully disseminated to the rural poor if it is conceived as both an energy and an agricultural/health intervention. It is important to note that the technology has to be selected in accordance with the given agro-ecological, sociocultural and economic parameters.



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Annex I

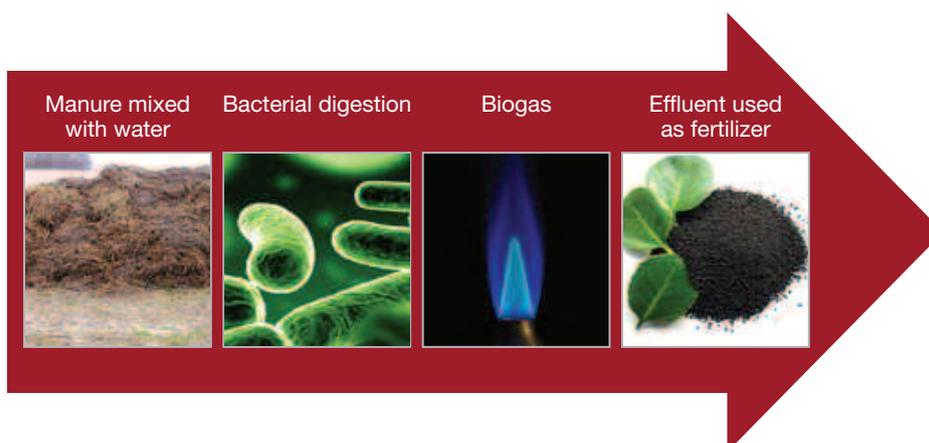
General information on biogas digesters

Biogas is a simple technology that produces gas for cooking by using a mixture of animal, crop and human residues in a hermetic tank. Biomass waste is first mixed with water and then put into a plastic tank, also known as a bio digester. Inside the digester is an anaerobic environment where micro-organisms and bacteria digest the biomass, producing methane and carbon dioxide. The gas rises up into the tank, passes through a small pipe and arrives at the cooker.

Anaerobic digestion is a thermo-chemical process that occurs in the absence of oxygen and transforms organic matter into a biogas composed principally of methane and carbon dioxide. This reaction starts naturally in large heaps of organic matter, like agricultural biomasses. The methane rate varies between 50 and 80 per cent, according to the type of process and biomass used. Micro-organisms achieve anaerobic digestion in two steps: the first is a transformation of complex substances into intermediate composts, like acetic acid and hydrogen, which become the food for the methanogen micro-organism families during the second step. The effluent produced is an excellent fertilizer because of its high concentration of ammonium. Slurry is one of the most environmentally sound organic fertilizers in use today: it does not pollute the atmosphere during its application and does not pose health hazards to the user and/or to animals nearby.

The process

Using a bio digester is simple: the digester is initially filled with water until it overflows. This creates an air lock, with water in the lower two thirds of the tank and air in the top third. Then a daily 'charge' of manure-water slurry is added. Once in the chamber, the bacteria start decomposing the organic matter. The time it takes to



complete the process is called retention time. As the matter flows through the tank, biogas begins to accumulate in the upper part of the digester. This gas can be transported to the kitchen by a hose or pipe fitted with a valve, or it can be stored in a separate plastic container.

Anaerobic digestion (AD) occurs when organic material decomposes biologically in the absence of oxygen. This process releases biogas while converting an unstable, pathogen-rich, nutrient-rich organic substrate like manure into a more stable and nutrient-rich material with a reduced pathogen load. Biogas is composed of approximately 65 per cent methane, with the remaining content being mostly carbon dioxide and other trace gases (Jones, 1980). The leftover, more stable substrate can be a good source of fertilizer, or in some cases, further composted and reused as a bedding material. The figure below shows a schematic diagram of how the anaerobic digestion process takes place.

Anaerobic digesters can be categorized based on:

1. The operating temperature of the AD unit;
2. The AD unit process design. This allows either separate acidogenesis and methanogenesis reactions or mixed acidogenesis and methanogenesis reactions. These temperature ranges are identified as psychrophilic (68° F, 20° C), mesophilic (95–105° F, 35–41° C) and thermophilic (125-135° F, 52-57° C). The pH levels of the digester environment should be maintained as close to neutral (pH 7.0) as possible (Jones, 1980); and
3. Manure for biogas. Manure can be used for the production of energy (methane) and the remaining liquid slurry (by-products) can be used as organic fertilizer. It is important to note that there have been cases where organic fertilizers have given higher yields to farmers in comparison with synthetic fertilizers.

Annex II

Numerical figures for a typical biogas digester system

General information on a 6m³ bio digester:

Price: from US\$100 to US\$800

Daily output of biogas: From 2 to 5m³ per day

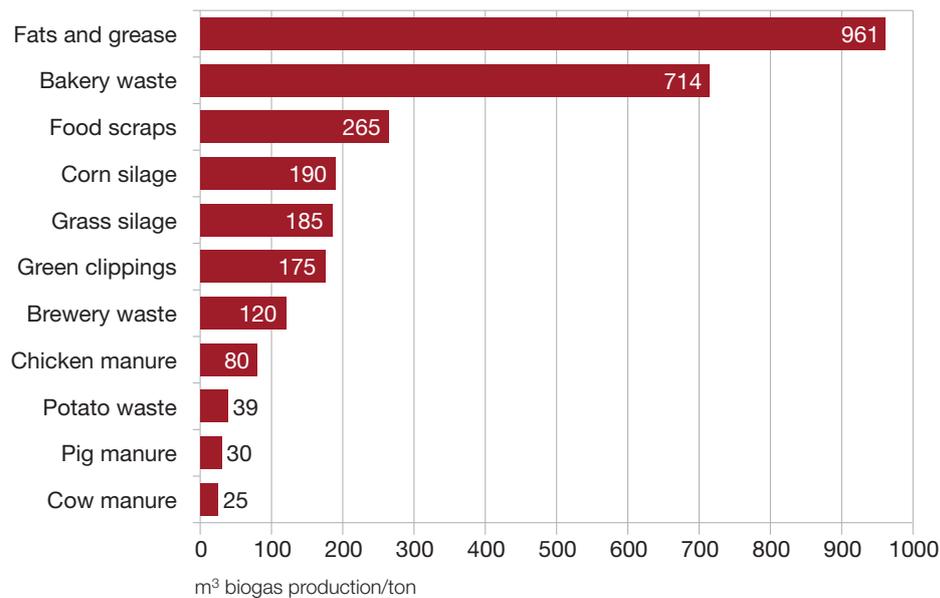
Lifetime: Plastic digester up to 10 years, cement or brick construction up to 25 years

CO² emission limited in the atmosphere per year: up to 2,000 kg

Wood saved per year: up to 1,500 kg

Time saved collecting firewood: up to 1,100 hours per year

Table showing average biogas production per type of material



Biogas energy digesters successfully treat all of these substrates

Source: Basisdaten Biogas Deutschland, March 2005: Fachagentur Nachwachsende Rohstoffe e.V.

Annex III

Solid manure production from different livestock¹⁵

Solid manure production from dairy cattle

Animal type	Production (lb/day/1,000 lb of animal)	Moisture content (percentage at time of spreading)
Lactating cow	18.5	46
Dry cow	17.6	46
Heifer	16.9	46

Solid manure production from poultry

Animal type	Production (lb/day/1,000 lb of animal)	Moisture content (percentage at time of spreading)
Layer	25.2	40
Pullet	19.0	40
Broiler	33.3	40
Turkey	14.1	40

Solid manure production from horses and sheep

Animal type	Production (lb/day/1,000 lb of animal)	Moisture content (percentage at time of spreading)
Horse	14.1	22
Sheep	14.5	31

¹⁵ <http://www.wy.nrcs.usda.gov/technical/wycnmp/sec4.html>.

Annex IV

Summary of current problems and benefits of biogas digesters

Current problems	Benefits of biogas
Depletion of forests for firewood causes ecological imbalance and climatic changes	Makes a positive impact on deforestation; relieves a portion of the labour force from having to collect wood and transport coal; helps conserve local energy resources
Burning of dung cakes creates a source of environmental pollution and decreases inorganic nutrients	Inexpensive solution to problem of rural fuel shortage; improves the living and health standards of rural and village communities; provides employment opportunities in small-scale industries
Untreated manure, organic waste, and residues lost as valuable fertilizer	Residual sludge is applied as top-dressing; good soil conditioner; inorganic residue is useful for land reclamation (restoration of soil nutrients)
Untreated refuse and organic waste pose a direct threat to health and sanitation	Effective destruction of intestinal pathogens and parasites; end-products are non-polluting and cheap; inoffensive odour
Initial high cost resulting from installation, maintenance, storage, and distribution costs of end-products	System pays for itself
Social constraints and psychological prejudice against use of human waste materials; lack of awareness of potential benefits	Income-generator and apt example of self-reliance and self-sufficiency

Annex V

List of safety measures for constructing a biogas system

1. Regularly check the entire system for leaks.
2. Provide ventilation around all gas lines.
3. The engine room roof must be vented at its highest point to allow lighter-than-air gases to escape. This is also true for greenhouses that have biogas digesters, engines, or burners in them.
4. Metal digesters and gas storage tanks must have lightning rods to conduct lightning to the ground. Gas lines must drain water into condensation traps.
5. No smoking or open flames are allowed near biogas digesters and gas storage tanks, especially when checking for gas leaks.
6. Methane, the flammable part of biogas, is a lesser danger to life than many other fuels. However, in the making and using of an invisible fuel, dangerous situations can arise unexpectedly and swiftly – such as when a gas pipe is accidentally cut.
7. In general, a digestion time of 14 days at 35° C is effective in killing the enteric bacterial pathogens and the enteric group of viruses. However, the die-off rate for roundworm and hookworm is only 90 per cent, which is still high. In this context, biogas production would provide a public health benefit beyond that of any other treatment in managing the rural health environment of developing countries.

Annex VI

Bottlenecks and remarks on the development of biogas

Aspect	Bottlenecks	Remarks
Planning	Availability and ease of transportation of raw materials and processed residual products	Use of algae and hydroponic plants offsets high transportation costs of materials not readily at hand. Easily dried residual products facilitate transportation
	Site selection	Nature of subsoil, water table, and availability of solar radiation and prevailing climatic condition
	Financial constraints: Digester design; high transportation costs; installation and maintenance costs; increasing labour costs in distribution of biogas products for domestic purposes	Use of cheap construction materials, emphasizing low capital and maintenance costs and simplicity of operation; provision of subsidies and loans that are not arduous
	Necessity to own or have access to medium-to-large number of cattle	Well-planned rural community development, ownership and biogas distribution schemes necessary
	Social constraints and psychological prejudice against the use of raw materials	Development of publicity programmes to counteract constraints relevant to illiteracy; provision of incentives for development of small-scale integrated biogas systems
	Technical	Improper preparation of influent solids leading to blockage and scum formation
Retention time of slurry and loading rate		Dependent upon digester size, dilution ratio, loading rate and digestion temperature
Corrosion of gas holder		Construction from cheap materials (glass fibre, clay, jute-fibre reinforced plastic) and/or regular cleaning and layering with protective materials (e.g. lubricating oil)

Aspect	Bottlenecks	Remarks
	Pin-hole leakages (digester tank, holder, inlet, outlet)	Establishment of "no leak" conditions, use of external protective coating materials
	Occurrence of CO ² reducing calorific value of biogas	Reduction in CO ² content through passage in lime-water
	Occurrence of water condensate in gas supply system (blockage, rusting)	Appropriate drainage system using condensate traps
	Improper combustion	Designing of air-gas mixing appliances necessary
	Maintenance of gas supply at constant pressure	Regulation of uniform distribution and use of gas; removal of water condensate from piping systems; appropriate choice of gas holder in terms of weight and capacity
Residue utilization	Risks to health and plant crops resulting from residual accumulation of toxic materials and pathogens	Avoid use of chemical industry effluents; more research on type, nature and die-off rates of persisting organisms; minimize long transportation period of undried effluent
Health	Hazards to human health in transporting night soil and other wastes (grey water)	Linkage of latrine run-offs into biogas reactors promotes non-manual operations and general aesthetics
Safety	Improper handling and storage of methane	Appropriate measures necessary for plant operation, handling and storage of biogas systems

Annex VII

Application of renewable energy technologies for different uses

Application	Examples
1. Food production and storage	Water pumping for crop production
	Water pumping for cattle
	Electric livestock fences
	Aeration pumps for fish and shrimp farms
	Egg incubators
	Refrigeration for storage (fruit, milk, etc.)
	Ice-making for storage (fish, etc.)
2. Food processing	Meat and fish drying
	Plant/seaweed drying
	Spice drying
	Cereal grain processing
	Coconut fiber processing
	Grain mills
	Lighting for processing plants
3. Materials processing	Rubber drying
	Sawmills
	Silk production
	Silkworm rearing
	Textile dyeing
4. Cottage industry	Bakeries (oven)
	Bicycle repair (power tools)
	Brick making (kilns)
	Carpentry (power tools)
	Electronics repair (soldering irons)
	Handcraft production (small electric tools)
	Sewing and welding
	Wood-working (drills, lathes)
	Workshop (small electric tools)
	Lighting for work places

Application	Examples
5. Drinking water	Desalination
	Potable water pumping
	UV or ozone water purification
6. Education	Computer/Internet
	Video
	School lighting
7. Health care	Small medicinal equipment
	Vaccine/medicine refrigeration
	Computer/Internet for telemedicine
	Clinic lighting
8. Community services	Broadcast media
	Village cinema
	Cellular/satellite telephone/fax
	Computer/Internet e-commerce
	Community center and street lighting

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