

African Biodigester Component

Lessons Learnt from Biogas Development Programmes

SEE – Clean Cooking
African Biodigester Component

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Caroline Makonnen, the Knowledge Management Advisor, provided the day-to-day guidance to the IAL and the Task Team Leader Ashington Ngigi.

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Funded by the Dutch Ministry of Foreign Affairs (DGIS), the Danish International Development Agency (DANIDA) and the European Union (EU), the African Biodigester Component (ABC) in Kenya aims at facilitating a shift of the biodigester market from its pioneering to the expansion phase where 20,017 small scale ((0 to 50m3) and 250 medium-sized (50 to 500m3) biodigesters will be constructed/ installed. This will be achieved by means of a well-balanced mix of demand-side, supply side, financing and enabling environment interventions, geared at boosting demand and supporting small scale and medium scale biodigester companies in acquiring more clients.

The component is implemented by a consortium between GIZ and SNV (the Netherlands Development Organisation) in cooperation with the Africa Bioenergy Partnership Limited (ABPL - ex-Kenya Biogas Programme).

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List of abbreviations and acronyms

ABC	African Biodigester Component
ABC-K	Association of Biogas Contractors of Kenya
ABPL	Africa Bioenergy Partnership Limited
ABPP	Africa Biogas Partnership Programme
BCEs	Biogas Construction Enterprises
BDS	Business Development Services
BIO-NET	Biogas Stakeholders Network
BMO	Business Member Organization
CBO	Community Based Organization
DGIS	Dutch Ministry of Foreign Affairs
EnDev	Energising Development Partnership Programme
EPRA	Energy and Petroleum Regulatory Authority
EU	European Union
FAO	Food and Agriculture Organization
GIZ	German Organization for Development Cooperation
GWh	Gigawatt hour
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
INGO	International Non-Governmental Organization
IRENA	International Renewable Energy Agency
KCIC	Kenya Climate Innovation Center
KEBS	Kenya Bureau of Standards
KENFAP	Kenya Federation of Agricultural Producers
KEPSA	Kenya Private Sector Alliance
KEREA	Kenya Renewable Energy Association
KICD	Kenya Institute of Curriculum Development
KIRDI	Kenya Industrial Research and Development Institute
KNQA	Kenya National Qualifications Authority
KVA	Kilovolt-amps
KW	Kilowatt
MFI	Micro Finance Institution
MoE	Ministry of Energy
MW	Megawatt
NGO	Non-Governmental Organization

NITA	National Industrial Training Authority
PSDA	Private Sector Development in Agriculture
RBF	Result Based Financing
REREC	Rural Electrification and Renewable Energy Corporation
RVO.nl	Netherlands Enterprise Agency
SNV	Netherlands Development Organization
TVET	Technical and Vocational Education and Training
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

Executive summary

The Energising Development (Endev) programme is a strategic partnership of likeminded donors and partners to promote energy access. It is co-managed by GIZ and Netherlands Enterprise Agency (RVO.nl). One of the two core components of Endev is promoting access to modern cooking solutions including biogas technologies. The target beneficiaries are households, social institutions, and small businesses – with great emphasis on rural and peri-urban areas. Under this component falls the Endev Africa Biodigester Component (ABC), which aims at facilitating a shift of the biodigester market in Kenya from its pioneering to the expansion phase as Kenya is the most mature market for biodigester in East Africa. Vivid companies, government support and technical institutes are supporting the deployment of biodigester technologies and services adapted to local market conditions. A key financial instrument in the deployment of ABC is a Result-Based Finance (RBF) facility for small-scale biodigesters, to not only catalyse the installation of 20,017 small-scale biodigesters, but to also enable suppliers of small-scale digesters to achieve economies of scale and drive sustainability.

In this context, the ABC Project has determined that knowledge management and dissemination for the biogas sector in Kenya is segmented, not systematic and there is no centralised knowledge management platform/ repository for sector data.

Different stakeholders implement projects/ programmes in parallel and the coordination of knowledge management is limited and further the knowledge created, or lessons learnt are often scattered and not readily available for sector players.

It is necessary to collect, collate and manage sector information in a manner that adds value to the stakeholders and facilitates the achievement of scale through lessons learnt, business models and best practice. Furthermore, pitfalls and failures from the past must be avoided through institutional memory that is well documented.

ABC Project has therefore undertaken this detailed inventory of existing and past biogas sector support programmes/ interventions in Kenya, the region/ sub–Saharan Africa and other Countries.

The results from this study provides summary of notable best practices across the reviewed biogas sector initiatives globally. These includes;

Project management and origination

- Involvement of all key stakeholders in design and planning builds in stakeholder interests and relevance, as stakeholders jointly prioritize their needs.
- Selection of Implementing Agencies should pay more attention to integrity of parties, beyond formal due diligence (soft due diligence).
- Exit strategy must be in place design stage and developed in participatory approach.

Institutionalization and coordination

- Public Private Partnership in project design and implementation greatly contributes to project success.
- Selection of Implementing Agencies should pay more attention to integrity of parties, beyond formal due diligence (soft due diligence).

Market access & uptake

- Linking community based organized organizations like dairy, tea and coffee cooperatives with BCEs and local finance institutions will catalyze uptake.
- Tying payments to functionality of bio digesters increases accountability, acceptability and minimizes nonfunctional units.

Post project and after sales support

- Establishing customer service centers (CSC) for monitoring digester construction, functionality and after-sales service provision can guarantee technical performance and sustained market confidence, hence growth.
- This set of knowledge and the associated literature will form the baseline repository to which further knowledge may be added within a knowledge management context. The scope and methodology used in this study are described below.

Problem Statement

This study report aims to capture biogas lessons learnt to better address the biogas sector development challenges that include different stakeholders implementing projects in parallel, limited coordination in terms of knowledge management is limited, scattered lessons learned and lack of centralized knowledge management platform/ repository for sector data/ information.

Key Tasks and outputs

Prepare detailed inventory of existing and past biogas sector programs/ interventions
Review all the existing literature on past and present studies on biogas interventions
Establish lessons learned from these interventions
Develop recommendations on best practices.

Approach, Methodology and Workflow

Step 1: Creating inventory of biogas programs, initiatives, studies and reports worldwide
Step 2: Referencing, categorization and bucketing of information and data gathered
Step 3: Literature review
Step 4: Analysis and interrogation based on specific parameters
Step 5: Drawing of lessons learned and identification of best practices
Step 6: Bundling of lessons learned to generate knowledge framework.

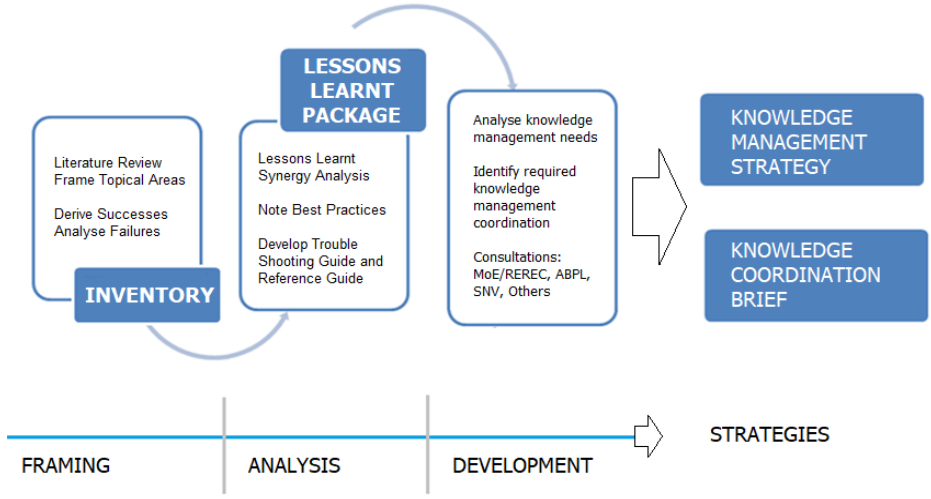


Figure 1: Execution Workflow

Key Lessons Learnt topics

In conducting the analysis of lessons learned per project, the study approach is divided into two main elements i.e., technical and non-technical elements. Further, for each element there are sub elements to brings out the lessons learnt in the specific subject matter components as captured in table below.

TECHNICAL	NON-TECHNICAL
Technology Efficacy and Affordability	Project management and origination
Training and Capacity Assessment	Access to Finance and Financing Models
After sales Operation and Maintenance	Market Access and Business models
Policies, Standards and Regulations	Institutionalization and Coordination

Table 1: Lessons Learnt Classification

Technical Analysis and Interrogation

The technical analysis for biogas involves interrogation on technology, efficacy and affordability, training and capacity, after sales operation and sustainability and policies, standards and regulations. Innovations should be designed, with affordability built in, to deliver the highest quality biogas for the lowest possible cost. Training and capacity encompass a whole range of activities designed to empower biodigesters installers and provision of business development skills. After-sales operations and sustainability analysis the support mechanism available that the biodigester installers and or company gives to its clients after they've purchased a biogas product. This may refer to biogas maintenance, warranties, bio slurry management and use etc. Lastly, the analysis seeks to explore the policy and institutional frameworks including regulations and standards in promoting biogas development in a particular country.

Non-Technical Analysis and Interrogation

The non-technical analysis includes interrogation on project management and origination, access to finance and financing models, market access and business models and institutionalization and coordination. Effective project management requires careful planning and strategizing from the very beginning. However, this kind of work relies on essential project origination knowledge and skills in project feasibility and formulation of objectives, implementation strategy and reviews. Access to finance and financing models looks at the role and involvement of banks and MFIs in promoting biogas through credit facility, existence of biogas financing options such as subsidy, result based and carbon financing. Market access and business models analysis the involvement of community-based groups and stakeholders, prevalent business models and strategies for awareness creation. The Institutionalization and coordination look at partnerships and industry organization (Existence of associations and niche groups), public and private sector involvement and the level of coordination and collaboration among stakeholders

Lessons Learnt Geographical Coverage

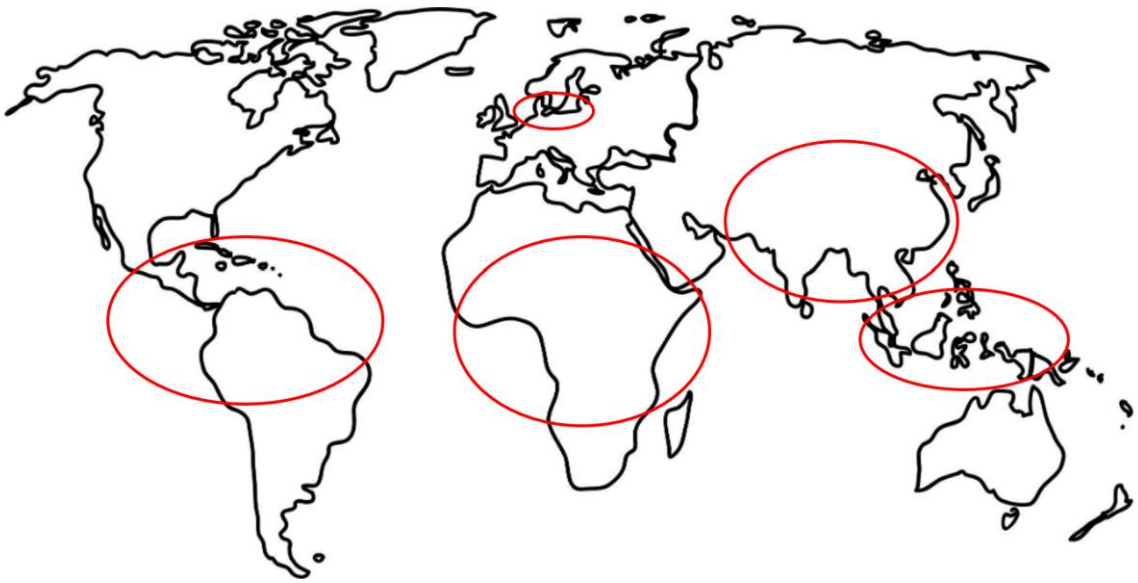


Figure 2: Geographical Coverage by Countries

General regions covered by this study

Priority in this study

Europe (2)	America and Canada (1)	Asia (8)	Latin America (2)	Africa (15)
Netherlands	California	India	Brazil	East Africa Kenya, Rwanda, TZ, UG
Germany		Cambodia, Vietnam , Indonesia, Pakistan	**Mexico**	West (Burkina Faso), Niger, Nigeria, Mali, Togo)
		China		Southern (Zambia, Malawi, Zimbabwe, SA)
		Nepal		Central (Equatorial Guinea)
		Japan		North Ethiopia

Table 2: Countries covered in this study

The countries marked in red were found to have more publicly available information on biodigesters than others.

Overview of Biogas Technology Value Chain

Definition of Terms

Renewable energy:

Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed

Bioenergy:

A form of renewable energy that is derived from organic matter, including wood, agricultural products, organic wastes, municipal solid waste and other living cell materials

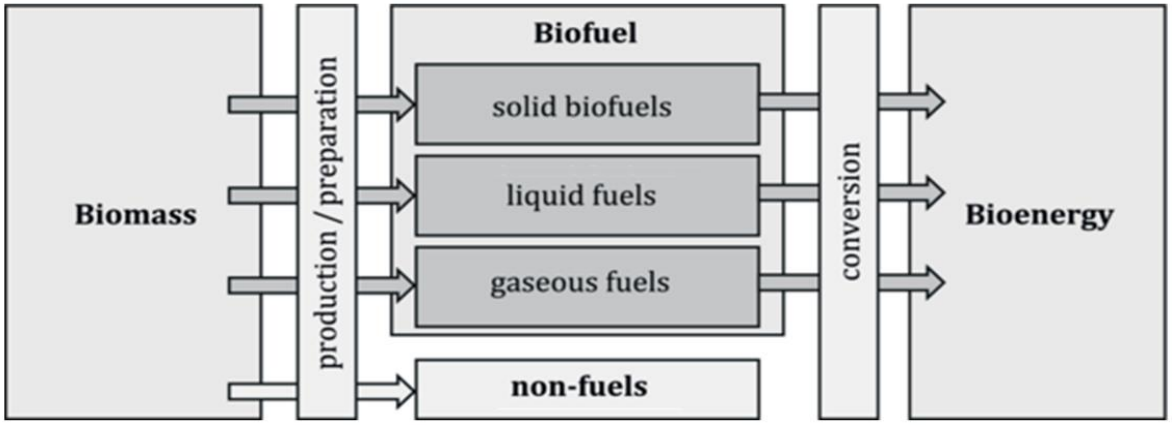


Figure 3: Bioenergy Flow Diagram

Biofuel:

A fuel that is produced through contemporary biological processes

Biogas:

A type of biofuel that is naturally produced from the decomposition of organic matter in an anaerobic (absence of oxygen) environment

Biomethane:

Biofuel that has been through a purification process which removes any CO2, hydrogen sulphide, and water from the original biogas composition

Bio slurry:

The liquid discharged at the bio-digester outlet after gas has been tapped off.

Biogas and Biomethane Value Chain

The production and use of biogas and biomethane embody the idea of a more circular economy, bringing benefits from reduced emissions, improved waste management and greater resource efficiency. Biogas and biomethane also provide a way to integrate rural communities and industries into the transformation of the energy sector.

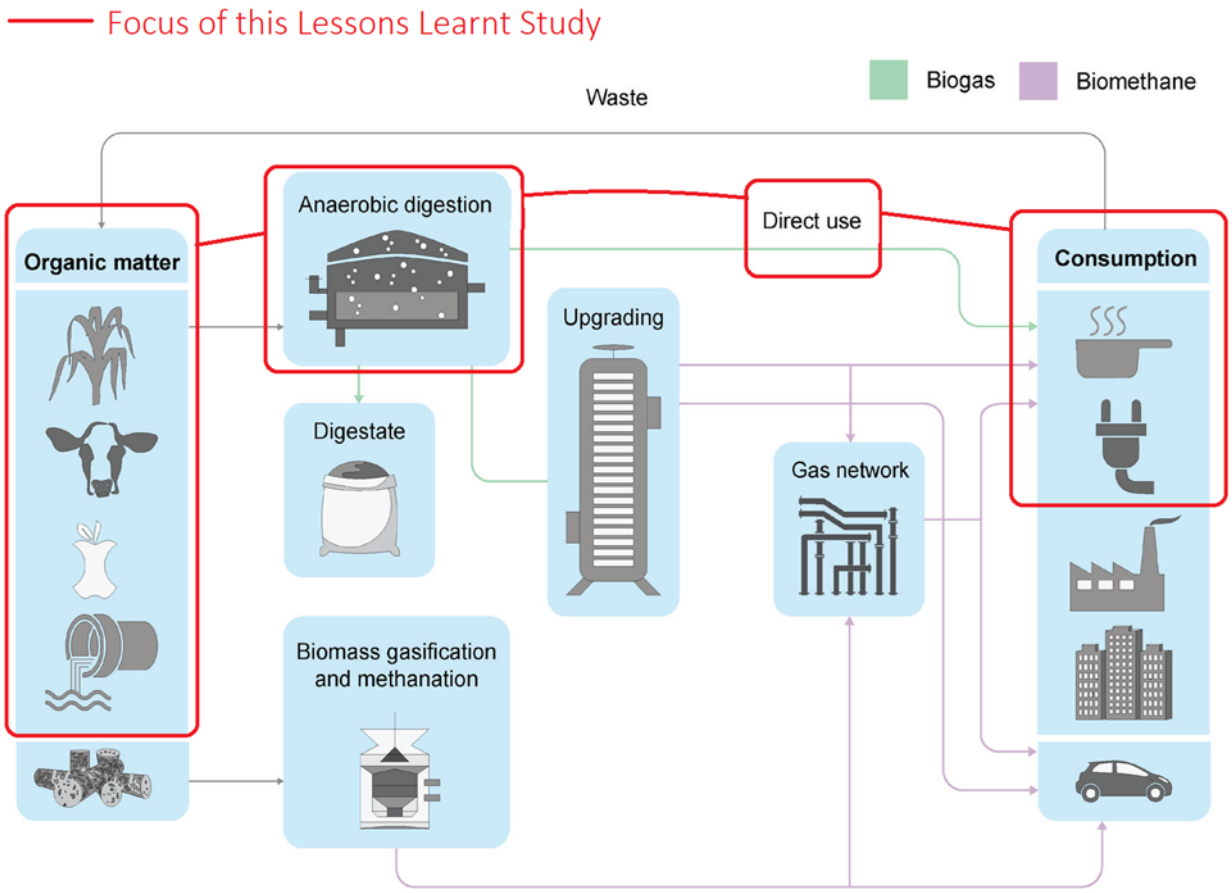


Figure 4: Biogas and Biomethane Value Chain[1]

Technology Types and Common Designs

There are mainly three configurations of anaerobic digesters as shown in the figures below; A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. Floating-drum plants consist of an underground digester and a moving gas-holder. The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. A balloon plant consists of a heat-sealed plastic or rubber bag (balloon), combining digester and gas-holder. The gas is stored in the upper part of the balloon. The inlet and outlet are attached directly to the skin of the balloon.

[1] RG GI002 PP5

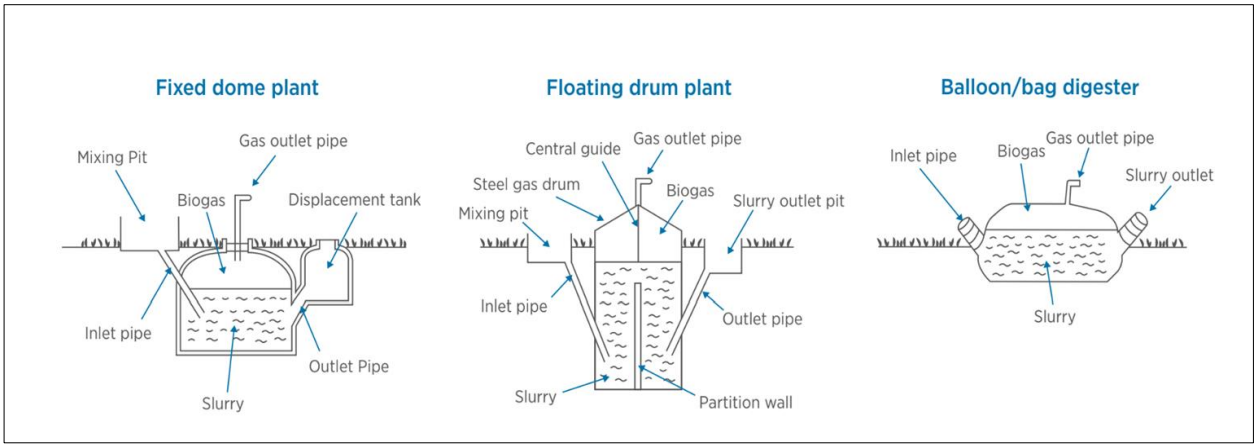


Figure 5: Technology Types and Common Designs2 (Source: IRENA, 2016b)

Biogas Benefits and Impacts

Biogas is an eco-friendly and renewable source of energy that has several advantages. It doesn't pollute the environment and reduces soil, water, and air pollution. It produces organic manure as a byproduct and is a low-cost method to produce energy. Biogas encourages a circular economy and generates employment, especially in rural areas. Biogas plants significantly curb the greenhouse effect and help cut reliance on fossil fuels. Biogas systems recycle organic waste into renewable energy and soil products while reducing GHG emissions. The figure below summarizes the benefits of biogas under energy, environment and food security.

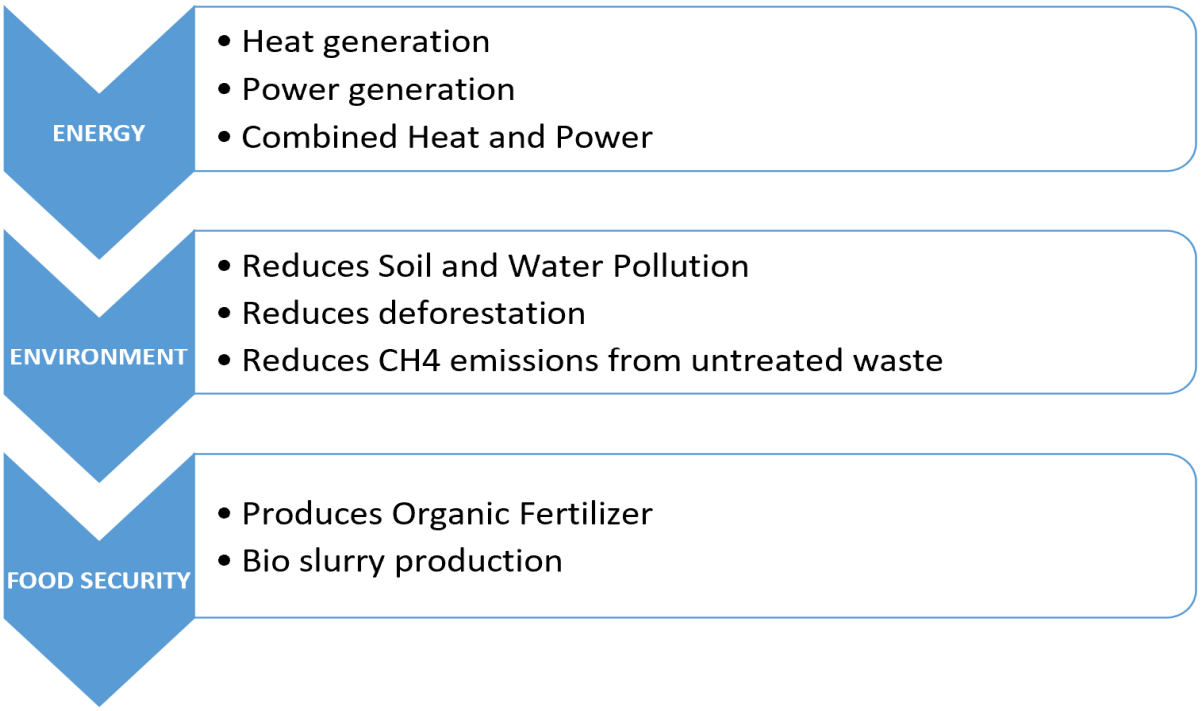


Figure 6: Biogas Benefits and Impacts of Biogas

[2] RG GI006 PP10

Biogas Sector Key Stakeholders

These stakeholders are drawn from institutions and programmes in the frontline in promoting biogas development in the country. They are further classified into two i.e., government led ministries and departments and non-government organizations as shown in the table below.

Government Ministries and Departments	Non-government Stakeholders
• Energy	Academia: Training Institutes
• Agriculture	Development Partners and UN bodies
• Environment	Non-Governmental (NGOs and Community-Based Orgs. (CBSOs)
• Trade	Financial Institutions and Cooperatives
• Labour	Private Sector: Industry, Professionals, Technicians, Consultants
• Social Inclusion and Gender	Professional Bodies, Business Member Organizations (BMOs)
• Waste Management	Farmer Organisations and Aggregators
• Forestry and Natural Resources	Research and Development Institutes
• Regulatory Authorities	
• Standards Bodies	
• Statistical Bodies	

Table 3: Governmental and Non-governmental biogas stakeholders

Operationalization and troubleshooting

Common problems encountered during digester operationalization requiring mitigation during deployment and use include:

- Scum formation
- Cracks in the bio digester dome
- Leakage from gas pipes and fittings
- Inadequate bio digester feeding
- Improper feed composition i.e. wrong Carbon-Nitrogen ratio (C/N)
- Ammonia Content- To avoid biogas plant difficulties, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L (Source: KENPRO report Oct 202).
- Volatile fatty acids (VFAs), or organic acids and include acetic acid, propionic acid, and butyric acid, valeric acid, caproic acid responsible for decomposing organics and generating gases.

Global Biogas Sector & Growth Learnings

Bioenergy Potential – Global Overview

Bioenergy accounts for roughly one-tenth of world total primary energy supply today (IEA report). Bioenergy remains by far the largest renewable heat source and is expected to lead growth with a 12% (1.7 Exajoule) increase during 2019-2024. Bioenergy is expected to lead renewable heat expansion, its use rising 12% during 2019-24, with almost two-thirds of this increase in industry.

Biogas and Biomethane within Global Bioenergy Consumption

The graph below shows that at the moment, biogas and biomethane are only a small part of overall bioenergy consumption. Biogas and biomethane today account for less than 3% of total bioenergy demand, and represent an even smaller 0.3% share of total primary energy. However, there is a strong potential role for biogas and biomethane in the transformation of the global energy system[3].

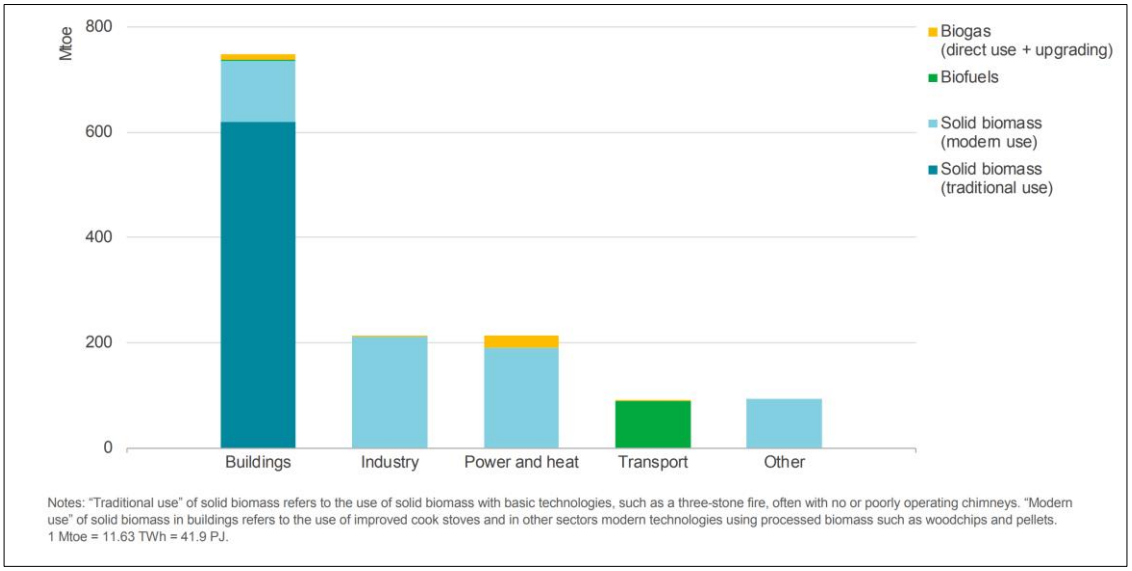


Figure 7: Global bioenergy consumption by type of source and sector (Source: IEA, 2018)

[3] RG GI002 PP22

Biogas and biomethane production in 2018 against the sustainable potential

Biogas and biomethane production in 2018 were around 35 million tons of oil equivalent (Mtoe), only a fraction of the estimated overall potential. Full utilisation of the sustainable potential could cover some 20% of today's worldwide gas demand[4].

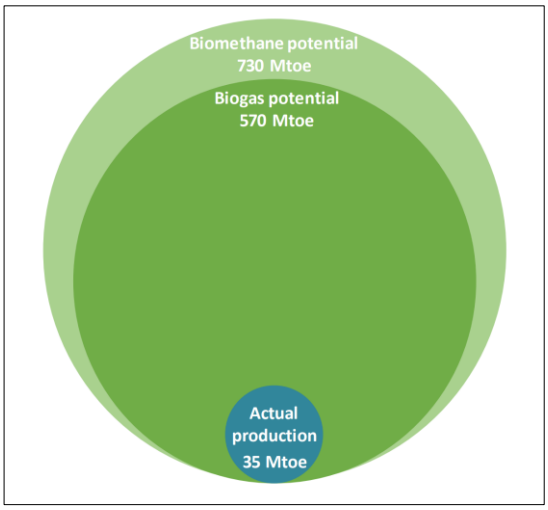


Figure 8: Biogas and biomethane production forms a small part of bioenergy potential (Source: IEA, 2018)

Biogas Production Potential by Feedstock

Every part of the world has significant scope to produce biogas and/or biomethane, and the availability of sustainable feedstocks for these purposes is set to grow by 40% over the period to 2040[5].

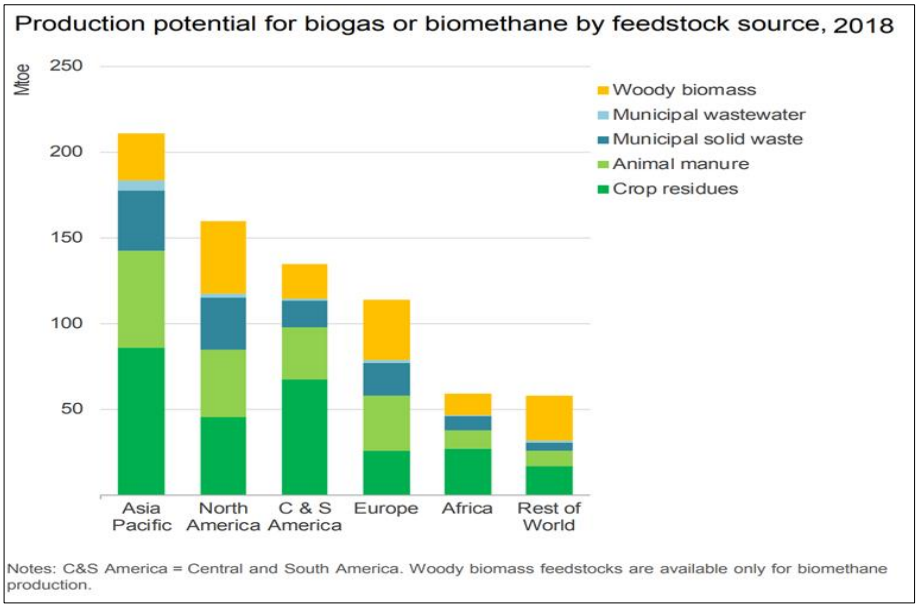


Figure 9: Biogas Production Potential by Feedstock (Source: IEA, 2018)

Biogas Installed Generation Capacity and Consumption by sector

Most production today goes to the power sector, for the production of electricity.

[4] RG GI002 PP6
[5] RG GI002 PP7

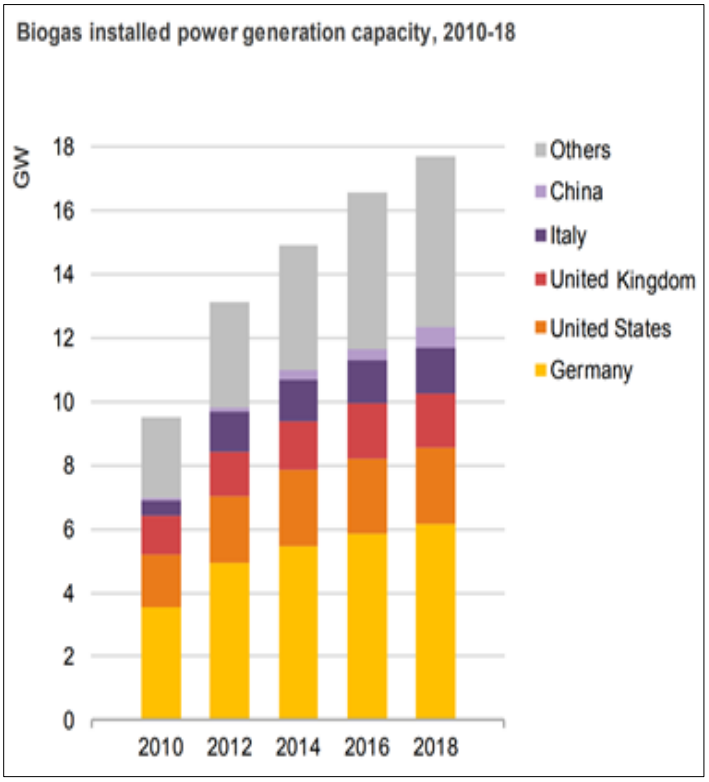


Figure 10: Biogas Installed Generation Capacity (Source: IEA, 2020)

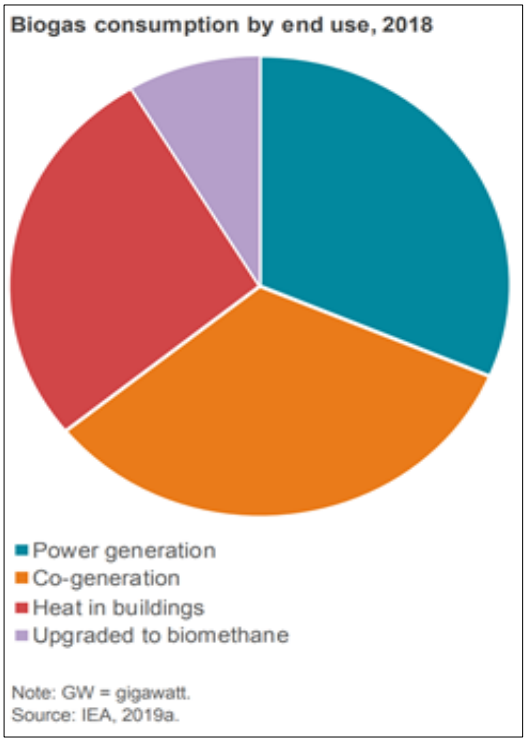


Figure 101: Biogas Consumption by sector (Source: IEA, 2019a)

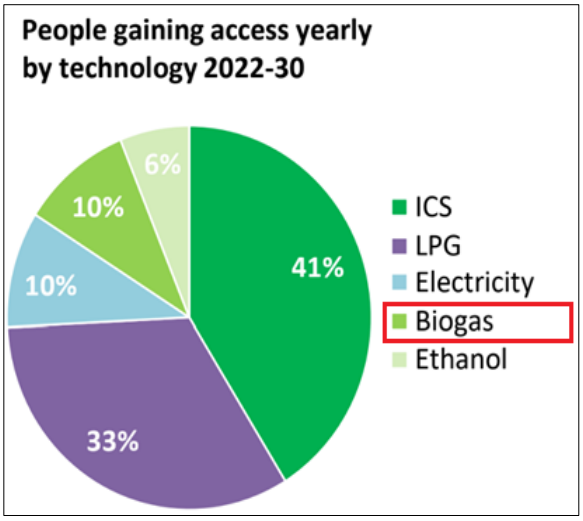


Figure 112: Biogas contribution to clean cooking (Source IEA,2022)

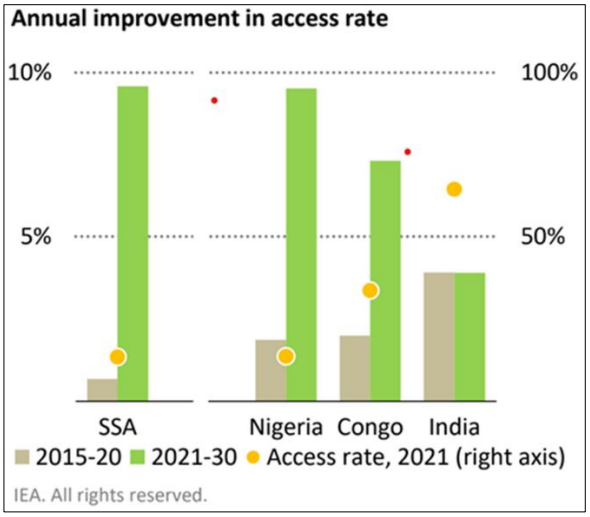


Figure 123: Annual improvement in access rate6 (Source: IEA,2022)

Biogas Uptake Distribution in Selected Countries

The use of biogas for cooking continued to increase in 2016 as shown in figure below. Asia leads in total installations of domestic biogas plants, most of which are in China (42.6 million units at the end of 2016) and India (4.7 million units), with an estimated 620,000 units installed elsewhere in the region. Asia also saw more new installations of domestic biogas plants in 2016 than any other region. In Africa, 68,000 biogas plants had been installed as of late 2016, mainly through the African Biogas Partnership Programme; markets for biogas plants are growing on the continent, particularly in Kenya and Ethiopia.

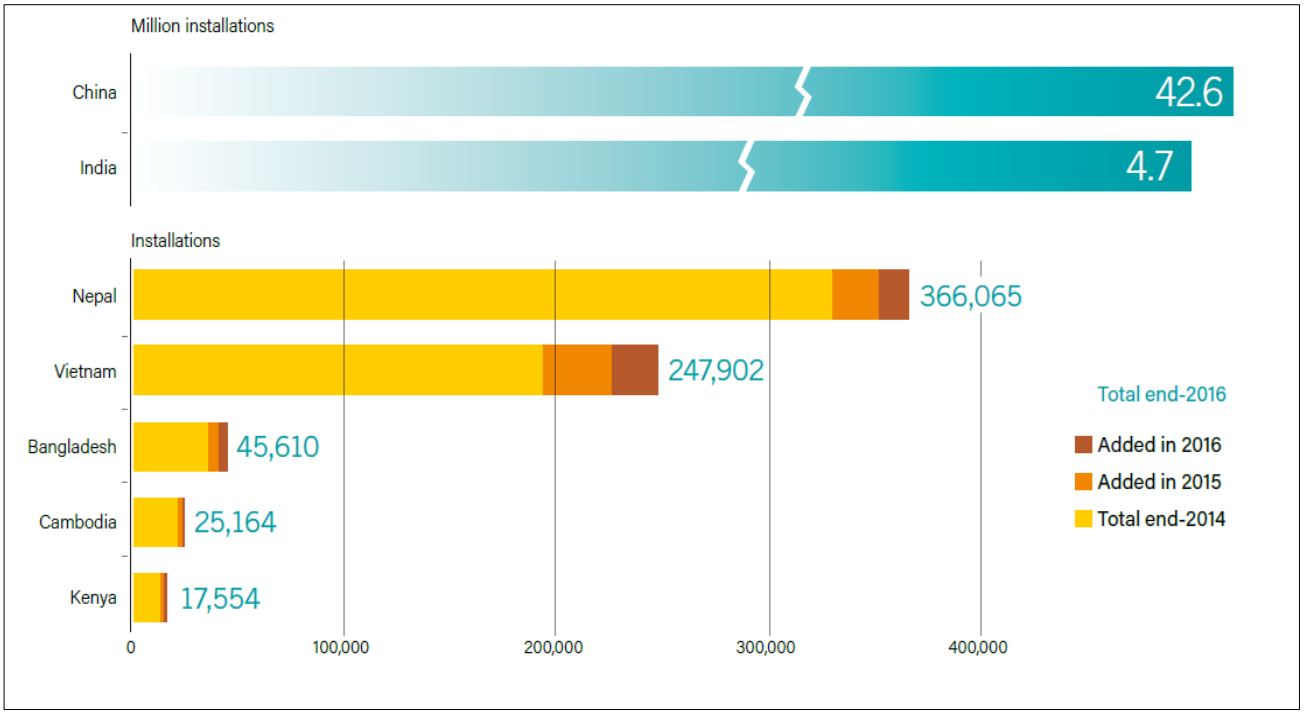


Figure 14: Domestic Biogas Plants Installed in Top 5 Countries, Total and Annual Additions, 2014-2016[7]

[6] IEA GI 003_Africa Energy Outlook

[7] RG ER009 PP104

Trends in Global Electricity Generation from Biogas

The biogas industry is growing globally. IRENA on renewable capacity statistics 2022 shows biogas generation capacity has grown from 1,443,923 MW in 2012 to 3,0635,926 MW in 2021 That is over 100% growth in nine years.

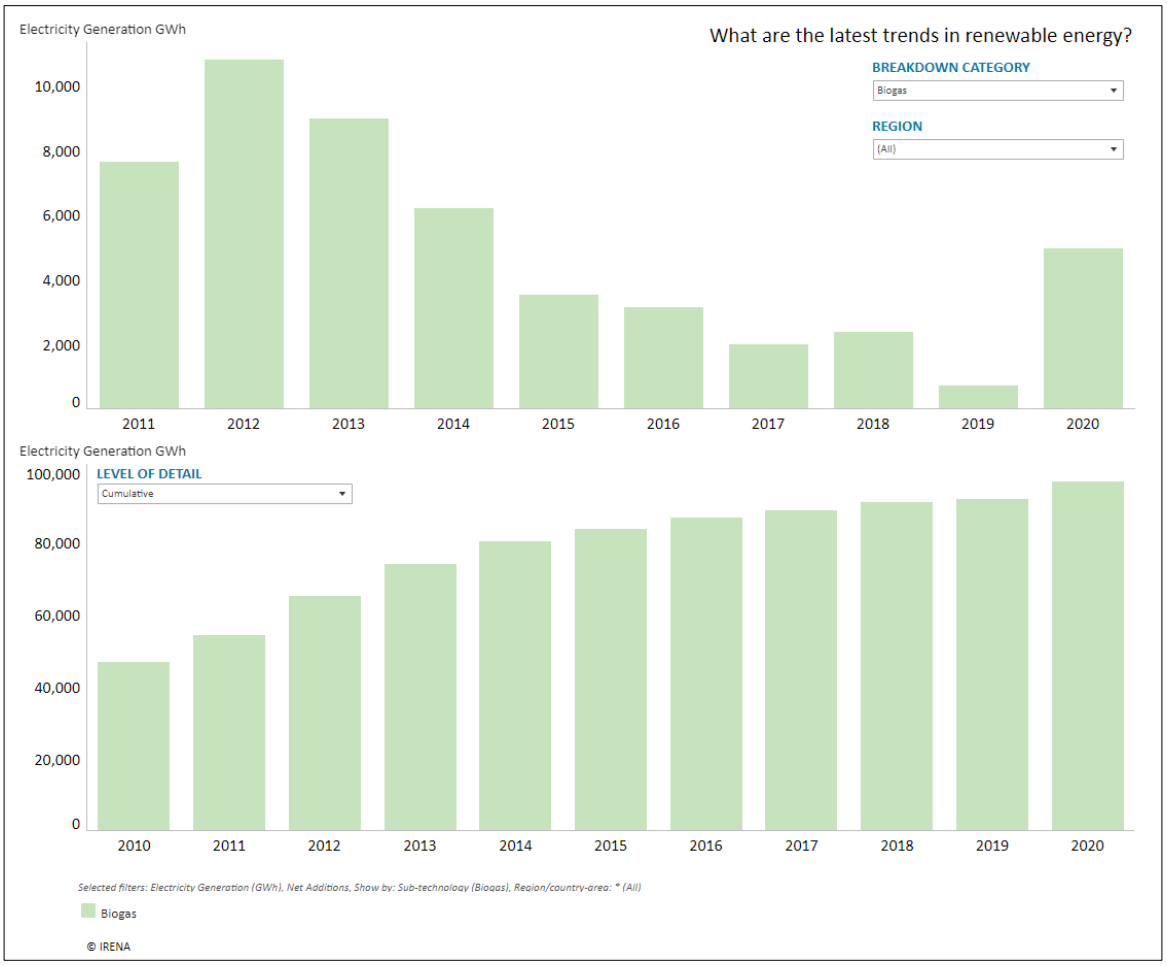


Figure 15: Statistics on global electricity generation (Source: IRENA,2022)

Summary Global Observations

- Biogas and biomethane provide a way to integrate rural communities and industries into the transformation of the energy sector.
- Biogas and biomethane are related products with different applications, but they both originate from a range of organic feedstocks whose potential is underutilised today.
- The feedstocks available for sustainable production of biogas and biomethane are huge, but only a fraction of this potential is used today
- Possibilities to produce biogas and biomethane are widely distributed around the world
- Biogas offers a local source of power and heat, and a clean and cheap cooking fuel for households, especially in rural areas
- The future of biogas is upgrading and bio methane production
- Most of the biomethane potential is more expensive than natural gas, but the cost gap narrows over time and the true cost of fossil fuels such as natural gas is not included
- Low-carbon gases are essential to energy transitions; supportive policies are required to unlock the potential for biogas and biomethane.

•

Learnings about Kenya's Biogas Sector

Kenya Biogas Sector – General Observations

It is estimated that Kenya has 21,000 biogas digesters distributed through efforts from both the government and private sector against potential of1,483,375 small-scale and 105,622 medium-scale biodigesters8 (GIZ, 2023). The use of biogas for cooking is projected to reach 0.8% by 2030, while electricity generation from biogas will be at 0.07% of the renewable energy mix.

There are sufficient policy frameworks for accelerated biogas sector growth but not well coordinated nor implemented. Most of biogas activities are in the Pioneering Phase, with Kenya scoring an average 50% of enabling environment scale. Financing opportunities, though available in the market, are not readily accessible to bio digester installers, enterprises, and end users. There is currently no nationally recognised training curriculum for practitioners in the biogas sector.

There are currently about 90 companies active in the biodigester industry in Kenya. Biodigester installation is still very much a male-dominated sector. Women owners represent 12% of the owners while 31% of the staff are women

The current number of annual sales and installations ranges from 1 to 1,700 per year per company. The digester functionality rates have increased from below 60% to 82% and about 89% of households with functional bio digesters use bio-slurry as an organic fertilizer for their crops while all of them use the gas for cooking.

Technology efficacy and affordability

Policies, measures and programs to encourage switching to clean cooking fuels are needed to overcome many barriers. The most critical affordability factor is the initial upfront costs. The best solutions and business models vary according to local circumstances.

Upfront costs, particularly of stoves and related equipment, can represent a large share of monthly income for extremely poor sub-Saharan African households. For example, the price of an improved charcoal cooking stove typically represents on average around one-third of monthly income, half for LPG, about three- quarters for electricity and around six-times for biogas stoves and digesters. Household biodigesters have higher upfront costs but much lower fuel and operating costs than other clean cooking options.

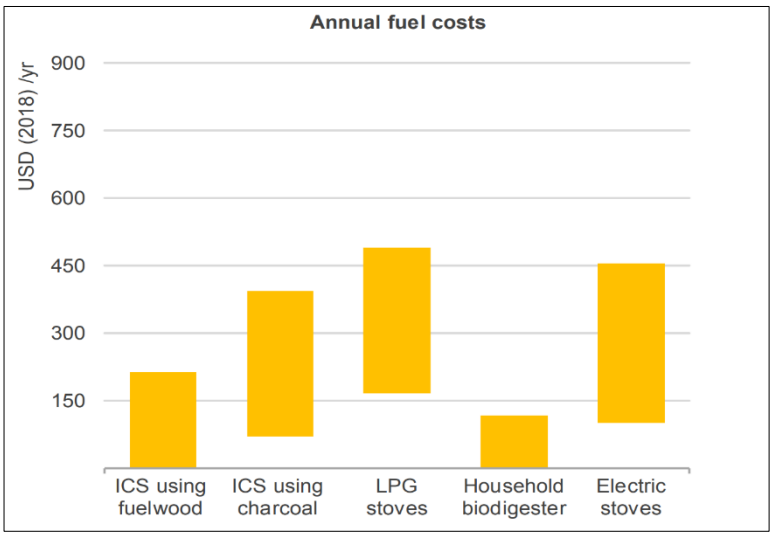


Figure 16: Kenya - Annual Fuel Costs (Source: Outlook for biogas and biomethane | IEA 2020 pp539)

[8] KEN SP002 PP31

Plant Size	Digester Size (m^3)	Gas Production per Day (m^3)	No. of cooking hrs per day (for one burner)	Cost (Kshs)	Cost (USD)
4m^3	3.0	1.0	2.2	70,000.00	602.0
6m^3	4.5	1.5	3.3	85,000.00	731.0
8m^3	6.0	2.0	4.4	95,000.00	817.0
10m^3	7.5	2.5	5.6	110,000.00	946.0
12m^3	9.0	3.0	6.7	125,000.00	1,075.0
14m^3	10.5	3.5	7.8	150,000.00	1,290.0
18m^3	13.5	4.5	10.0	189,000.00	1,625.0
22m^3	16.5	5.5	12.2	235,000.00	2,021.0
26m^3	19.5	6.5	14.4	280,000.00	2,408.0
34m^3	25.5	8.5	18.9	250,000.00	3,010.0
50m^3	37.5	12.5	27.8	420,000.00	3,612.0
66m^3	49,5	16.5	36.7	600,000.00	5,160.0
80m^3	60.0	20.0	44.4	680,000.00	5,848.0

Table 4: Bio digester Installation Cost by Size(Source: KENPRO Feb 9 2022 Wanjohi et al)

Bodies, relevant legislation and frameworks in place

- Energy Act No. 1 of 2019
- Energy and Petroleum Regulatory Authority (EPRA)
- Rural Electrification and Renewable Energy Corporation (REREC)
- Renewable Energy Resource Advisory Committee
- Net metering provisions
- National Energy Policy, 2018
- Guidelines for Regulation of Biofuels
- Bioenergy Strategy 2020
- Bioenergy Strategy Action Plan, 2022.
- Kenya National Climate Change Action Plan 2018–2022
- National Environment Policy, 2013
- National Solid Waste Management Strategy, 2014
- Agricultural Policy, 2021
- Fertilizer and Animal Foodstuffs Act, 2012
- Kenya Climate Smart Agriculture Strategy (2017-2026)
- County Energy Plans (CEPs).

Policy and strategies

Biogas	Short Term 2018-2022	Medium Term 2018-2026	Long Term 2018-2030
1. Develop and implement public awareness programs on the benefits and potential of biogas technology.	✓	✓	✓
2. Undertake and promote RD&D of biogas energy technologies	✓	✓	✓
3. Provide appropriate fiscal incentives for local manufacture of biogas plant and equipment, large scale production, storage and distribution.	✓	✓	✓
4. The government to initiate capacity building programs on biogas technology in learning institutions.	✓	✓	✓
5. The government to develop and enforce legal and regulatory requirements on biogas.	✓	✓	✓
6. Support domestic and community based biogas plants among urban, rural population and institutions.	✓	✓	✓
7. Promote the use of biogas as an alternative to woodfuel and kerosene for domestic and commercial energy needs.	✓	✓	✓
8. Roll out biogas initiatives to supply the remaining public institutions including prisons, schools and hospitals as well as biogas bottling plants across the country.	✓	✓	✓

Table 5: Policies and strategies in Kenya (Source: KENPRO Feb 9 2022)

Applicable Incentives

These incentives may include exemption from stamp duty for instruments executed in transactions relating to loans from foreign sources for purposes of investing in the energy sector, investment deductions at the rate of 100% for power generating plants and equipment and double taxation agreements (DTAs) between Kenya and a number of countries.

Standards and regulations

Standards for domestic systems:

- The domestic biogas stoves (KS 2520:2014)
- The standards on domestic biogas lamps (KS 2521: 2014)
- The standards on design and construction of domestic biogas plants (KS 2566-1:2015)
- The standards for fixed-dome domestic biogas plants (KS 2566-2: 2015) and
- The floating drum domestic biogas plants (KS 2566-3: 2015).

Standards for Commercial systems:

- Biogas systems — Code of practice for farm and industrial scale biogas systems (KS 2951:2022).

Regulations:

- Draft Biofuels Guidelines (ERC).

Training and Capacity Assessment

Prevalent training needs:

- Most masons who get hired in the biogas sector already have masonry experience and only need training in special installation features of a biodigester.

- Most masons acquire training in biogas piping through experience not through a piping course for biogas.
- Most companies do not have business plan or marketing strategy and hence require a lot of BDS skills
- Training in biodigester design and installations
- Training in bio slurry management and valorization
- There is no existing official Training manual for biodigester installation.

Competency of digester installers/ companies

- The ABC biogas company inventory study established that of the companies interviewed, almost all the 41 companies are formal, only 5 are of informal character. 17 are “Registered Limited Companies”, 8 “Private Limited Companies” and 4 indicated “Sole proprietorship”.
- The total number of staff per enterprise is rather low: 12 do not have any permanent staff, meaning that the owner him/ herself is the main workforce, 17 employ (with or without contract) up to 5 permanent staff, 2 between 6 and 10, 6 between 11 and 20 and 3 between 21 and 50.
- The total number of permanent staff with and without contract adds up to 615 of which only 62% have a contract.
- Only six companies mentioned the lack of technical and/ or managerial skills for further expansion of their bio digester activities. It means that most companies have sufficient access to skilled masons, either on their pay list or in their vicinity.

Business development skills support
The biogas company inventory study[9]:

- 38 out of 41 companies interviewed have received trainings in Biogas construction and installation: 19 by GIZ-PSDA, 18 by KBP and 12 by others such as KCIC and KNDP.
- Companies trained by GIZ-PSDA, have proven their capability to construct quality digesters even with larger volumes beyond 100m3.
- To construct a fixed dome digester an ordinary mason needs special training, which is currently neither part of any vocational curriculum nor training institute in Kenya.
- It is recommended that the Ministry of Energy build up and maintain a database of trained bio digester masons in each county.
- Most masons who get hired in the biogas sector already have masonry experience and only need training in special installation features of a bio digester.

Institutionalization and Coordination

Public and private sector involvement

- Apex policy custodian: Ministry of Energy, Department of Renewable Energy
- Guiding policy: National Bioenergy Strategy and Action Plan
- Apex private sector body: Kenya Private Sector Association (KEPSA,) through Kenya Renewable Energy Association (KEREA) and Biogas Stakeholders Network (BIO-NET); BIO-NET leads discussions in KEREA Bioenergy working group.

Partnerships and industry organization

[9] KE BLF_ER001 Page 34

- NGOs and development partners like GIZ, UNIDO, AECF, KBPL, SNV and SIDA (see analysis of support areas attached)

Market Access

Business Models and Access to Finance and Carbon Schemes
Involvement of community-based groups and stakeholders

- Marketing approach based on promoting benefits of biogas through marketing hubs with dairy cooperatives and CBOs
- KBP established 40 biogas community-based organisations (CBOs) at the constituency level
- Biodigester marketing hubs were to provide sales, training and extension information on biodigester, and bio-slurry.
- The mandate of the CBOs was to disseminate information on biogas, market stimulation, and linkages with the local leaders and biogas contractors.

Promotion and Awareness Raising
Most promotional campaigns are based on three approaches:

- Customer focused i.e. gender benefits (women and children)
- Technology focused: facility ownership and accruing benefits (e.g. energy production and bio slurry as fertilizer)
- Environmental Benefits focus

Examples of Marketing Models

- The Kenya Biogas Program adopted a specific marketing model using 'Biogas Marketing Hubs'.
- This approach relies on concentrating bio-digester information, training, sales, extension and marketing efforts on beneficiaries that have common interests; such as dairy, coffee and tea farmer Cooperatives at local level.
- The biodigester marketing hubs were to provide sales, training and extension information on biodigester, and bio-slurry.
- The Africa Bioenergy Partnership Limited (ABPL) is transforming these models into community-based organisations (CBOs) at the constituency level and aims to reach 200 by the end of 2023 with a total membership of 2,500 farmers.
- The mandate of the CBOs is to disseminate information on biogas, market stimulation, and linkages with the local leaders and biogas contractors.
- ABPL will also attract carbon credit with a premium through this use-centered model. The premium is estimated at 25€ / tCO2eq against 15€ / tCO2eq for a classic carbon credit.

Biodigester Curriculum Development Experiences in Kenya

Curriculum Development: Objectives and Key Institutions in Kenya

The main objectives include:

1. Establish a competency- based curriculum at all levels;
2. Utilize technology to enhance innovation in the implementation of competency- based curriculum.
3. Identify and procure appropriate technology for utilisation in the competency- based curriculum

4. Create an enabling environment for performance-based learning and transform assessment to check knowledge, skills and abilities required for the performance of certain tasks
5. Initiate organizational linkages and networks implementation of competency- based assessment to promote adoption

The key actors

The actors include Kenya Institute of Curriculum Development (KICD) whose mandate is to develop quality curricula and curriculum support materials responsive to the needs of the society. Others actors are the Kenya National Qualifications Authority (KNQA) that coordinates and harmonizes education, training, assessment and quality assurance of all qualifications awarded in the country; with the view to improving quality and international comparability. The National Industrial Training Authority (NITA) mission is to provide quality industrial training for enhanced productivity. Trainings are tailored to the need of the industry. The TVET Curriculum Development Assessment and Certification Council undertakes design and development of curricula, examination, competence assessment and certification in TVET. Lastly, there are Higher Learning Educational Institutions e.g. JKUAT, Strathmore University College and Professional Organizations and Industry associations e.g. BIO-NET.

Examples of established biogas training institutes

Some of the examples of established biogas training institutes and the associated course offered are Tianjin Agricultural University in China offering Biogas Production Engineering (undergraduate course), Centre for Energy Studies, Institute of Engineering in Nepal offering Advanced Biogas Training (supported by SNV/ BSP), Indian Institute of Technology, Delhi (Biogas Development and Training Centre) offering Fundamentals of Biogas Production, Power Generation and Compressed Biogas Technology and Jomo Kenyatta University of Agriculture and Technology (Institute of Energy and Environmental Technology) that offers short courses on demand.

Industry training manuals and codes of practice in Kenya

- KEBS: Kenya Standards for Domestic Systems (2014) and Farm scale biodigesters (2022)
- EPRA: Guidelines for Regulation of Biofuels (2022)
- NITA: Biogas Systems Skills Upgrading Course Curriculum (2014)
- BIO-NET: Biogas Construction Training Modules (2018)
- KBPL: KMD Construction Manual 2020
- GIZ: Biogas Technology: A Training Manual For Extension (2009)
- ILO: ILO Modules of Employable Skills (MES)

Examples of existing curriculum

- Pakistan: Curriculum Technical Supervisors Fixed Dome.pdf (tvetreform.org.pk)
- Pakistan: Curriculum Technical Supervisors Floating Drum.pdf (tvetreform.org.pk)
- Pakistan: Curriculum Technicians Floating Drum.pdf (tvetreform.org.pk)
- India: Curriculum Technicians Fixed Dome.pdf (tvetreform.org.pk)
- Nepal: Biogas Technology A Training Manual for Extension (sswm.info)
- Cambodia: Biogas Handbook – English version.pdf (unido.org)

Summary guidelines/ steps for curriculum development

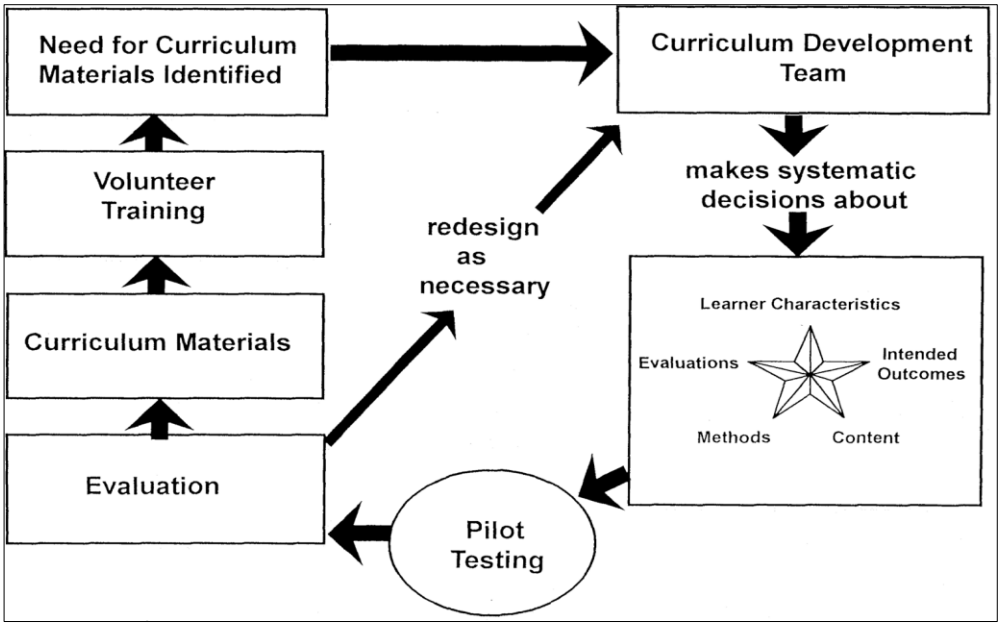


Figure 17: Steps for curriculum development (Source: www.fao.org)

Stakeholder framework for curriculum development

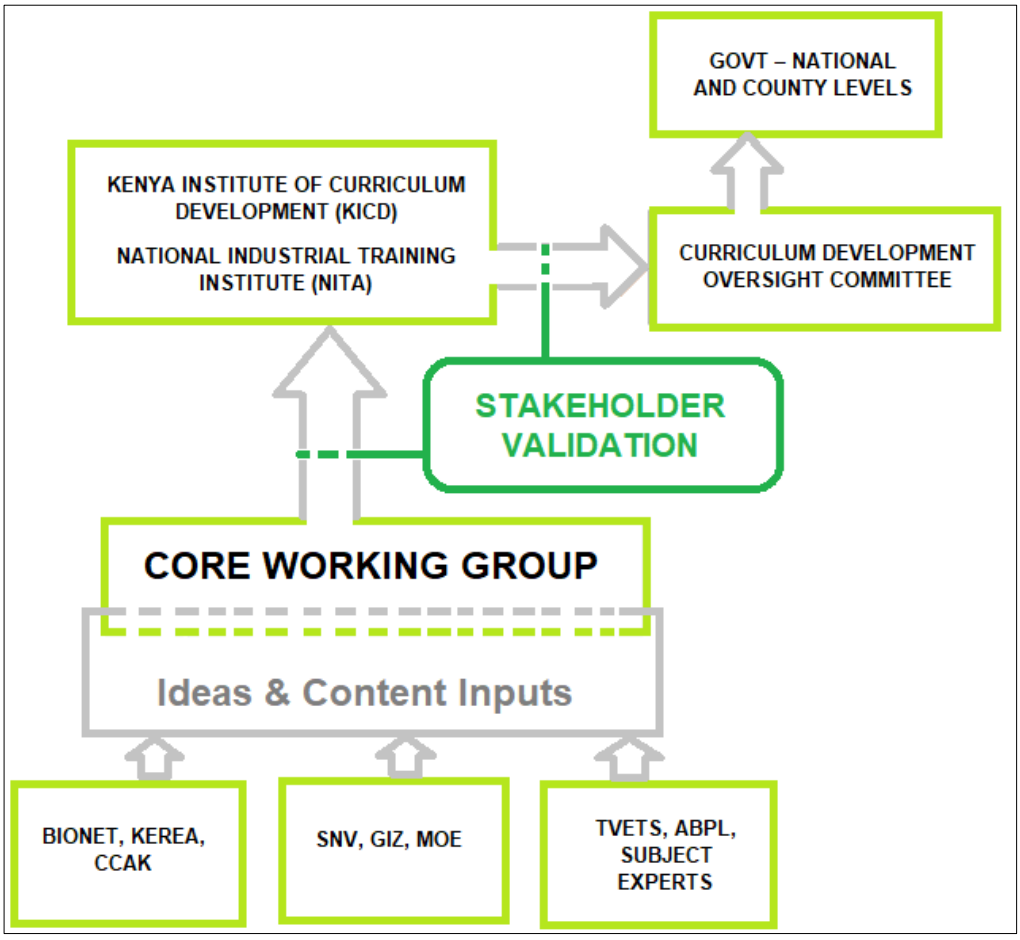


Figure 18: Proposed framework for Kenyan context (Source: IBE/ 2017/ OP/ CD/ 02.)

Country & Project Lessons Learnt – Deep-Dive

This chapter covers the detailed analysis of each project and brings out the lessons learnt in the specific subject matter under technical and non – technical components.

Analysis Flow

- Mapping and prioritisation
- Inventory research and repository established
- Overview of key projects and reports
- Objectives and main actors
- Industry associations
- Lessons learned along thematic areas

Mapping and prioritisation rationale

- Evidence of significant past or present biogas projects
- Presence of NGO, INGO, CBO projects
- Some level of government support
- Public private partnerships
- Community involvement
- Interest of ABC Project Implementation Team

Characteristics of specific projects analyzed in detail:

- They were big multi agency or national level projects running over a long period of time, not less than 3 years.
- They were located in developing or middle-level economy countries.
- Objectives and aims of the projects were clear, with Informative outcomes
- Level of information and data available was reasonable.



Key Observations

Thematic areas addressed by different biogas projects in Africa

Most Countries active in biogas in Africa have been supported by ABPP

Key thematic areas have been (i) access to energy, (ii) health (indoor air pollution) (iii) environmental protection, (iv) employment and income generation, (v) agricultural production (use of bio slurry) and (vi) sanitation.

Themes	RWANDA	KENYA	BURKINA FASO	ETHIOPIA	UGANDA	TANZANIA
Energy						
Sanitation						
Health (indoor air pollution)						
Environmental protection						
Employment and income generation						
Agricultural production						

	Code
Highest priority	
High priority	
Low priority	
Lowest priority	



Kenya

General biodigester sub-sector overview

Biogas Sector Objectives[10]

Develop and implement public awareness programs on the benefits and potential of biogas technology.
Undertake and promote Research, Development and Demonstration (RD&D) of biogas energy technologies
Provide appropriate fiscal incentives for local manufacture of biogas and equipment.
Develop and enforce legal and regulatory requirements on biogas
The government to initiate capacity building programs on biogas technology in learning institutions.
Support biogas plants among urban, rural population and institutions
Roll out biogas initiatives to supply the remaining public institutions
Potential
A feasibility study on biogas established that it is possible to construct 6,500 biogas digesters annually in Kenya, and that the country has the potential to establish 1.5 million small scale and 105,000 medium-scale biodigesters. It is estimated that 60,000 biogas digesters have been installed11.
Bio digester sales have fluctuated over the years – unsteady market with average sales of 58% against 80% set target.

Key actors in Biogas Sector

- Ministry of Energy
- Kenya Bureau of Standards
- Kenya Industrial Research and Development Institute
- SNV
- GIZ

[10] KEN PR001 PP34
[11] KEN SP002 PP31

Draft

- Dutch Ministry of Foreign Affairs (DGIS)

Sector associations and related actors

- Kenya Renewable Energy Association (KEREA)
- Clean Cooking Association of Kenya (CCAK)
- Kenya Biogas Stakeholders Network (BIO-NET) whose members include:
- Association of Biogas Contractors of Kenya (ABC-K)

National Implementing Agencies under Africa Biogas Partnership Programme (ABPP)

- Federation of Agricultural Producers (KENFAP) was NIA during Phase I
- Kenya Biogas Program (KBP) during Phase II.

Clean cooking energy access realized vs. planned:

- Kenya targets universal access to clean energy by 2028 with access estimated in 2020 at 19.5%.

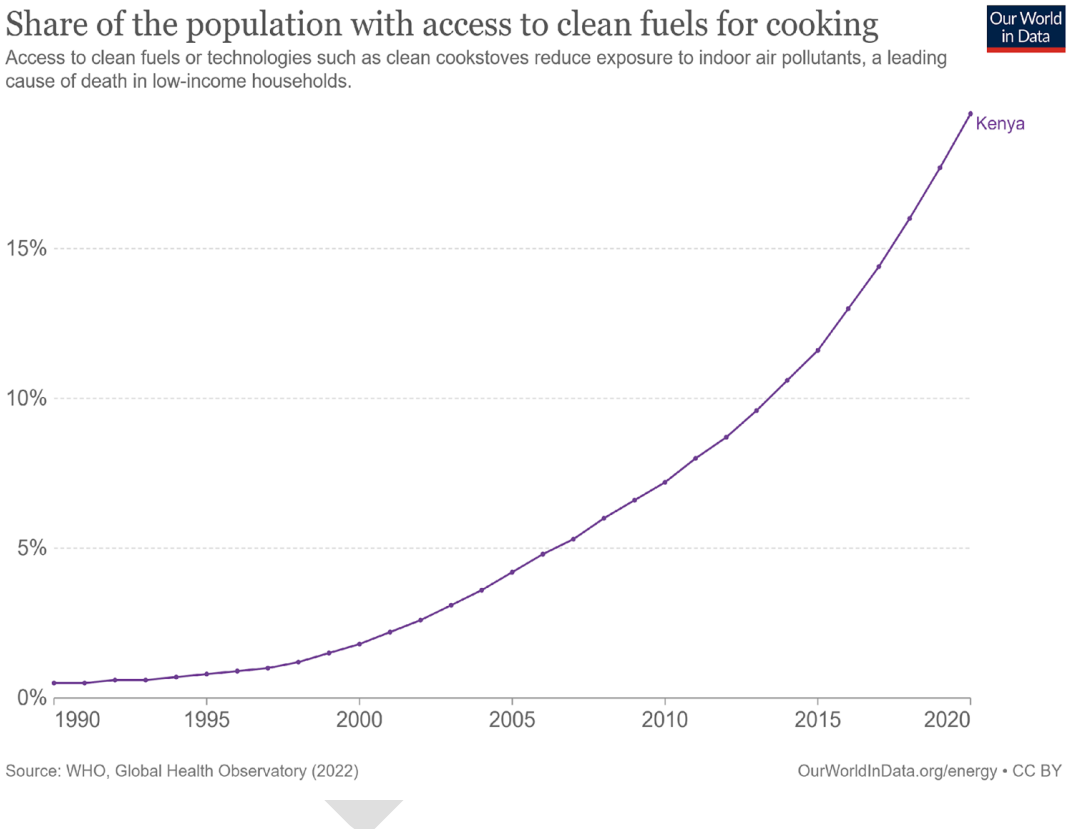


Figure 19: Share of population with access to clean fuels for cooking (source: WHO, Global Health Observatory, 2022)

Most installations in Kenya are by freelance technicians, compared to- Biogas Construction Companies.

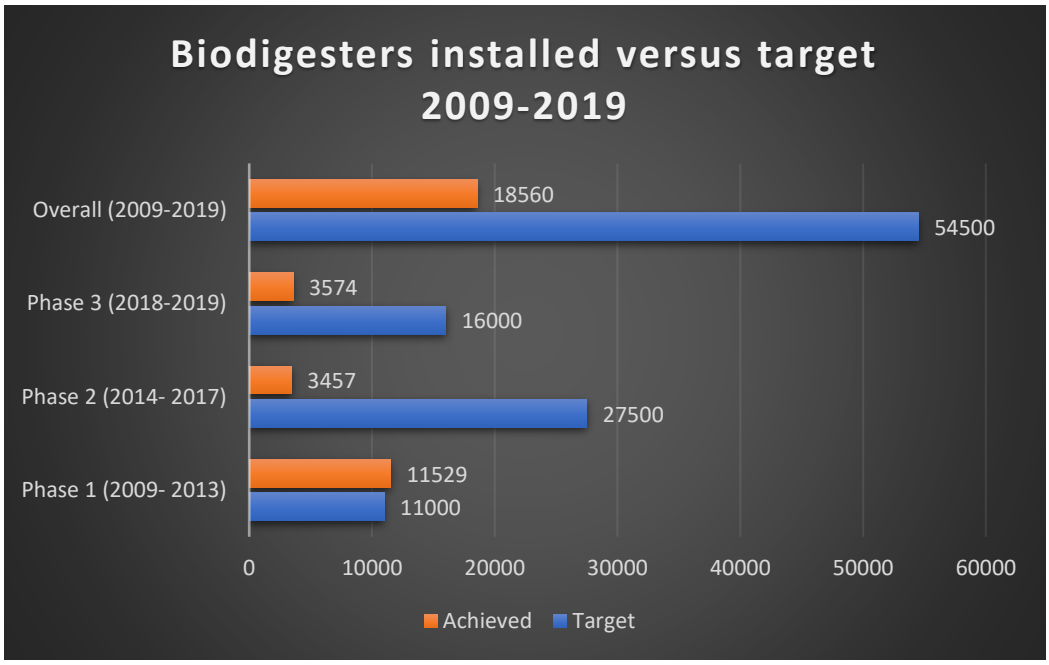
BCE share in total production	2012	2013	2014	2015	2016	2017
Ethiopia	20%	19%	18%	24%	19%	23%
Kenya	32%	55%	69%	96%	45%	53%
Tanzania	71%	83%	85%	91%	94%	n/a
Uganda	95%	99%	99%	96%	73%	67%
Burkina Faso	27%	39%	56%	92%	75%	99%
Average	49%	59%	65%	80%	61%	61%

ABPP Programme Report (March 2019)

Table 6: BCE share in total production (Source: ABPP Programme Report, March 2019)

Country-level potential vs. achieved installations from 2009 to 2019

- Potential 1.5 million small scale and 105,000 medium-scale biodigesters 12
- Phase 1 (2009–2013): target 11,000 13- installed 1152914.
- Phase 2 (2014–2017): target 27,500 – installed 345715.
- Through 4S@Scale: target 16,000 - installed 3574.



[12] KEN SP002 PP31
[13] KEN ER001 PP24
[14] KEN RF002 PP2
[15] RG RF001 PP26

Figure 20: Biodigesters installed versus target, 2009-2019

Key biogas sector initiatives

- MoEP and GIZ - Special Energy Programme, implemented in 1987-1992 (the first rigorous intervention to promote biogas in Kenya).
- Kenya National Domestic Biogas Project/ Kenya Biogas Programme (KENDBIP) by African Biogas Partnership Programme (ABPP)
- MoEP Energy Centers which initiated installation and demonstration of mainly floating drum bio digesters
- Promotion of Private Sector Development in Agriculture (PSDA) GIZ programme
- MoEP projects on institutional biogas digesters using cow dung and sewage
- JKUAT plant on production of biogas from human waste for cooking and electricity generation
- MoEP and flower farms - pilot project on biogas production of biogas from farm/ flower waste
- MoEP project with Kenya Prisons Services (biogas from human waste for cooking and electricity generation) installed 13 biogas plants.
- GIZ African Biodigester Component (ABC) Project

Financial institutions financing biogas loans

Biogas loans are classified as Asset finance loans or Agribusiness loans and therefore no subsidy, customers are expected to give a deposit of 20-30% and they get financed up to 70-80%.

The cost of the loan is dependent of the cost of funds of the lender and so they vary. Notably the Banks are cheaper than the Micro finance Banks. The biogas companies have MOUs with Banks and scout for customers.

The lenders appraise the customers and make the final decision depending on customer's eligibility.

Examples of these institutions;

- Microfinance banks e.g. KWFT, SMEP and SUMAC
- Credit only MFI's e.g. Juhudi Kilimo, Bimas, Jiweze, Eclof, Premier Credit, Ushindi Bora and Letshego
- Banks e.g., KCB and Equity
- Sacco e.g., Taifa Sacco

Examples of Biogas Power Generation in Kenya

Estimated Potential Vs FiT Policy

- Biggest potentials for electricity production from biomass mostly come from the agro-industrial business and from municipal solid waste.
- The total potential installed electric capacity range from 29 to 131 MW el , generating 202 to 1,045 GWh el / a of electricity, which is about 3.2 to 16.4 % of the total Kenyan electricity production of 6 360 GWh el as of 2007/ 08
- The extent of actual realisation of this potential will depend on the incentives provided for investment, in particular the tariff framework.

- FiT values for biogas projects below 10MW are 9.5 $ Cts/ KWh

Examples (medium scale)

- CB Roses Thika 69 KVA equivalent of 55.2kW (assuming power factor o 0.8)
- PJ Dave Flowers Kajiado 125 KVA equivalent of 100kW
- Mangu High school 20 KW
- Biogas Power Holdings (EA) Ltd, Kilifi 150 KW
- Homa Bay Biogas Power Project 69 Megawatte (MW), upcoming
- Keekonyokie Slaughterhouse Kajiado

Promotion of Private Sector Dev. in Agri. PSDA

- PSDA was a bilateral technical assistance programme jointly implemented by the German Agency for International Development (GIZ) on behalf of the Government of Germany and the Ministry of Agriculture on behalf of the Government of Kenya.
- PSDA closely collaborated with other agricultural sector Ministries, mainly with the Ministry of Livestock Development, Ministry of Fisheries Development and Ministry of Cooperative Development and Marketing.
- Lead executing agency: Ministry of Agriculture
- Overall term: 2003 to 2015
- Three components addressed:
    - Improvement of the Policy Framework for Agriculture and Agribusiness
    - Strengthening of Implementation Capacities for Value Chain Development
    - Promotion of Resource Friendly Technologies
- The following high-potential value chains supported by PSDA were;
    - Beef cattle
    - Dairy Goats
    - Fisheries
    - Potatoes
    - Mangoes
    - Passion Fruit
    - Sweet Potatoes
    - Poultry

Kenya National Domestic Biogas Programme (KENDBIP)

Kenya National Domestic. Biogas Programme (KENDBIP) was part of the Africa Biogas Partnership Program (ABPP), a series of projects funded in several African Countries by the Netherlands Government via the Directorate General for International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs.
The initial phase was implemented by the Kenya National Farmers' Federation (KENAFF) while the later phase was by the Kenya Biogas Program (KBP), a Public Private Partnership between Hivos, SNV (Netherlands Development Organization) and DGIS.
RBF project Biogas Business Boost Benefitting Farmers (4B-F), which supports the private sectors in Kenya, Tanzania and Uganda to develop markets for renewable energy.

Key objectives, sponsor and indicators of the project

Project	Sponsor	Duration	Project Objectives	Technologies	Implementation Structure	Key Indicators
ABPP – Kenya **KNDBP**	DGIS	2009-2019	Phase 1 set-up of National Implementing Agencies (NIA), the establishment of technical and programmatic skills and the promotion of the bio digester technology. Phase 2 - market-oriented development; • Strengthen and increase the demand side of the bio digester markets: • Strengthen and increase the supply side of the bio digester markets: • Improve bio digester operation and maintenance: • Creation of a supportive institutional environment:	Fixed dome bio digester -4, 6 & 8 m3 and 12m3 for tubular digesters	NIA established and manages funds and facilitate in coordinating role among : masons, BCE, biogas associations, financial institutions (banks, MFI and SACCO), training centers, development organizations and governments. National Biogas Steering Committees (NBSC) advise the NIA. They include representatives of different Ministries.	1. # of installations 2. Cost reduction: 25-30%. 3. Credit availability: 40-60% end-user credit. 4. Bio slurry: 90% of bio digester owners use their slurry for productive activities 5. In 2015, at least 80% of the sales of biogas systems is realized by BCEs

Installations

Year	Target	Installed units
2009-2013	11000	11529
2014-2017	27500	3457
2018-2019	16000	3574
Total	**54500**	**18560**

The Kenyan numbers fluctuate between years, and although the country produced most digesters, it achieved only 32% of target.
2009- 2013 reported more installation because of the subsidy. Withdrawal of the subsidy in subsequent years led to drop in installations.

Project management and origination

Project feasibility and objective setting; project implementation strategy; reviews and learnings

- Multi actor: government, private sector, development partners, FIs, NGOs involved

- The Federation of Agricultural Producers (KENFAP) was National Implementing Agency (NIA) during Phase I and the Kenya Biogas Program (KBP) was NIA for Phase II16.
- ABPP-1 Evaluation (2015) and the ABPP-2 Mid-Term Review (2016) pointed out unrealistic planning of bio digester installation, but this did not lead to formal review of the programme country target17.
- NDBP set target was to build 54 500 digesters by the end of 2019 and achieved installation was 18,560 representing 34% of the set target18.

#	Challenges	Opportunities
1	Risk in managing stakeholders – case of KENFAP irregularities	To leverage on existing partners/ stakeholders' structure in place

Lessons learnt

- Implementation plans must include viable risk mitigation on management and be flexible to respond to emerging dynamics of the project.
- Project implementation plan should be flexible to accommodate reviews on realistic targets
- Setting of targets requires thorough analysis of the underlying uptake fundamentals.

Institutionalization and coordination

Partnerships and industry organization (existence of associations and niche groups); public and private sector involvement; level of coordination and collaboration.

- Involvement of KENAFF which was the KENDBIP National Implementing Agency (NIA) and host farmer organization was discontinued in late-2015 after the discovery of irregularities19.
- Implementation was taken over by Kenya Biogas Partnership (KBP), a new private-public formation.
- The implementation period saw a significant expansion in the partnership network with over 160 institutions and organizations collaborating with the programme.

Lessons learnt

- Changes in management or implementation agencies during active implementation should be accompanied by reduced rather than increased targets, to account for the expected loss of momentum.
- Expansion in partnerships or networks do not necessarily directly correlate to achievements of targets.

[16] RG ER004 PP11
[17] RG ER004 PP15
[18] KEN ER001 PP24
[19] KEN ER001 PP24

Market access and business models

Involvement of community-based groups and stakeholders; prevalent business models; strategies for awareness raising.

- Biogas marketing hubs were introduced to link community based and rural organizations like dairy and coffee cooperatives with BCEs and local finance institutions. The aim was to identify high potential market areas and target consumers who have regular income and/ or easy access to loans20
- Women led in the uptake of biogas plants loans reportedly accounting - for 78% of borrowers as compared to men (22%).
- Support to new entrants in the biogas marketplace, focusing on prefabricated bio digesters with lease to own models in 2018, leading to a reduction of costs for clients.

Challenges	Opportunities
• Fixed-dome bio digesters which have been heavily marketed faced access challenges due to affordability and technical installation barriers.	• Emergence of markets for tubular bio-digesters with ease of installation and financing via lease to own models.

Lessons learnt

- Targeted marketing for the different value chain is promising to access wide potential market for biogas in Kenya.
- Targeting women groups yielded more biogas loan uptake as they understand well the cost benefits for biogas compared to wood fuel / charcoal.

Access to finance and financing models

Involvement of banks and MFIs; subsidy models and approaches; results-based and carbon financing.

- In its first phase, households received a subsidy with funding from DGIS to cover 30 per cent of installation costs for a bio digester (25,000 Kenyan shillings or KSH; roughly €223)21.
- The subsidy was reduced in the second phase, from June to December 2013, to cover 20 per cent of installation costs (KSH18,500 or roughly €160). The subsidy was withdrawn at the end of 201322.

[20] RG ER004 PP26
[21] KEN ER004 PP11
[22] KEN ER001 PP7

- In terms of access to credit, the target was to have at least 40-60% of bio digesters financed with end-user credit. For Kenya the percentage of bio digesters financed with end-user credit was 23% in 2017 and 61% in 201823. The raise was due to the introduction of Lease-to-Own models for prefabricated biodigester.
- Prefabricated biodigesters are a more accepted collateral than fixed-dome biodigesters as they can be recollected by biogas companies if a client fails to pay instalments.
- The program initiated various credit partnerships with financial institutions, culminating in joint MoUs to finance biogas installation. These institutions included Kenya Women's Finance Trust (KWFT), Letshego formerly Micro Africa and Taifa Sacco
- The conditions for credit to end-users were flexible with prefabricated bio digesters.

#	Challenges	Opportunities
1	• Fixed-dome bio digesters were not acceptable as collateral for credit financing by financial institutions.	• Emergence of markets for tubular bio-digesters with lease to own model. The conditions for lease to own model by prefabricated bio digesters companies seemed preferred in Kenya and should be supported.

Lessons learnt

- Lease-to-own bio digester financing has demonstrated high potential for scaling, in comparison to traditional financial institution credit for bio digesters which has been supported and promoted hugely but without significant uptake and implementation success by the FIs.

Technology efficacy and affordability

Design and functionality; sizing and pricing; deployment challenges

- Fixed dome 4, 6, 8 or 12 m3; most were 8 m324.
- The installation of prefab digesters increased in Kenya - 201725
- Production costs/ m3 ranged from EU 130 in 2012 to 100 in 2017. This was equivalent to minus 16% in cost reduction26 this was because of the cost reduction measures.

[23] RG ER004 PP22

[24] RG ER004 PP16
[25] RG ER004 PP23
[26] RG ER004 PP20

- High upfront cost of USD 500 to USD 1000 was challenging and out of reach for most Kenyan farmers27.

	Challenges	Opportunities
1	• The high up-front investment for users is one of the main barriers for dissemination of bio digesters.	• Tubular bio digesters offer cheaper option and payment in installments

Lessons learnt

- Upfront costs of biodigesters without viable financing mechanisms present a major uptake barrier. However, there exists options/approaches aimed to strengthen the demand for bio digesters by increasing affordability, through cost reduction and access to credit. Targeting farmers with a constant source of revenues (dairy farmers) has proved to be a successful strategy for most biodigester companies.

Training and capacity assessment

Prevalent training needs; competency of digester installers; business development skills support.

- Quality management remained a key pillar of the program, 40 supervisors engaged to back up the ten biogas technicians to enhance quality control services.
- 82 of the 577 trained masons registered their business companies and operate as business entities (source: https:/ / www.africabiogas.org/ countries/ kenya/)

#	*Challenges*	*Opportunities*
1	No steady biogas market year round.	Emerging new biogas market – prefabricated bio digesters.

Lessons learnt

- Formalized private sector biogas installers operating as biogas enterprises present the most viable biogas sector development pathway. They can benefit from public tenders even if some barrier persists as participation to public tender requires licensed civil engineers.

After sales operation and maintenance[28]

[27] KEN RF002 PP2

[28] RG ER004 PP18

Existence of aftersales support; bio slurry management and use; sustainability and scalability.

- Phase 1, payment of BCEs and masons were linked to the delivery of an operational biodigester; assuming that it would be used and be functional.
- As of 2015, quality assurance became a priority area for investment. The results-based co-financing by EnDev induced the introduction of the functionality benchmark "gas in the kitchen".
- Bio digester functionality improved over the years. The overall ABPP-2 functionality rate of all year bio digesters (2014-2017) in Burkina Faso is 75% (54% in 2014), in Uganda 76% (60% in 2014), in Kenya just above 70%, and in Ethiopia below 60% (60% in Phase 1)
- Functionality in all countries has risen to a current level of over 90% for newly-installed bio digesters[29].

#	Challenges	Opportunities
1	Limited willingness and ability to pay for after sale support by end users.	Entry of new market players of selling non-masonry, prefabricated bio digesters.

Lessons learnt

- Strengthening the system of monitoring bio digester quality construction and putting in place remediation measures for non-functional bio digesters increase functionality. One of them is carbon financing as carbon financing aggregators must maintain functionality of the constructed / installed biodigesters to benefit from the credit.

Policies, standards and regulations

Enabling environment policies; availability and application of standards; regulations and enforcement.

- ABPP was not successful in generating governmental subsidies for end-users in Kenya[30]
- The GoK has launched its own fully subsidized biogas programme in 2022
- In Kenya, standards for digesters were developed and approved with support of ABPP, but not developed into a common framework for bio digester market development[31] nor made mandatory.

[29] RG ER004 PP18
[30] RG RF005 PP25
[31] RG ER001 PP15

#	Challenges
1	• Withdrawal of proposed government subsidy had an impact on project achievements.

Lessons learnt

- Political will and focus of government to support a national biogas programme is crucial and should be nurtured to a level where it is unaffected by implementation challenges.
- The project's theory of change framework should be in place with an elaborate set of objectively-verifiable indicators, targets and sources of verification.
- Monitoring and evaluation should be anchored to web-based database (Salesforce) to provide real-time data capture and management.

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