IFAD
Investing in rural people

How to do

Mainstreaming portable biogas systems into IFAD-supported projects

Environment and climate change

How To Do Notes are prepared by the IFAD **Policy and Technical Advisory Division** and provide practical suggestions and guidelines for country programme managers, project design teams and implementing partners to help them design and implement programmes and projects.

They present technical and practical aspects of specific approaches, methodologies, models and project components that have been tested and can be recommended for implementation and scaling up, including best practices and case studies that can be used as a model in their particular thematic field.

How To Do Notes provide tools for project design and implementation based on best practices collected at the field level. They guide teams on how to implement specific recommendations of IFAD's operational policies, standard project requirements and financing tools.

The **How To Do Notes** are "living" documents and will be updated periodically based on new experiences and your feedback.

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List of acronyms

CBA	cost-benefit analysis
EFA	economic and financial analysis
GHG	greenhouse gas
IMI	Initiative for Mainstreaming Innovation
KES	Kenyan Shillings

Introduction

Access to modern renewable energy services is a key factor in eradicating poverty and ensuring food security. Today, 2.5 billion people rely on traditional biomass fuels (charcoal, dung, firewood) as their principal source of energy for cooking and heating. And more than 80 per cent of these people (over 1.7 billion) live in either sub-Saharan Africa or South-East Asia. Replacing these traditional fuels with renewable sources of energy can significantly change living conditions in these regions, particularly for women. Women here may have little say in making decisions, including those related to the home. Yet they can experience health problems deriving from everyday household tasks. The smoke inhaled when burning these fuels during cooking, for example, can cause respiratory disease and eye infections. Every year, more than 4.3 million people die from chronic obstructive respiratory disease due to exposure to indoor air pollution (World Health Organization, 2012). The heavy work involved in collecting firewood can also lead to back pain and exhaustion: the average Kenyan woman walks a distance of 3 km every other day carrying a weight of up to 30 kg on her back.

There is a need to promote clean, modern and decentralized sources of energy as an alternative to traditional biomass fuels. This How To Do Note provides guidance for IFAD country programme managers and for policy makers and development practitioners working to achieve this goal.

What is biogas?

Biogas is a renewable energy obtained from biodegradable organic matter such as kitchen, animal and human waste. Cost-effective biogas systems can stem methane emissions from livestock manure by recovering the gas and using it as an energy source. The organic matter is inserted into a sealed digester and, in the absence of oxygen, anaerobic bacteria consume the organic matter to multiply and produce biogas, which can be piped directly to a cooking stove.

Strategic context

Since May 2012, IFAD has been piloting a new biogas system, the Flexi Biogas system, which is a portable above-ground system that is simpler to use and less costly to build and operate than traditional fixed dome systems. The Flexi Biogas system does not require an agitator and its digester is not a sealed tank but simply a 6 m x 3 m plastic bag made of PVC tarpaulin and housed in a greenhouse tunnel.[1] Table 1 compares the Flexi Biogas and fixed dome systems at optimum production rates.

The Flexi Biogas system can contribute to climate change mitigation and adaptation by reducing the level of greenhouse gases (GHGs) released into the atmosphere. At present, 25 per cent of all CO_2 emissions in developing countries derives from the use of firewood and charcoal as principal sources of energy (mainly for cooking, lighting and heating). Taking into consideration the fact that an average household of 4-6 members can consume up to 7 kg of firewood per day, the adoption of biogas can save approximately 2,500 kg of firewood per household per annum.[2]

Women benefit from the Flexi Biogas system in a number of ways. For instance, there is less need to collect firewood each day and carry it long distances – a task that is usually undertaken by women. Where local conditions allow, the time saved can be used for women's capacity-building and empowerment, which can eventually raise living standards for the whole community.

The Flexi Biogas initiative is in keeping with IFAD's Environment and Natural Resource Management (ENRM) policy framework,[3] which is built around 10 core principles that need to be systematically promoted in IFAD projects. More specifically, in this case, the focus is on the second principle – recognition and greater awareness of the economic, social and cultural value of natural assets.

[1] For more information on how a portable biogas digester works, see http://www.ifad.org/pub/thematic/biogas.pdf. For a more general understanding of how biogas works, see *Livestock and Renewable Energy*, available at http://www.ifad.org/lrkm/factsheet/energy.pdf

[2] To date, the National Biodigester Programme in Cambodia has deployed over 22,500 biodigesters, which have saved a cumulative total of over 1,500 hectares of intact forest.

[3] See www.ifad.org/climate/policy/enrm_e.pdf

When biogas technology is integrated into a farming system, crop residues and other organic waste can be used to provide a clean source of energy and a high-quality, effluent organic fertilizer. When used instead of expensive chemical fertilizers, this by-product can represent an additional financial benefit for smallholder farmers.

Lessons from experience

Research and field surveys in Kenya have shown that traditional fixed dome systems are more expensive than the Flexi Biogas system and require 3-4 dairy cattle (table 1). Fixed dome systems also require ownership of land, as well as expertise in installing, maintaining and operating the system, if they are to be sustainable in the long term. The Flexi Biogas system, on the other hand, is proving to be a significantly better alternative to fixed dome systems. Annex I summarizes the key lessons learned from the pilot testing of portable biogas systems in Kenya and Rwanda.

Table 1: Comparison of fixed dome and Flexi Biogas systems

	6 m^3 Fixed dome	4 m^3 Fixed dome	6 m^3 Flexi Biogas
Cost (Kenya)	US$1 200	US$750	US$600
Cattle equivalents required (kg of manure/day)	3-4 (40 kg)	3 (30 kg)	1-2 (20 kg)
Gas production (cooking time)	1 000 l/day (120 minutes)	500-600 l/day (60 minutes)	1 000 l/day (120 minutes)

The pilots were conducted during the past two years with the collaboration of the following IFAD-supported projects: Smallholder Dairy Commercialization Programme in Kenya; Kirehe Community-based Watershed Management Project in Rwanda; Orissa Tribal Empowerment and Livelihoods Programme in India; and Participatory Smallholder Agriculture and Artisanal Fisheries Development Programme in São Tomé and Principe. Results obtained in Kenya and Rwanda are more comprehensive because the pilots here have been running for two years. Although the pilots in India and São Tomé and Principe have not been running as long, their results mirror those of Kenya and Rwanda. The four projects have been selected on the basis of their geographic spread, specific agroecological and cultural challenges, and engagement in national agriculture and rural development policy formulation processes that aim to scale up clean sources of renewable energy such as biogas systems. The following guidelines provide a methodology for more inclusive biogas initiatives.

Guidance for design and implementation

Step 1: Project identification

Identification of energy needs and beneficiaries. Individual/household demand for energy (cooking, lighting, heating, electrical appliances, etc.) needs to be calculated at this stage. Statistics suggest that in rural communities approximately 1 ton of firewood per person per year is consumed (about 2 kg per person per day). Given that biogas energy directly reduces the daily workload of rural women (e.g. water and firewood collection), women must be included among the beneficiaries from the beginning of the project. The criteria for selecting beneficiaries include:

- Very low income levels (unable to afford fees to join groups or associations)
- More than two-three hours daily spent collecting firewood
- At least one or two cows owned, or cow manure readily available for initial load

During the identification/planning phase, the following aspects must be considered:

- To ensure ownership, the beneficiaries should be motivated enough to provide labour during installation (leveling land, collecting manure and loading the digester)
- Individual beneficiaries must agree to pay a monthly users' fee (based on traditional energy costs and beneficiaries' income levels)
- Data need to be gathered on gas production levels and available feedstock

Why is the technology so well received by smallholder farmers?

The Flexi Biogas system has had a positive impact on farmers and their families, particularly women. Marie Goreti Twagirumukisa is one such farmer in Rwanda. She owns two cows, one of which was given to her by the government to thank her for having raised a child she had saved during the 1994 genocide. With the manure from her cows she can produce enough energy to cook for about three hours per day. A double-burner gas cooker was provided as part of the biogas kit. "I'm very happy with the biogas. It's easy to use and it saves me time as I don't need to collect wood anymore," she said. "I went to see a conventional system and thought it was too complicated for me to use, so I chose this one." Biogas also has health benefits for small farmers, because they no longer have to breathe in the smoke produced by burning wood inside their house.

Step 2: Project preparation

On-site requirements. Sufficient cow manure (minimum 200 kg) and an equivalent amount of water are needed to start up the biogas system.

Selecting location for biogas system installation. The digester needs to be installed mid-way between the kitchen and the livestock stall/grazing area. This should simplify the process of collecting fresh dung to feed the digester. Other requirements include the following:

- The digester should be placed above flood level. To minimize pressure leakage, the biogas system should be no further than 15 metres from the kitchen. The size of the plot required for the biogas unit is 7 m x 2 m.
- The system should be positioned on land that has been levelled and has a maximum incline of 5 per cent over the whole length so that the substrate inside the digester flows in one direction (cross-flow methodology).
- Solar radiation must not be blocked by trees. It is important to bear in mind that tree branches can break in harsh winds and damage the digester envelope and the greenhouse tunnel.
- Partners, extension service agents and M&E officers should gather information about institutions currently working on rural energy issues. Efforts should focus on identifying and incorporating structures already in place in order to complement, rather than compete with, ongoing biogas initiatives.

Step 3: Project implementation

Installation time. If sufficient labour is available locally, the digester can be installed within three hours. Connecting the biogas pipe to the household kitchen requires approximately one more hour, depending on the distance to the kitchen and the type of wall/roofing materials that the biogas pipe has to be passed through (bamboo, bricks, cement, earth, iron sheets, wood, etc.). A domestic Flexi Biogas system requires a minimum of 200 kg of (preferably fresh) cow manure and an equivalent volume of water. The digester must be filled up to the level of the inlet and outlet pipes, so that no air can enter and methane can be produced. Implementation plans should take into consideration: (i) the labour required to collect dung; (ii) the number of cattle (hence available amount of manure); and (iii) the way livestock is kept (stalled versus grazing).

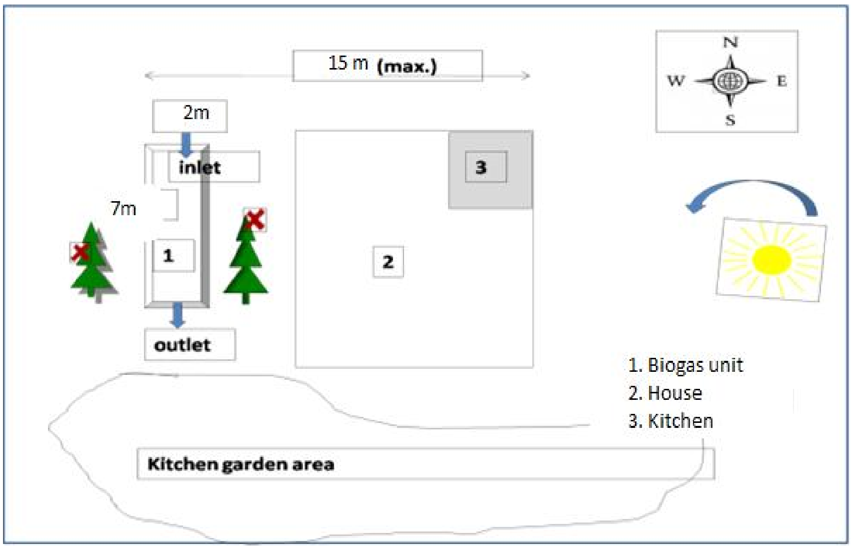
Participatory process. Beneficiary farmers can help to instal the biogas system,which is quite straightforward and simple.Children and young people can also take part, for example in levelling land. This participatory approach fosters a greater sense of ownership, meaning that farmers have a greater interest in operating, managing and troubleshooting the system.

Project cost. There are three Flexi Biogas models, each with a different gas capacity. Table 2 shows the costs (inclusive of a double-burner biogas stove and transportation and installation) for these models in Kenya.

Table 2. Cost of Flexi Biogas systems in Kenya

Model	People served	Daily capacity (m^3)	Cost (US$)
Domestic (DBG)	4-6	3.5	600
Total energy (BG6)	10+	9	810

Ultimately, the type of Flexi Biogas system chosen will depend on the number of people in the household and their daily cooking requirements. General data suggest that, in Africa, an average rural family of four to six people consumes 700-1,000 litres of cooking fuel per day (not including the charcoal used for heating).[4] Rural families that acquire Flexi Biogas can start saving on firewood and charcoal costs within a week of installation. By contrast, fixed dome biodigesters require about 30 days to produce combustile methane gas, given the longer retention time and higher operating temperature needed for the biodegradable material loaded in such systems to break down. These technical features have implications for the income levels of the beneficiaries, as the return on investment is significantly slower with fixed dome biodigesters than with Flexi Biogas.



Schematic diagram of the ideal layout for a biogas system

Field testing has shown that the medium model (BG5) generally meets daily cooking and heating requirements. One disadvantage is that the Flexi Biogas system does not support biogas lamps because the pressure fluctuates and is often too low. However, biogas lamps are also considered inefficient because they consume 100-200 litres of biogas per hour.

Transportation costs and import duties need to be factored into the total cost of the system. The technology is in its infancy and at present the technical service provider is operational only in the East Africa region.[5]

Key performance indicators. The IFAD Results and Impact Management System (RIMS) has recently been updated to integrate indicators related to climate change adaptation. The relevant indicators for technologies that have the potential to curb GHG emissions include:

- **Indicator 1.1.18**: number of individuals (disaggregated by sex) adopting technologies that reduce or sequester GHG emissions [at the output level]
- **Indicator 2.1.8**: number of tons of GHG emissions (CO_2e) avoided and/or sequestered [at the outcome level]

[4] In Kenya, rural communities spend an average of KES2,500-3000 (US$28-34) on low quality, health-damaging fuels (kerosene, charcoal and firewood), mainly for cooking and lighting.

[5] Several operations–- to be funded through IFAD's climate finance window, the Adaptation for Smallholder Agriculture Programme (ASAP) – are being planned in a number of countries, including Bangladesh, Cambodia, Mali, Nepal and Viet Nam.

Depending on the project specifications, other M&E indicators may be included to assess:

- How women and men use energy sources and what impact this has on a changing climate
- Adaptation strategies that have been developed in energy use
- Reduction in household energy costs and the workload of women and girls (e.g. time spent collecting firewood)
- Income-generation through activities deriving from the introduction of clean, decentralized sources of renewable energy
- Other agricultural production/processing activities and different feedstocks available.

Step 4: Project evaluation and feasibility

Capacity-building. There are various biogas technologies, for example fixed, floating-drum and tubular. Understanding each one and its comparative advantage in a given context is essential because each system has different requirements. Annex III contains a checklist for implementing Flexi Biogas systems manufactured by Biogas International Ltd.

Quality control systems and training mechanisms. Ideally, local technicians at the village level should be trained to ensure proper backstopping and troubleshooting. Annex II provides a detailed operation and maintenance checklist.

After-sales services and other indirect opportunities. As well as creating a need for after-sales services, biogas systems can produce a surplus of energy that can be used, for example, to power agricultural machinery, minimize post-harvest losses or support livestock development (e.g. chick breeding). Cost-sharing programmes can be established to create a sense of ownership. No systems should be given for free. Subsidies should be targeted to the poorest households with evident difficulties in purchasing biogas technology independently. Ultimately, monthly user payments must be designed to reflect users' current expenditure on conventional fuels.

Awareness-raising. Knowledge of the key operation and maintenance issues and the benefits of organic fertilizer (bioslurry) is important. Bioslurry is a good alternative to chemical fertilizers and can help to rebuild soil health. Home sanitation can also improve as a result of better management of livestock manure.

Conclusions and strategic recommendations

Rural communities face an energy gap. Many of their needs – such as household lighting, irrigation, refrigeration and post-harvest processing – remain unmet. Using the Flexi Biogas system, a family with just one or two cows can produce 60-100 kg of high-quality fertilizer, 2.8 m^3 of biogas for cooking and 12 litres of milk on a daily basis. IFAD's pilot project has opened up new channels and potential partnerships for implementing flexible biogas systems. The model used not only creates employment in rural areas but also addresses two of the challenges facing sub-Saharan Africa: nutrition security and availability of clean fuel. The following are key strategic recommendations for project design that includes biogas-related activities:

Strategic recommendations

1. Consider energy requirements at the farm level, where economic activities are often related to agricultural production and processing, fish farming, livestock rearing, water pumping or small-scale industries. Many of these activities require only small amounts of power (ranging from 100 watt to 3 kilowatt), yet related expenditures on low-quality energy sources (kerosene, firewood, charcoal and other traditional biomass sources) are high, in terms of the costs, time and labour involved.
2. Involve women and other under-represented groups (i.e. youth and children). Besides its detrimental environmental impacts, firewood burning is particularly harmful to women who often cook in areas with insufficient ventilation. Toxic gases (carbon monoxide and nitrogen oxide) and dust particles build up in unventilated areas and present a health risk for women. Gaining the

support of men and raising their awareness of the benefits that can accrue to their families as a result of women's economic empowerment can also be critical in lightening the load on women and, in the long-run, adjusting traditional patterns of workload distribution.

3. Adopt a value chain approach with a focus on organic fertilizer. The potential benefits of using bioslurry and, simultaneously, reducing dependence on chemical fertilizers are huge, yet this market remains largely untapped.
4. Consider how other livelihood systems would be affected by a large-scale promotion of biogas. Charcoal and firewood suppliers would clearly be affected given that – in most cases – charcoal and log producers are based in rural areas and are represented by agents in peri-urban and urban areas. A range of other agents (transporters, vendors, side-road traders, lorry drivers, etc.) would also be affected and would need to seek other livelihood opportunities.

Additional resources

- Flexi Biogas systems: Inexpensive, renewable energy for developing countries. IFAD Technical Brochure. Available at: http://www.ifad.org/pub/thematic/biogas.pdf
- Livestock Thematic Papers: Livestock and Renewable Energy. Available at: http://www.ifad.org/lrkm/factsheet/energy.pdf
- IFAD video interview with the designer of the Flexi Biogas system. Available at: http://www.youtube.com/watch?v=qh3mmgiybTw
- Scaling and commercializing mobile biogas systems in Kenya: A qualitative pilot study. Benjamin Sovacool. 2014. Available at: file:///C:/Users/k.sehgal/Downloads/Sovacool-et-al-RE-Kenya.pdf]
- Blog: A new biogas system for Rwanda. Available at: http://www.ruralpovertyportal.org/country/voice/tags/rwanda/rwanda_biogas
- Article in International Journal for Sustainable Development (Rural 21). Available at: http://www.rural21.com/english/current-issue/detail/article/flexibiogas-a-climate-change-adaptation-and-mitigation-technology-00001145/
- IFAD video: Rwanda – Cooking with Biogas. Available at: http://www.unmultimedia.org/tv/unifeed/2014/10/rwanda-cow-dung-biogas/

List of references

Appels, L., J. Baeyens, J. Degreve, and R. Dewil. 2008. Principles and potential of the anaerobic digestion of waste-activated sludge. Progress in Energy and Combustion Science, Vol.34, 755-781

Botero, R. and T.R. Preston. 1971. Feeding value of cattle manure for cattle. Journal Animal Science 30: 274-294

Dana, R. 2010. Micro-Scale biogas production: A beginners guide. National Sustainable Agriculture Information Service 1-10

Daxiong, Q., G. Shuhua, L. Baofen, and W. Gehua. 1990. Diffusion and innovation in the chinese biogas program. World Development, Vol. 18:4, 555-563

Garnett, T. 2009. Livestock-related greenhouse gas emissions: Impacts and options for policy makers. Environmental Science and Policy 12: 491-503

Ghimire, P.C. 2007. Final report on technical study of biogas plants installed in Pakistan. Asia/Africa Biogas Programme, Netherlands Development Organisation (SNV)

Hamilton, K. 2010. Scaling up renewable energy in developing countries: Finance and investment perspectives. Energy, Environment and Resource Governance Programme Paper, Chatham House, UK

Hamlin, A. 2012. Assessment of social and economic impacts of biogas digesters in rural Kenya. SIT Graduate Institute, ISP Collection

Hendriksen, G. 2011. Biogas support mission in Rwanda. Feasibility assessment. International Fund for Agricultural Development (IFAD)

International Finance Corporation (IFC). 2012. Household lighting fuel costs in Kenya. Market Intelligence Note, Issue 2 Dec. 2012

Kenya National Domestic Biogas Programme (KENDBIP). 2009. KENBIM domestic biogas construction training. Training manual. Nairobi: Kenya National Federation of Agricultural Producers.

Myles, R. 2008. Practical pictorial field guide on Grameen Bandhu biogas plant. Integrated Sustainable Energy And Ecological Development Association (INSEDA), India

Mariara, J.K. 2009. Global warming and livestock husbandry in Kenya: Impacts and adaptations. Ecological Economics 68: 1915-1924

Ochieng, F.X. 2010. Survey of Plastic Tube Digesters in Kenya: A field assessment survey of the Performance of Plastic tube digestors in Kenya. Study Report commissioned by GIZ and Energie Konsult Ltd

Thornton, P.K. M. Herrero. 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems (101), 113-127

World Health Organization (WHO). 2012. Household air pollution and health. Fact sheet No. 292, updated March 2014.

Annex I – Key lessons learned from pilot testing of portable biogas systems in Kenya and Rwanda

Criteria	Lessons learned
Social	▪ Illiterate farmers are able to install, maintain, operate and troubleshoot user-friendly technology. ▪ Enough gas is produced to fulfil daily cooking requirements of a family of 4-6 members. For example, *githeri* (a local kidney beans and maize dish) takes three hours to cook on a biogas stove. ▪ A regular supply of biogas reduces the task of gathering firewood, especially for women and girls. On average, about two hours a day are saved, providing more time for women and girls to engage in activities such as handicrafts, study, recreation, and rest, as well as livestock maintenance and other daily chores. ▪ Some farmers have chosen to use biogas to generate lighting at night so that children are able to study. This has led to the systematic inclusion of a solar panel and a battery in the Flexi Biogas kit. ▪ Farmers in Kenya and Rwanda have been able to extend their cropping area by 0.5 ha as a result of the additional time; increases in yield and income still need to be quantified. ▪ The biogas stove can be transferred indoors, making cooking during the rainy season easier. ▪ The Flexi Biogas system digests all of the organic substrate so produces no bad odour and does not attract flies. ▪ There is no need to own livestock in order to operate a biogas system because manure can be collected or purchased to kick-start the system. ▪ Increased social prestige and satisfaction result from energy self-sufficiency.
Economic	▪ Savings of US$44-50 per household per month have been achieved as a result of reducing the costs associated with firewood, charcoal and labour. Additional benefits – such as those deriving from improved health, the use of bioslurry instead of chemical fertilizers in home gardens, better nutrition from home gardens using bioslurry, and improved education of children – still need to be economically quantified. ▪ The Flexi Biogas system is affordable – half the cost of fixed dome systems in Kenya and Rwanda. ▪ Sourcing biogas tank material from China can drive costs down. (IFAD and Biogas International Limited undertook a mission to China in 2013 to identify suppliers and manufactures.) In Kenya, the cost of PVC tarpaulin is ten times higher and biogas tank material is unavailable. ▪ Design modifications (e.g. standardizing the biogas system length) have reduced manufacturing costs. ▪ Return on investment is relatively quick, with a cost-recovery period of less than one year. ▪ Jobs are created for young people.
Technical	▪ The system is light (50 kg) and easy to transport and install. Installation takes about four hours in total, compared with a minimum of 20 days (in Kenya) for the fixed dome system, which requires excavation, construction, and complex logistics. ▪ It is simple to use and easy to maintain (mainly to unblock). ▪ Sufficient biogas is produced within 7-10 days to meet household needs, compared with 20-30 days for the fixed dome system. This is in part due to the use of the "greenhouse tunnel", which raises the temperature, allowing bacteria to thrive, and thus speeds up biogas production. ▪ The system works with different types of organic feedstock available locally. ▪ The cross-flow methodology ensures that bioslurry is fully digested; there is no residual methane or pathogens. ▪ The system is expandable and can thus accommodate higher energy requirements as needs and incomes increase. ▪ Training technicians to install, operate and maintain the system is simple; a learning-by-doing approach is used. ▪ The Flexi Biogas system has several comparative advantages over other biogas digesters in rural areas. It is portable and can be transported easily to remote areas on a bike or donkey; it requires no skilled labourers (such as bricklayers); installation of the system only requires land to be levelled, rather than gravel, stones, bricks, sand and cement to be transported; and the system begins producing sufficient volumes of biogas faster than other systems.
Health	▪ Eliminating smoke from the kitchen reduces occurrence of chronic respiratory diseases and eye infections. ▪ Using bioslurry as a fertilizer in home gardening improves nutrition and diet diversification. ▪ Better management of livestock manure improves homestead sanitation. ▪ Cooking areas need to be properly ventilated to avoid carbon monoxide and nitrogen oxide poisoning.

Criteria	Lessons learned
Environmental	▪ Reducing firewood consumption by approximately 2 kg per person per day[6] leads to decreased deforestation and land degradation. ▪ Methane[7] emissions are reduced through better livestock manure management. ▪ Bioslurry is a good alternative to chemical fertilizers and supports improved soil health. ▪ Dependence on fossil fuels is reduced.
Policy	▪ Secure land tenure is not required because the system can be moved if necessary. ▪ The Flexi Biogas system is consistent with national rural energy strategies and embedded in IFAD project operations. It should be coupled with national rural energy subsidies to reduce unit costs. ▪ It is more difficult for Flexi Biogas to compete in areas where firewood is freely available. ▪ South-South initiatives have been promoted to influence policy dialogue on rural energy issues in developing countries. To date, IFAD has attended a number of events to raise the profile of Biogas International Ltd and the Flexi Biogas technology: - Convention on Biogas at Indian Institute of Technology (New Delhi, September 2012) - South-South Development Expo (Vienna, November 2012) - South-South Development Expo (Nairobi, October 2013) - South-South initiative to identify Chinese manufacturing partners (June 2013) - Workshop on Public-Private Partnerships in Biogas Sector (SNV) (Hanoi, November 2013) - International Conference on Sustainable Energies (Milan, December 2013) - Awareness campaigns: Well Told Story – Shujaaz FM in Kenya

[6] CO_2 emissions from firewood account for 25 per cent of global GHG emissions in developing countries.

[7] Methane has 22 times the heat capturing potential of CO_2 and is a more potent GHG.

Annex II – Operation and maintenance checklist

Identify problem	Cause	Solution
Is the digester being fed every day?	The digester should be fed daily with about 20 kg of manure and an equivalent amount of water.	▪ For the digester to function properly, the bacteria responsible for producing methane must receive a continuous supply of biodegradable material. If cow manure is not available, use kitchen garden waste or sewage
Is there a smell of gas?	A loose connection A damaged tap in the kitchen A hole in the plastic digester A faulty gas cooker knob	▪ Turn off the gas switch at the digester. Check all connections, starting with the taps in the kitchen up to the gas outlet, and the plastic pipes, joints, clamps and gate valves. ▪ If there is a hole in the digester, this can easily be repaired with sticking plaster or glue intended for reinforced PVC tarpaulin.
Is not enough gas being produced?	A loose connection A broken section of the pipe Water has collected in pipes, impeding gas flow	▪ Turn off gas switch at the digester. Check all connections, starting with the taps in the kitchen up to the gas outlet from the digester. ▪ Unblock the exhaust pipe by flushing water down and/or using a stick
Is there enough water in the trap bottle?	Evaporation can cause water level to fall below desired amount	▪ Check bottle periodically and add water when below required level.
Can you see a lot of gas in the digester but none or very little is available at the stove?	Not enough pressure inside the reservoir Accumulation of water	▪ Place sand bags (20 kg in total) on top and in the centre of the digester bag. ▪ Water evaporates and condenses in the gas pipes, which can block the gas from reaching the stove. The gas pipes need to be dewatered every two months by blowing water through to unblock them
Is there not much gas visible in the digester in the morning?	Forgot to turn off the gas switch at the stove. Outlet/overflow opening needs cleaning	▪ Remember to turn off switch after cooking
Is the colour of the biogas flame not clear blue?	Traces of hydrogen sulphide are higher than average (0.3 per cent)	▪ Change the hydrogen sulphide filter in the t-fitting of the security valve ▪ Filter replacement every six months is recommended.
Is a lot of soil accumulating on the sides of the digester?	Usually a long-term issue that is resolved by avoiding locations with very sandy soil or low land towards which rain washes a lot of soil. Composting pits not properly maintained or cleaned	▪ Make channels to divert rainwater or consider a rooftop that can harvest rainwater. Rainwater can be collected and used in the digester when mixing feed.
Is the slurry smelly?	Feeding digester too much or too often	▪ Slow down and reduce the quantity of substrate fed into the biogas system
Has the tunnel and/or piping collapsed?	Various reasons	▪ Call technical service provider. It is important that air does not permeate into the tunnel and that in cooler areas/seasons the tunnel is kept sealed
Is the tunnel zip broken?	Wear and tear	▪ Have repairs done locally, sewing machine needed

Annex III – Safety measures

Read carefully when installing or using a biogas system

1	Check the whole system regularly for leaks.
2	Provide ventilation around all gas lines.
3	Always maintain positive pressure in the system
4	Vent the roof at its highest point to allow lighter-than-air gases to escape
5	Ensure that gas lines drain water into condensation traps
6	Prohibit smoking or open flames near biogas digesters and gas storage tanks, especially when checking for gas leaks
7	Do not feed products such as antibiotics, liquid detergent, pesticides and hand soap or branches, soil, straw and twigs into the digester

Annex IV – Checklist for mainstreaming biogas systems in IFAD projects

	Preconditions	Notes	To consider	Checked
General user data	Knowledge of user's economic situation	▪ Number of people ▪ Income levels ▪ Literacy rates ▪ Land and space titles	Willingness, particularly of women farmers, to pay for biogas systems	
	Household structure	▪ Wall materials ▪ Earth/mud ▪ Wood/bamboo/iron sheets ▪ Cement/bricks ▪ Other, specify	Potential for installing a 50 watt solar panel to meet lighting needs	
	Crop residues	▪ Maize cobs used as a source of fuel ▪ Maize cobs are plentiful and supplied	Household's primary source of cooking fuel	
	Land use	▪ How much land is allocated to crops? – Food crops – Commercial crops – Trees	Types and quantities of vegetable waste	
	Livestock	▪ How are livestock kept? – Grazing system – Stalled ▪ Number of cows ▪ Number of goats ▪ Number of pigs ▪ Number of chicken ▪ Number of donkeys ▪ Number of rabbits	▪ How are livestock kept? – Time may be required to collect manure ▪ Broiler houses (number of chickens)	
	Water availability	▪ Dry season (months) ▪ Distance to source of water	Need a minimum of 20 litres per day	
Farm and domestic assets	Domestic	▪ Cooker/gas stove ▪ Refrigerator ▪ Radio ▪ Television		
	Transport	▪ Car/truck ▪ Motorcycle ▪ Bicycle ▪ Cart (animal-drawn)		
	Farm equipment	▪ Hoes/spades ▪ Shovel/ploughs ▪ Sprayer pump ▪ Water pump		

	Preconditions	Notes	To consider	Checked
Farm and domestic assets (continued)	Types of fuel used	▪ Fuel wood – Cost – Quantity ▪ Charcoal – Cost – Quantity ▪ Kerosene – Cost – Quantity ▪ LPG – Cost – Quantity ▪ Electricity – Cost – Quantity ▪ Dry manure – Cost – Quantity ▪ Saw dust – Cost – Quantity ▪ Other biomass residues		
	Fertilizer	• Traditional types and quantities of fertilizer • Crops fertilized • Familiar with organic fertilizer		
Functioning of biogas system	Potential sites for biogas plant	▪ Distance between biogas plant and livestock stall ▪ Distance between biogas plant and gas consumption site		
Functioning and maintenance	Manure	▪ Initial loading rate @ 500 kg ▪ Daily loading rate @ 20 kg (4 m^3 biogas model)	After the initial load, the system can run on any biodegradable matter without blocking or crusting (scum formation)	
	Vegetable/ kitchen waste	• Daily loading @ 5-10 kg (4 m^3 biogas model)	Use of a pulverizer or grinder is recommended	
	Water	▪ Initial loading rate @ 500 litres ▪ Daily loading rate	Any input is fed at a ratio of 1:1 (substrate:water)	
	Bioslurry	▪ Use ▪ Distance between biogas plant and vegetable garden		

Annex V – Pictorial field guide to implementing portable Flexi Biogas systems

STEP 1: Level the ground

STEP 2: Roll out the digester envelope

STEP 3: Position the tunnel

STEP 4: Load the substrate

Flexi Biogas system with surplus gas storage balloon

Flexi Biogas system with surplus gas storage balloon

Beneficiary farmers in Nakaru, Kenya

Annex VI – Economic and financial analysis

How to include benefits from provision of biogas and solar home systems in a cost-benefit analysis

Introduction

1. At present, about 85 per cent of energy consumed by rural communities is used predominantly for cooking and lighting purposes. Kerosene is the main energy source for lighting, while firewood and charcoal are mostly used for cooking. The combustion of these traditional biomass resources has significant negative health implications, such as chronic respiratory diseases and eye infections. Moreover, farmers in sub-Saharan Africa and South-East Asia spend a considerable amount of their income (US$10 to US$30 per month) on these low quality and health-damaging energy sources.

2. This section assesses the economic and financial viability of including portable and traditional fixed dome biogas systems (coupled with solar home systems) in IFAD's project design. It provides practical examples of how to quantify benefits resulting from investments in these type of devices at the household level.

3. The following cost-benefit analysis (CBA) – which is intended to serve as a guidance and decision-making support tool for IFAD country programme managers in-house and for policymakers and development practitioners – shows the payback period and cost-benefit ratios of specific renewable energy technologies. In this regard, it is important to distinguish the perspective of a commercial enterprise (driven by monetary profits) from that of a social enterprise (driven by blended values that are relevant for society at large); the latter governs the following report.

Benefits of access to biogas energy

4. Access to clean, decentralized renewable sources of energy such as biogas can have direct benefits for farm productivity, along with multiple other socio-economic benefits for the household, the community and the environment. However, these streams of intangible benefits[8] are generally difficult to quantify, and are hence omitted from a standard CBA.
5. The following analysis examines the Initiative for Mainstreaming Innovation (IMI)[9] project, funded by the Department for International Development (DFID) and managed through IFAD, in order to show that non-monetary benefits can give rise to income generation opportunities deriving from:
   - **Time saved** through not having to collect firewood and fetch water
   - **Reduction in sickness** among household members due to elimination of smoke caused by combustion of firewood and charcoal
   - **Increased agricultural productivity** through the use of organic fertilizer (bioslurry) and through the provision of fodder for livestock
   - **Increased income and nutrition** from home gardening and caring for small livestock
   - **Other intangible benefits**: reduction in malnutrition (especially in children), due to increased food availability and safer food preparation; improved school attendance by children; increased safety and security, especially for women and children.

Economic and financial analysis (EFA)

6. Most social enterprises recognize the importance of non-financial resultsyet traditional economic and financial analyses tend to focus only on costs and benefits that are quantifiable in monetary terms. The overarching objective of this EFA is to corroborate a transparent cash flow, bringing out the monetary benefits that accrue to smallholder farmers from the adoption of renewable energy technologies and

[8] Intangible benefits may refer to improved health (including more time to rest), better nutrition from home gardens due to bioslurry use, and reduced methane emissions from better livestock manure management.

[9] This note does not pretend to cover all possible cases but presents some useful examples of how this could be done, building on the DFID-funded IMI project: *Making Biogas Portable: Renewable Technologies for a Greener Future*.

resultant displacement of firewood, charcoal and kerosene. The direct financial benefit of biogas is therefore determined as a reduction in fuel expenses.

7. Data gathered from beneficiaries of IFAD's Smallholder Dairy Commercialization Programme (SDCP) in Nakuru (Kenya) indicate that average cooking fuel requirements for rural households amount to about 700-1,000 litres per day, while expenditure on firewood and charcoal for cooking is on average about 60 cents per day (US$17 per month). Collection of firewood – usually by women and children – takes about 3 hours daily, which could be spent on other productive activities or leisure and relaxation.[10]

8. In Kenya, households spend about US$10 per month on kerosene lamps (10 litres at 93 cents per litre). Two major disadvantages of kerosene use are health issues (due to inhalation and accidental burns) and volatile, rising fossil fuel prices. Biogas lamps can reduce fuel costs but consume about 100 litres of biogas per hour and are therefore considered inefficient. In view of this, the project combines the biogas technology with small solar home systems, comprising a solar panel (50 watt), an automotive battery (75 Ah), a charge controller, four lamps and a socket for a phone charger or an inverter, at a cost of US$300 (including installation fees).

9. Another benefit of using a biogas digester is the production of bioslurry, which has demonstrated high nutrient concentrations. This effluent can partially replace common chemical fertilizers and improve soil fertility and crop productivity, thereby increasing income levels.[11]

Cost of constructing fixed dome biogas digesters

10. Calculating the size of investment needed for the construction of a fixed dome system requires information on prices of raw materials, which – depending on country and location specificities (i.e. transport costs to rural areas) – may vary significantly. The investment and recurrent costs include all construction and operating costs of traditional fixed dome biogas systems, as follows:

   - *Investment costs*, which should take into account replacement costs at the end of the lifespan of the infrastructure, which will vary depending on the type of intervention (i.e. every 20, 15 or 10 years) and should be calculated as costs *per unit*

   - *Operation and maintenance (O&M) costs*, which should be considered over the time-frame of the economic analysis (i.e. 20 years), starting in the year following the construction of the unit. The following are baseline costs for installing a fixed dome biogas system in Kenya:[12]

Biogas digester size	*4 m^3*	*6 m^3*	*8 m^3*	*10 m^3*	*12 m^3*
Materials (US$)	405	550	645	690	785
Technical service fee including installation (US$)	285	345	345	460	460
Total cost (US$)	690	895	990	1,150	1,245

Source: Damwe Energy Services, Nairobi, Kenya

11. In addition to construction materials and technical assistance, farmers installing a fixed dome biogas system would need to arrange for the following:
   - Funds to purchase piping material and cover various contingencies (around US$57)
   - Excavation of the digester hole, as per contractor's instructions
   - Two unskilled labourers to assist in the installation

[10] The EFA calculates the opportunity cost of not having to collect firewood in monetary terms based on the average cost of unskilled labour per hour in Kenya.

[11] There is a recognized knowledge gap relating to the application methods and the effects of manure digestion, which is directly dependent on the amount of nutrients in the slurry. IFAD is working with SNV, and with FAO through the Climate and Clean Air Coalition, to identify agricultural practices that can handle bioslurry in a way that generates maximum benefits and reduces short-lived climate pollutants (SLCPs).

[12] For more information, see: http://www.ifad.org/pub/thematic/biogas.pdf. Full report available at: http://www.ifad.org/lrkm/factsheet/energy.pdf

Operation and maintenance (O&M) costs

12. For the daily operation and maintenance of a traditional fixed dome system, each farmer uses:
    - *Animal dung* – an initial load of 5 tons of cow manure and, subsequently, 60 kg per day. It is preferable (but not essential) to have cattle stalled in a zero-grazing system. If not stalled, human labour should be taken into account (i.e. time spent collecting dung and loading the system)
    - *Water* – initial load of 5,000 litres, plus 60 litres per day
13. Findings from the IMI project suggest that although traditional fixed dome biogas systems are reliable, in Kenya such systems are more expensive (US$1,200) and require 3-4 dairy cattle and ownership of land. In addition, expertise in operating and maintaining the biogas system is needed to ensure proper after-sales services and troubleshooting.

Cost of constructing Flexi Biogas systems

14. The Flexi Biogas system is a portable biogas technology designed and manufactured in Kenya by a private commercial enterprise, Biogas International Ltd.[13] In rural areas, the system has a comparative advantage over other biogas digesters as it is portable and can be transported easily on a bike or donkey to remote areas, does not require skilled labour (e.g. bricklayers) or construction materials (e.g. gravel, stones, bricks, sand and cement) and its installation only requires flattening of the ground.
15. Calculating the costs of a Flexi Biogas unit is straightforward because the entire system comes as one package. Additional costs to be taken into account are transportation and import duty costs, both of which are country-specific.
16. **Investment costs.** The current retail price of a medium-sized Flexi Biogas system with a capacity of 5.5 m^3 is US$600, including a single burner stove. A larger system with a total biogas capacity of 9 m^3 that can power agricultural machinery, such as water pumps or chaff cutters, costs US$825. This cost includes the system's three main components: (i) PVC tarpaulin biogas tank; (ii) greenhouse tunnel made of woven polyethylene plastic; and (iii) inlet and outlet pipes/joints (costs dependent on in-country availability).

Operation and maintenance (O&M) costs

17. For the daily operation and maintenance of Flexi Biogas systems, each farmer uses approximately:
    - *Animal dung* (cow manure) – initial load of 1 ton and, subsequently, 20 kg per day
    - *Water* – initial load of 1,000 litres, plus 20 litres per day (mixing ratio of dung:water is 1:1)[14]
18. Also to be considered are the following aspects:
    - The absorptive capacity of farmers to operate and maintain the system is high; therefore, there is limited need for skilled expertise to ensure proper operation of the technology
    - Training technicians to install the system and provide operation and maintenance services is simple and done through a learning-by-doing approach

Cash flow analysis

19. The following cash-flow analysis draws on data gathered over the past two years in Kenya and Rwanda. The EFA takes into account the fact that energy requirements can vary significantly, depending on the number of household members. Three options are assessed: (i) domestic Flexi Biogas (DBG) with a solar home system; (ii) medium-sized Flexi Biogas (BG5) with a solar home system; and (iii) traditional fixed dome digester with a solar home system.

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[13] Since May 2012, this new generation of biogas systems has been piloted in three IFAD projects: Smallholder Dairy Commercialization Programme (SDCP) in Kenya, Kirehe Community-based Watershed Management Programme (KWAMP) in Rwanda, and Orissa Tribal Empowerment and Livelihoods Programme (OTELP) in India.

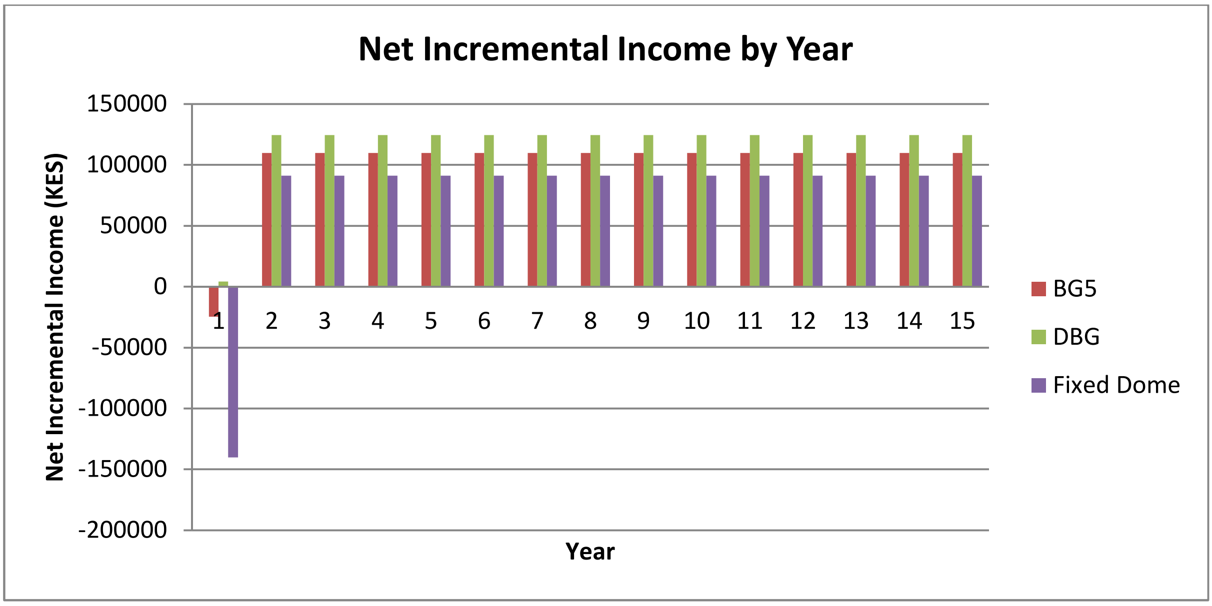
[14] In Kenya, one cow yields 10-20 kg of dung per day. A domestic system (4 m^3) would require 1-2 buckets (of 20 kg each) per day, depending on external temperatures. The warmer the temperature, the less dung required. A larger system (10 m^3) would require 3-4 buckets per day.

20. In the analysis, the underlying assumption is that rural households consume about 2.3 kg of firewood per day, and that only 70 per cent of this daily firewood consumption can be offset. This is because firewood savings are not constant throughout the year. Firstly, biogas production tends to decrease during the rainy season, so farmers have to use firewood as well in order to meet their cooking needs. Secondly, the hydraulic retention time of the biogas digester – the time it takes for the bacteria inside the digester to stabilize and produce biogas at full potential – is 30-45 days. Therefore, once the biogas system has been installed, farmers also need to use firewood in conjunction with the biogas being produced for the first month. Lastly, the EFA does not consider cultural cooking habits – for example, the preparation of *chapatti* and *githeri* (local kidney beans and maize dish). On occasion, women prefer using firewood in order to give a "smoked" taste to a food item.
21. The prevailing daily wage for unskilled labour (including family labour) amounts to 75 Kenyan Shillings (KES). Farmers usually dedicate 45 hours/month (approximately 1.5 hours per day) to operate and maintain the biogas system. This mainly relates to the collection of dung to feed the digester. Although the EFA assumes that cows are kept in zero-grazing systems and therefore manure is free, a minimum cost per kilogram is assigned to manure in order to show that even when manure is purchased, a biogas system is still an economically viable option.[15]

Results

22. All three cash-flow analyses include solar home systems and are based on certain assumptions, such as a reduction in direct fuel expenses, readily available cow manure and the possibility of generating revenue through the sale or adoption of bioslurry. One other important aspect to consider is the fact that integrated biogas systems reduce the release of harmful GHGs such as methane and nitrous oxide. This amount needs to be quantified for optimal evaluation of the cost-efficiency of any biogas technology.

[15] The EFA does not consider the costs of maintaining cattle (such as fodder, water and veterinary services).



23. The graph shows that the payback period or break-even point is 9 months for the domestic Flexi Biogas model, 14 months for the medium-sized Flexi Biogas and 22 months for the fixed dome digester.

		Year														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BG5	Benefits	102 600	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449	179 449
	Tunnel					40					40					40
	Costs	127 214	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531	69 531
	Net incremental income (KES)	(24 614)	109 917	109 917	109 917	109 877	109 917	109 917	109 917	109 917	109 877	109 917	109 917	109 917	109 917	109 877
	NPV @ 12 628 471															
	B/C 2.2	1 153 585	525 071													
DBG	Benefits	102 628	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485	179 485
	Tunnel					40					40					40
	Costs	98 266	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016	55 016
	Net incremental income (KES)	4 363	124 469	124 469	124 469	124 429	124 469	124 469	124 469	124 469	124 429	124 469	124 469	124 469	124 469	124 429
	NPV @ 12 740 461															
	B/C 2.8	1 153 824	413 321													
Fixed Dome	Benefits	107 358	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476	188 476
	Costs	247 404	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402	97 402
	Net incremental income (KES)	(140 046)	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074	91 074
	NPV @ 12 413 938															
	B/C 1.5	1 211 260	797 322													

Concluding remarks

24. A set of assumptions underpin the outcomes of the EFA and require contextualization, otherwise they can be misleading. For example, the number of days saved from illness is valued in monetary terms, although it is difficult to monetize health benefits. The EFA considers the trickle-down benefits from time saved (e.g. by not having to collect firewood) as benefits dependent on the local environment – some households will use the time saved for productive activities, others for leisure (e.g. more time spent with children) and rest. In Nakuru (Kenya) for instance, many farmers rear chickens and generate an additional revenue stream through their sale.

25. IFAD projects that address energy access at the household level must take into account the agricultural value chain. Experiences around the world show that biogas technology can replace diesel fuel to power agricultural machinery (water pumps, rice milling machines, chaff cutters, etc.) thus boosting agricultural production and stimulating related value chains. This is significant, given that energy requirements in rural communities are largely unmet, mostly in areas related to household lighting, irrigation, refrigeration and post-harvest processing.

26. The EFA shows that, with appropriate financing mechanisms in place, and where baseline surveys indicate that the adoption of biogas is demand-driven and there is a willingness to pay, using biogas in an integrated farming system (with just one or two cows) can provide 60-100 kg of high quality fertilizer, 2.8 m^3 of biogas for cooking and lighting needs, and 12 litres of milk on a daily basis,. IFAD's pilot project has opened up new channels and potential partnerships for globally testing the 'One Cow model'. In Rwanda, the Kirehe Community-based Watershed Management Programme (KWAMP) is promoting a model comprising: two cows; a biogas system and a solar component including a 50 watt panel; a 75 Ah automotive battery; a charge controller; 5 lamps and a socket for phone charger or inverter. The model not only creates employment in rural areas but addresses two of the major problems in sub-Saharan Africa –nutrition and availability of clean fuel.

Detailed EFA tables

Domestic Flexi Biogas (DBG) with solar home system

1.1 Input - Output budget		Price	*Months*											
	Unit	(KES)	1	2	3	4	5	6	7	8	9	10	11	12
Benefits														
Firewood savings	kg	9		12	24	23	23	23	34	34	34	34	23	23
Charcoal savings	kg	48		2	4	6	6	6	6	6	6	6	6	6
Chemical fertilizer savings	kg	90			120				240	240	240	240		
Kerosene savings	lt	83		164	164	164	164	164	164	164	164	164	164	164
Costs														
Hardware components	lumpsum	39 974	1											
Unskilled labour	persday	600	4											
Solar panel (45 watt)	no.	29 980	1											
O&M costs														
Manure	kg.	2	1 000	580	580	580	580	580	580	580	580	580	580	580
Family labour	hrs	75	45	45	45	45	45	45	45	45	45	45	45	45
Automative battery	no.	5 214	1											

1.2 Inflow-Outflow budget (KES)	*Months*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Benefits												
Firewood savings		105	210	196	196	196	294	294	294	294	196	196
Charcoal savings		99	197	296	296	296	296	296	296	296	296	296
Chemical fertilizer savings			10 800				21 600	21 600	21 600	21 600		
Kerosene savings		13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638
Total benefits		13 842	24 845	14 130	14 130	14 130	35 828	35 828	35 828	35 828	14 130	14 130
Costs												
Hardware components	39 974											
Unskilled labour	2 400											
Solar panel (45 watt)	29 980											
Sub total installation costs	72 354											
O&M costs												
Manure	2 086	1 210	1 210	1 210	1 210	1 210	1 210	1 210	1 210	1 210	1 210	1 210
Family labour	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375
Automative battery	5 214											
Sub total O&M costs	10 675	4 585	4 585	4 585	4 585	4 585	4 585	4 585	4 585	4 585	4 585	4 585
Net income (KES)	(83029)	9257	20261	9545	9545	9545	31243	31243	31243	31243	9545	9545
Payback period	(73 772)	(53 511)	(43 966)	(34 420)	(24 875)	6 368	37 612	68 855	100 098	109 644	119 189	119 189

Medium-sized Flexi Biogas (BG5) with solar home system

1.1 Input - Output budget	Unit	Price (KES)	Months 1	2	3	4	5	6	7	8	9	10	11	12
Benefits														
Firewood savings	kg	9		12	24	23	23	23	34	34	34	34	23	23
Charcoal savings	kg	48		2	4	6	6	6	6	6	6	6	6	6
Chemical fertilizer savings	kg	90			120	-	-	-	240	240	240	240	-	-
Kerosene savings	lt	83		164	164	164	164	164	164	164	164	164	164	164
Costs														
Hardware components	lumpsum	55 616	1											
Unskilled labour	persday	600	4											
Solar panel (45 watt)	no.	29 980	1											
O&M costs														
Manure	kg.	2	1 000	1 160	1 160	1 160	1 160	1 160	1 160	1 160	1 160	1 160	1 160	1 160
Family labour	hrs	75	45	45	45	45	45	45	45	45	45	45	45	45
Automative battery	no.	5 214	1											

1.2 Inflow-Outflow budget (KES)	Months 1	2	3	4	5	6	7	8	9	10	11	12
Benefits												
Firewood savings		104	208	194	194	194	291	291	291	291	194	194
Charcoal savings		99	197	296	296	296	296	296	296	296	296	296
Chemical fertilizer savings			10 800	-	-	-	21 600	21 600	21 600	21 600	-	-
Kerosene savings		13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638	13 638
Total benefits		13 841	24 843	14 128	14 128	14 128	35 825	35 825	35 825	35 825	14 128	14 128
Costs												
Hardware components	55 616											
Unskilled labour	2 400											
Solar panel (45 watt)	29 980											
sub total installation costs	87 996											
O&M costs												
Manure	2 086	2 419	2 419	2 419	2 419	2 419	2 419	2 419	2 419	2 419	2 419	2 419
Family labour	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375	3 375
Automative battery	5 214											
sub total O&M costs	10 675	5 794	5 794	5 794	5 794	5 794	5 794	5 794	5 794	5 794	5 794	5 794
Net Income (KES)	(98671)	8046	19049	8333	8333	8333	30030	30030	30030	30030	8333	8333
Payback period	(90 625)	(71 576)	(63 242)	(54 909)	(46 576)	(16 545)	13 485	43 515	73 546	81 879	90 212	98 546

Fixed dome biogas digester with solar home system

1.1 Input - Output budget	Unit	Price (KES)	Months 1	2	3	4	5	6	7	8	9	10	11	12
Benefits														
Firewood savings	kg	9			12	24	34	34	34	34	34	34	34	34
Charcoal savings	kg	48			2	4	6	6	6	6	6	6	6	6
Chemical fertilizer savings	kg	90			126	0	0	0	252	252	252	252	0	0
Kerosene savings	lt	83		164	164	164	164	164	164	164	164	164	164	164
Costs														
Hardware components	lumpsum	112 970	1											
Technical service fee	persday	4 345	6											
Unskilled labour	persday	600	10											
Solar panel (45 watt)	no.	29 980	1											
O&M costs														
Manure	kg	2	5000	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Technical support	hrs	543			2				2					2
Family labour	hrs	75	45	45	45	45	45	45	45	45	45	45	45	45
Automative battery	no.	5 214	1											

1.2 Inflow-Outflow budget (KES)	Months 1	2	3	4	5	6	7	8	9	10	11	12
Benefits												
Firewood savings		0	104	208	291	291	291	291	291	291	291	291
Charcoal savings		0	99	197	296	296	296	296	296	296	296	296
Chemical fertilizer savings			11340	0	0	0	22680	22680	22680	22680	0	0
Kerosene savings		13638	13638	13638	13638	13638	13638	13638	13638	13638	13638	13638
sub total benefits		13638	25181	14043	14225	14225	36005	36005	36005	36005	14225	14225
Costs												
Hardware components	112970											
Technical service fee	26070											
Unskilled labour	6000											
Solar panel (45 watt)	29980											
sub total installation costs	175020											
O&M costs												
Manure	10428	4380	4380	4380	4380	4380	4380	4380	4380	4380	4380	4380
Technical support			1086				1086					1086
Family labour	3375	3375	3375	3375	3375	3375	3375	3375	3375	3375	3375	3375
Automative battery	5214											
sub total O&M costs	19017	7755	8841	7755	7755	7755	8841	7755	7755	7755	7755	8841
Net income (KES)	(194037)	5883	16340	6288	6470	6470	28064	29150	29150	29150	6470	5384
Payback period	(188154)	(171814)	(165526)	(159056)	(152586)	(124522)	(95373)	(66223)	(37073)	(30603)	(25219)	(19836)

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