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Glossary of terms

Biogas	A gaseous mixture consisting mainly of methane and carbon dioxide produced by the anaerobic decomposition of organic matter.
Cost-reflective tariffs	Tariffs set to recover all the allowable costs of each regulated and licensed activity. "Allowable costs" in this case means all operating costs reasonably incurred, all capital costs prudently invested, and a fair rate of return on used and useful utility assets.
Innovation	An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).
Generation	The process of converting energy into electricity and/or useful heat from a primary energy source such as wind, solar radiation, natural gas or biomass.
Renewable energy	Non-fossil sources of energy capable of use for the generation of electricity including wind, solar, hydro, biomass and geothermal.
Research and development	Research and experimental development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of human knowledge and to devise new applications based upon it. The term R&D covers three activities: basic research, applied research and experimental development.
Science, technology and innovation policy	The field of study of the areas of science, technology and innovation and the use by countries of STI policy as a means of harnessing knowledge for promoting development.
Solar energy	Energy irradiated from the Sun to the Earth that can be harnessed for human use such as thermal applications and electricity generation.
Technology transfer	The transfer of the components of technology (which may include technological knowledge contained in plant, machinery and equipment, production processes, software, manuals and patents) from one economic agent to another.
Vision 2030	Zambia's first-ever written long-term plan, which expresses the aspirations of the Zambian people to be accomplished by the year 2030. It articulates the appropriate national and sector goals to meet people's aspirations.

Abbreviations

8NDP	Eighth National Development Plan
BAZ	Biofuels Association of Zambia
CEC	Copperbelt Energy Corporation
COVID-19	coronavirus disease (of 2019)
EESAP	Energy Efficiency Strategy and Action Plan
EG	Expert Group
ERB	Energy Regulation Board
FGD	focus group discussion
GDP	gross domestic product
GHG	greenhouse gas
IEA	International Energy Agency
IPP	independent power producer
IRP	Zambia Integrated Resource Plan
ISO	International Organization for Standardization
MoA	Ministry of Agriculture
MoE	Ministry of Energy
MoEd	Ministry of Education
MoFL	Ministry of Fisheries and Livestock
MoGEE	Ministry of Green Economy and Environment
MoH	Ministry of Health
MoLG	Ministry of Local Government
MoLNR	Ministry of Lands and Natural Resources
MoTS	Ministry of Technology and Science
NDP	National Development Plan
NEP	National Energy Policy
NGO	non-governmental organization
NIS	national innovation system
NISIR	National Institute for Scientific and Industrial Research
NSTC	National Science and Technology Council
NTBC	National Technology Business Centre
PPP	public–private partnership
R&D	research and development
RACI	responsible, accountable, consulted, informed
REA	Rural Electrification Authority
SADC	Southern African Development Community
SC	Steering Committee
SDG	United Nations Sustainable Development Goal
STI	science, technology and innovation
TA	technology assessment
TVET	technical and vocational education and training
ZABS	Zambia Bureau of Standards
ZEMA	Zambia Environmental Management Agency
ZESCO Ltd	Zambia Electricity Supply Corporation

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Executive summary

"Technology assessment" (TA) refers to the systematic evaluation and analysis of the potential impacts, benefits, risks and challenges associated with the introduction, adoption or modification of a specific technology. The goal of TA is to provide informed insights that can guide decision makers, policymakers and stakeholders in making well-informed choices regarding the development, deployment or regulation of technology. This process involves a comprehensive examination of the technological, economic, social, ethical and environmental aspects of a particular technology.

The UNCTAD pilot project on TA in the agriculture and energy sector in sub-Saharan Africa included the governments of Seychelles, South Africa and Zambia as pilot countries. Zambia participated through the Ministry of Technology and Science (MoTS) with a focus on enhancing Zambia's TA capabilities through the assessment of the adoption and scaling up of small-scale biogas technology in Zambia. The UNCTAD TA project aimed to build the capacity of national science, technology and innovation (STI) policymakers, academia, the private sector and other stakeholders in sub-Saharan Africa, as well as to propose policies and mechanisms ("know-how") to support the learning, diffusion and adoption of technologies in the energy and agricultural sectors. It is also aimed to build resilience to, and recovery from, the COVID-19 pandemic and future health emergencies.

For a long time Zambia had been energy sufficient as the ability to generate power far outweighed the demand for that power. However, in the 2014/15 rainy season, a drought showed the inability of the country to produce enough energy to meet the demand of the local economy. The situation led to massive load-shedding of up to eight hours a day and forced the government to make decisions on power imports at a huge cost to the national treasury to keep the economy and social services afloat. This undoubtedly raised questions among policymakers concerning security of supply and diversification of the energy sector.

The economy, government treasury and the State utility have never fully recovered from the power cuts that continued in subsequent years and the situation has exposed the insufficiency in investments in power generation. While the country is endowed with many resources to generate electricity, such as coal, the need for transition to renewable energies such as solar, wind and green hydrogen, to name a few, makes it difficult to raise money for generation using fossil fuels. The Government of Zambia therefore decided that the energy sector would be the focus of TA.

Given the problems that Zambia has regarding energy, it was essential that the country began to understand what energy technologies it could employ to improve environmental safety, economic growth, national security and fuel choice by creating new and better ways of using and converting energy. Thus, as part of the TA exercise, Zambia selected small-scale biogas production as the technology for assessment. As such, the objective of the present report is to highlight the current energy landscape, opportunities for biogas, and identify policy options that allow for actions to be initialized that lead to the implementation of biogas technology in the country. A combination of a review of the expert literature, secondary data analysis, relevant policy reports, a stakeholder survey and focus group discussions (FGDs) have led to the following findings:

- Although biogas technology is well established in developed countries, it is still relatively new in Zambia. While known by industry players, it has yet to gain widespread awareness among the general population. The dissemination of information related to biogas appears to be very limited and negative perceptions of the technology exist, with one of the leading sources of information on biogas being social media. It is therefore necessary to conduct public-awareness campaigns to educate citizens about the benefits of biogas technology, dispel myths and encourage adoption through informational materials and community outreach.

- Stakeholders are concerned over the drawbacks of conventional energy sources such as charcoal and wood. A major benefit of using biogas technology is its positive impact on the environment. Biogas could have a favourable environmental impact by reducing methane emissions, a potent greenhouse gas (GHG), and relieving pressure on landfills by transforming organic waste into biogas. By offering a clean and sustainable substitute for conventional wood fuel for cooking and heating, biogas helps to protect forests. In doing so, biodiversity is preserved and deforestation is reduced.
- The largest obstacle to the widespread use of biogas is the technical difficulty associated with design, building and maintenance. Knowledge and ability of users, as well as regulations that support the development and implementation of biogas systems are also lacking. This is because proper design, building and maintenance are necessary for biogas systems. Technical difficulties may occur from poorly managed systems, which could result in decreased energy output or system malfunctions.
- The Government of Zambia has a critical role to play in the promotion of biogas technologies in the country. Through laws, incentives and supportive policies, Zambia's government can encourage the use of biogas and propel the sector's expansion. Considering this, the government's most crucial duties in advancing biogas technology are to create supporting policies and regulations, increase capacity and launch public-awareness initiatives.

In summary, innovative methods are now being explored in rural areas to move away from the most common types of heating methods such as using charcoal and firewood, with many programmes being run that are based on gas and biomass. Even though the uptake of gas in rural areas remains low due to perceptions of the dangers of gas, it is seen as a step in the right direction and could help reduce deforestation as the world transitions into a cleaner and greener global economy. It is clear that farm and household biogas will play a significant role in increasing access to basic services such as cooking and lighting, diversifying the energy mix and providing a cleaner and sustainable energy source. However, the gaps identified for the widespread adoption of biogas will need to be addressed, as proposed by the policy recommendations in this report. The adoption of biogas in Zambia, as in many other countries and contexts, can be influenced by various socioeconomic factors, and women and marginalized groups may face specific challenges in this process, such as access to land resources, financial constraints, social norms and gender roles, community dynamics and awareness, and access to information.

The following policy recommendations have been proposed:

1) Educational and training programmes: As awareness of biogas systems remains low among the general population, there is a need to enhance educational and training programmes. This entails several strategic actions including, for instance, the development of a practical curriculum that covers the fundamentals of biogas technology and the implementation of certification programmes to formally recognize individuals who have successfully completed biogas training.

2) Research and development incentives: To counter the decline in local research and development (R&D) in the technology, there is a need to introduce government-funded research grants, as well as to establish of platforms for the international exchange of knowledge and technologies related to biogas, among other measures.

3) Financial support mechanisms: To incentivize the adoption of biogas systems, new financial support mechanisms should be developed. These could entail the inclusion of biogas projects in carbon credit programmes, the provision incentives for manufacturers of biogas equipment to reduce costs and make technology more affordable, as well as other mechanisms.

4) Policy framework for feedstock management: For biogas systems to operate regularly, a robust policy framework for feedstock management needs to be established. This will require the implementation of several measures including, for example, the development of clear classifications for different types of feedstocks suitable for biogas production, the enforcement of regulatory standards for feedstock quality and the engagement of communities in the identification and collection of suitable feedstocks.

5) Grid connection policies: For biogas to play a significant role in future electricity production on a larger scale, it is important to outline mechanisms for its integration into the grid. These will be buttressed by several elements including the simplification and streamlining of the application process for grid connection of biogas facilities and the formulation of requirements for biogas systems to maintain grid stability and power quality.

6) Community engagement and awareness: As household biogas systems would predominantly target local communities, community engagements and awareness of these systems will be essential, including among women, youth and marginalized groups. This policy recommendation advocates for the creation of communication materials and campaigns in local languages to ensure effective communication and the involvement of communities in the planning and decision-making processes related to biogas projects, among others actions.

7) Quality standards and certification: As the number of biogas manufacturers and installers increases, quality standards and certification are essential. This policy recommendation outlines several measures to be taken including, for example, the engagement with standardization national and international organizations to contribute to the development of specific standards for biogas technology and the formation of technical committees consisting of experts in biogas technology, safety, environmental science and related fields.

8) Incentives for agricultural-sector integration: To capitalize on the dual benefits of biogas in energy and agriculture, it's essential to implement incentives for its integration in the latter. For instance, this could be achieved through the creation of community-based biogas hubs that allow multiple farmers to share a centralized biogas facility, as well as the provision of support for farmers to access markets that value environmentally friendly and sustainable agricultural practices, creating demand for biogas-enabled products.

9) Capacity-building for government agencies: For government institutions to effectively manage aspects related to the regulation and promotion of this technology, capacity-building is fundamental. This entails developing customized training modules covering various aspects of biogas technology and facilitating international collaboration and partnerships to access knowledge, expertise, and funding for biogas project development.

10) Inclusion of women, youth and marginalized groups: To ensure inclusivity in the adoption of the technology, this policy recommendation suggests introducing microfinance programs tailored for women, youth, and marginalized groups. Additionally, collaboration with NGOs and civil society groups specializing in women's and youth empowerment is proposed to jointly implement biogas adoption programs, among other measures.

Chapter 1. Introduction

The UNCTAD pilot project was launched to enhance the capacity of stakeholders in sub-Saharan Africa, particularly in the agriculture and energy sectors, by developing and implementing a tailored technology assessment (TA) methodology.

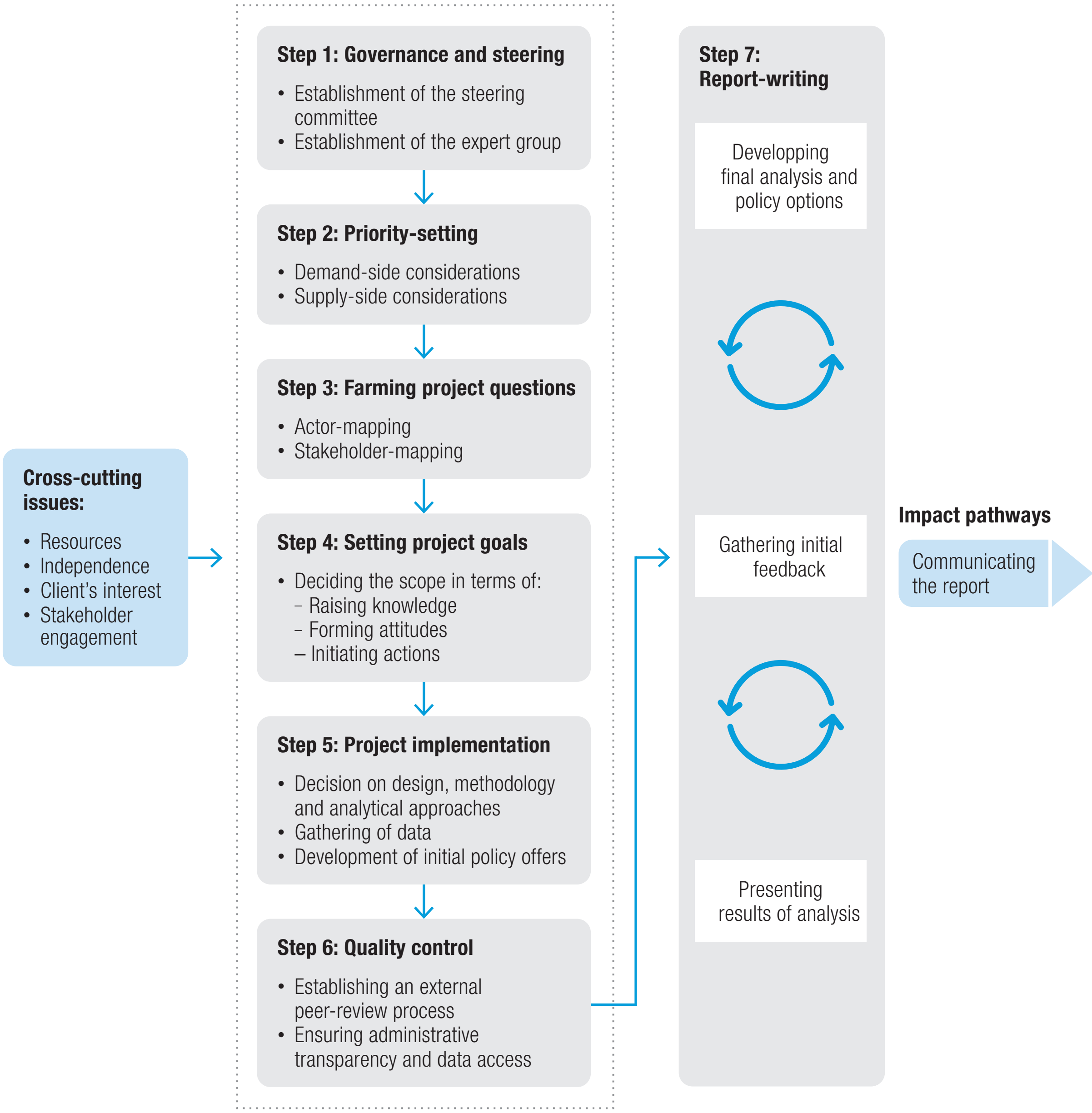
The UNCTAD pilot project on technology assessment (TA) in the agriculture and energy sectors in sub-Saharan Africa was initiated in 2019 with the participation of the governments of Seychelles, South Africa and Zambia. The UNCTAD TA project aimed to build the capacity of national science, technology and innovation (STI) policymakers, academia, the private sector and other stakeholders in sub-Saharan Africa, as well as to propose policies and mechanisms ("know-how") to support the learning, diffusion and adoption of technologies in the energy and agricultural sectors. It is also aimed to build resilience to, and recovery from, the COVID-19 pandemic and future health emergencies.

Zambia participated through the Ministry of Technology and Science (MoTS). The project was officially launched with the first stakeholders workshop organized jointly by UNCTAD and MoTS in April 2022. The workshop had the primary objective of enhancing the understanding of TA among stakeholders, and to pinpoint key areas within energy and agriculture where TA could significantly contribute to Zambia's development. Additionally, it sought to formulate a work plan for Zambia's engagement in the project. The workshop led to the decision to focus the project on the energy sector. Moreover, the proposed work plan was structured according to the seven-step approach outlined by the UNCTAD TA Methodology.

The UNCTAD TA Methodology was developed as part of the project due to the lack of TA methodologies specifically designed for African and other developing countries. These regions often lack a tradition of implementing TA and face challenges when adopting methodologies created for developed countries with established TA practices. As such, UNCTAD's tailored approach aims to foster effective TA in developing countries. The key steps of the UNCTAD TA Methodology are outlined in figure I. 1. Given that Zambia had not embarked on any TA initiatives before participating in the project, the UNCTAD TA Methodology provided the required guidance for the TA.

UNCTAD's tailored approach aims to foster effective TA in developing countries.

Figure I. 1
The steps of the UNCTAD TA Methodology



Source: UNCTAD (2022a).

Chapter 2. The TA process in Zambia

Zambia employed a thorough and structured approach to conduct the TA which grounded on inclusive stakeholder involvement, rigorous analysis of socio-economic factors, and the use of multiple data collection methods to ensure comprehensive insights.

The Zambia TA process followed the seven steps outlined in the UNCTAD TA methodology developed for the project. The first step in the execution of the TA was the establishment of its governing bodies, namely the steering committee and expert group. MoTS drafted terms of references for both entities and appointed members from relevant government ministries, academic institutions, regulatory bodies, and the private sector in December 2022.[1] While MoTS was in charge of the on-site coordination of the project, the steering committee was responsible for overseeing the TA's execution and expert group members validated inputs and suggestions from the UNCTAD consultant, as well as contributed with their own insights.

Following the establishment of the TA governing bodies, the project progressed to selecting the technology to be considered for assessment. This was based on a review of the national policy frameworks, development priorities, the energy sector and the National Innovation System (NIS), which are detailed in Chapters 3 to 5. The expert group convened to deliberate on selecting a technology or technology system by evaluating various technologies against predefined criteria, including resource availability, existing policy framework, assessment feasibility within a limited timeframe, skill availability, technology maturity, and local and external impacts. This process led to the selection of biogas as the technology to be assessed. Details on the selection process are provided in Appendix A.

In the third step, the socio-economic, political, and scientific aspects pertinent to biogas were analysed to pinpoint the precise problems or issues targeted by the TA and formulate an appropriate project design. This phase also involved the mapping of relevant actors and stakeholders, which was undertaken by means of a responsible, accountable, consulted and informed (RACI) matrix, and validated by the expert group, as discussed in Chapter 7.

The findings were derived through an inclusive, holistic, and multi-stakeholder approach.

[1] The composition of the steering committee and expert group is given in Appendix D.

A survey of stakeholders and focus group discussions provided evidence.

The fourth step established primary and secondary goals to be pursued by the TA exercise. The expert group set potential goals related to knowledge enhancement, attitude formation, and initiating actions on biogas development. These were instrumental in shaping the tools employed for the gathering of primary data for formulating relevant policy recommendations. A survey of 30 stakeholders was deemed the most appropriate research method. This approach aimed to collect comprehensive stakeholder inputs and provide a holistic understanding of the current landscape, challenges, and opportunities related to biogas adoption. Furthermore, focus group discussions (FGDs) conducted in December 2023 further delved into the topics covered in the survey and provided additional data. These topics are discussed in Chapter 8.

The findings were derived through an inclusive, holistic, and multistakeholder approach via the review of policy frameworks and data collection, and subsequently analysed and validated by the expert group. The results are outlined in Chapter 9. Finally, these results were used to formulate policy recommendations for biogas adoption, which were subject to validation by the expert group, the steering committee and relevant stakeholders in Zambia at a national stakeholder workshop that took place in February 2024. Based on the discussions during stakeholder validation the TA report was revised and presented to the steering committee for endorsement.

Chapter 3.
Policy frameworks

Zambia has an array of policies related to energy, technology, and innovation that emphasise the importance of diversifying the energy mix and promoting renewable and alternative energy sources such as biogas.

Several national policies in Zambia are key for assessment of a technology producing energy that is in large part based on agricultural outputs and byproducts, particularly energy policies. These policies highlight the high priority of sustainable development and energy security in Zambia.

3.1 National Energy Policy

Noting the overdependency on hydro as a form of electricity generation in Zambia, as well as the dynamics and emerging issues in the energy sector, the effects of climate change and advances in technology, the Government of Zambia, through the Ministry of Energy (MoE) developed the National Energy Policy of 2019 (NEP 2019). Among other things, the policyis aimed at guiding the energy sector in the development of electricity generation, transmission and distribution capacity. The NEP 2019 looks to facilitate the development and deployment of renewable and alternative energy. Furthermore, the policy will promote security of energy supply through diversification of energy sources at cost-reflective pricing that will promote new investment in the sector, consequently scaling up access to energy services in rural and urban areas. The NEP 2019 also considers climate change mitigation and adaptation while advancing sustainable development of the sector. In addition, the policy mainstreams gender and disability aspects aimed at increasing access to clean and efficient energy, thereby reducing poverty among vulnerable groups, especially women and children (Zambia, MoE, 2019). The NEP 2019 recognizes unsustainable and negative effects of traditional wood fuel and notes that the high dependence on wood fuel is due to low access and also unreliable electricity supply, high cost of efficient alternatives, and inadequate enforcement of legislation and coordination among key sector institutions. The NEP 2019 thus considers biogas and biofuels as a feasible alternative by ensuring that they are given priority in the energy market. The policy also lists the envisaged energy sources for Zambia (see table III.1).

3.2 Energy Efficiency Strategy and Action Plan

In 2022, recognizing the dynamic and changing nature of the energy sector, the MoE developed a strategic plan for the period 2022–2026. The strategic plan sights, among other things, changes in policy, legal and climatic change mitigation. The Energy Efficiency Strategy and Action Plan (EESAP) contains the strategic objectives and the accompanying set of actions necessary to achieve the overall objective of the NEP 2019. Ultimately, this objective is optimal energy-resource use to meet Zambia's domestic and non-domestic needs at the lowest total economic, financial, social, environmental and opportunity costs, along with the establishment of Zambia as a net exporter of energy. As part of its strategic

Sustainable development and energy security are high priorities in Zambia.

10 percent of renewable energy excluding hydro by 2026 targeted.

objectives, the plan looks at developing and enabling the legal instruments required to promote the efficient use of energy by increasing access to and facilitating the utilization of energy-efficient equipment and services, as well as by integrating clean energy sources into the Zambian economy. Under strategic objective number four, the MoE intends to utilize energy pricing as a tool to promote energy-efficient technologies such as biogas. In the EESAP, it is clear that biogas will play a major role in finding renewable and alternative energy sources that will be exploited for domestic cooking to replace charcoal and firewood. The EESAP expects that a biogas technology market uptake will be created and access to clean cooking solutions increased. In addition to this, biogas will benefit from the ministry's intention to enable an environment for energy service companies to participate in the biogas value chain. The MoE will also seek to improve sector laws, policies and regulatory frameworks to foster an atmosphere that will encourage more investments (Zambia, MoE, 2022).

3.3 Eighth National Development Plan

The Eighth National Development Plan (8NDP) came into being in 2022 for the period covering 2022–2026 under the Ministry of Finance and National Planning. As part of its development outcomes, Zambia aspires to become an industrialized and diversified economy. This will include increasing agricultural production and productivity, promoting mining of traditional and non-traditional minerals, encouraging value addition and manufacturing, and fostering rural industrialization and tourism diversification. Other strategies will include enhancing generation, transmission and distribution of electricity, and diversifying to other renewable as well as clean alternative energy sources. Strategy number six in the 8NDP looks to enhance generation, transmission and distribution of electricity. Reforms will be implemented to make the sector more efficient and effective.

Focus will be on increasing electricity generation capacity and promotion of alternative green and renewable energy sources as well as scaling up rural electrification. The increase in the generation capacity will be anchored on the reforms that will be undertaken in the electricity subsector to attract private-sector investments. Further, the operations of the national power utility ZESCO Ltd will be streamlined to promote efficiency and sustainability. As part of the diversification agenda, the government will continue promoting investments in green and clean energy solutions to make the energy sector more resilient and supportive of industrialization. During the 8NDP period, investments will also be made to upgrade electricity transmission infrastructure in an effort to reduce transmission losses and promote trade in electricity. The 8NDP also envisages an increase in the contribution of renewable energy (excluding hydro) from the current 3 per cent to 10 per cent by 2026. The 8NDP recognizes that in the energy sector, the focus will be switching towards green and renewable energy sources, such as biogas, solar and wind, and increasing energy-use efficiency as well as reducing electricity transmission and distribution losses from the national grid. As such, given the recognition by this policy document, biogas will benefit from any interventions to be implemented in the energy sector (Zambia, Ministry of Finance and National Planning, 2022).

Table III. 1
Energy sources in Zambia

Energy source	Description
Large hydropower	Over 6,000 MW in potential generation
Solar	Average solar irradiation of 5.5 kWh/m²/day with approximately 3,000 sunshine hours annually providing good potential for photovoltaic
Wind	Average wind speed of 6 m/second measured at 80 m above ground level
Geothermal	More than 80 hot springs spread out in different parts of the country
Small hydropower	Important role small hydropower plays in rural electrification and the off-grid space
Biomass (living)	Predominant source of energy in Zambia accounting for more than 70 per cent of total primary energy supply through charcoal and firewood
Biomass (dead)	Waste to be targeted may include, but not be limited to, municipal solid waste, sewerage wastewater, agricultural crop residues, livestock manure or waste, wood chips or biomass and industrial waste
Coal	Predominant source of energy in Zambia accounting for more than 70 per cent of total primary energy supply through charcoal and firewood
Uranium	Zambia has large deposits of uranium that can be utilized for energy production
Petroleum	Petroleum products contribute 9.4 per cent to the total national energy demand; there is an established infrastructure for petroleum import and trade

Source: Zambia, MoE (2019).

3.4 National Science, Technology and Innovation Policy

The 2020 National Science, Technology and Innovation Policy is a revision of the 1996 National Policy on Science and Technology. It aims to strengthen the policy framework for STI, broaden the balance of policy focus beyond a heavy emphasis on scientific research in the 1996 policy to include more on technology and innovation, and address several weaknesses in the national innovation system (see UNCTAD, 2022a). In order to keep pace with the demands of a knowledge-driven economy and ensure Zambia's competitiveness, the policy addresses research, innovation, human resource development and retention, infrastructure, financing and coordination of STI. It provides guidance on implementation of STI across various sectors such as agriculture, health, energy, education, manufacturing, mining and industry. It recognizes that the dominance of hydropower generation puts the country at risk due to changes in climatic conditions, such as global warming leading to insufficient rainfall and drought, as well as other competing needs for the water resources. These challenges pose a risk of inadequate water resources available for hydropower generation. Furthermore, the policy is clear that, despite the threats to the country's energy security, Zambia has limited R&D capacity to explore alternative sources of energy such as solar, wind, biofuels, geothermal, nuclear and biomass. Thus, the policy guides the MoTS in the overall coordination of national STI programmes as developed and implemented by the line ministries (Zambia, Ministry of Higher Education, 2020). Given the importance of diversifying the national energy mix, expanding biogas systems could provide significant diversification benefits as they could allow for energy independence for most communities and eventually allow for grid-connected users to have a sustainable energy source.

Chapter 4

Energy challenges in Zambia

Chapter 4. Energy challenges in Zambia

Zambia's energy landscape presents a complex web of challenges, notably low access to electricity, environmental degradation, and economic constraints.

4.1 Overview

Zambia has 3,812 MW of installed electricity generation capacity, of which approximately 83 per cent is hydro based (Energy Regulation Board (ERB), 2023). National access to electricity averages at approximately 46 per cent (2021 figures) as tracked by the World Bank's energy progress report (World Bank, 2023). The Government of Zambia set a goal for universal electricity access for all Zambians by 2030 (United States Agency for International Development, n.d.). Due to its dependence on hydro power, the country has faced drops in energy generation that have often led to load-shedding over the last eight years. In January 2023, the government announced a cut in electricity exports due to low power generation caused by a significant drop in water levels at the country's major dam Kariba. The power deficit in Zambia is expected to continue as rainfall has remained average to below average and given the persistently low levels of the Kariba dam at the start of each year. Therefore, load management will likely continue to be implemented for the next few years as water allocation from the regulator falls.

4.2 Low access to electricity

Access to electricity remains low in Zambia, a problem that policymakers have been trying to solve for years through on-grid and off-grid solutions. As noted previously, rural access to electricity remains at approximately 8 per cent and policymakers wish to increase this significantly by 2030 in line with Vision 2030. As Zambia's gross domestic product (GDP) grows, the demand for electricity is expected to increase. A recent cost-of-service study commissioned by the ERB determined that the increase in the number of customers has occurred primarily in urban areas. The study also found that income was an important determinant of demand across all customer categories. In Zambia, the cost of a new connection in a high-density urban area is just under $200, exceeding three times the minimum wage of $60. This makes it difficult to add customers to the grid in such areas, as the cost of connection far exceeds incomes and no innovative financing schemes exist in the market to allow a connection to be made with recoveries scheduled over time. The situation is even worse in rural

Zambia faces economic hardship due to power shortages.

areas as incomes are lower and the grid is far away. While off-grid solutions are being put in place, the cost of connection and subsequent price of power needs to be considered in order not to dissuade consumers due to purchasing-power limitations. In the absence of solutions to the hefty on-grid connection fees, potential rural grid users will continue to use traditional methods of cooking and heating that are detrimental to the environment (Energy Market and Regulatory Consultants, 2020).

The cost of a new connection in a high-density urban area exceeds 3 times the minimum wage.

The government however, via the MoE, has made increasing access to electricity a priority. It seeks to increase rural access to 20 per cent and urban access to 80 per cent by 2030. The government hopes to do this by, among other things:

a) Constructing stand-alone and off-grid systems (solar home systems and mini grids, household biogas systems);

b) Developing a geospatial least-cost planning tool to enhance electrification;

c) Developing a financing mechanism for implementation of an integrated electrification pathway for universal access.

Given that the majority of new customers are predicted to live in cities and have less-established electricity needs than existing customers due to fewer existing appliances, the efforts of the MoE to expand access to electricity will probably result in a decline in the demand for power per customer. Additionally, this would apply to new clients in rural areas. Large numbers of consumers will likely connect who are less wealthy and use less electricity than those who make up the initial customer base. Therefore, despite the realistic goals established, it is unclear how they may be fulfilled given the hefty on-grid connection fees (Energy Market and Regulatory Consultants, 2020).

4.3 Social challenges

Affordable energy is fundamentally connected to achieving development goals. It is directly addressed in the United Nations Sustainable Development Goal (SDG) 7. Access to affordable energy is essential because of its direct role in water, food and health security, as well as in social justice and equity. Increasing access to affordable energy is also a transformative resource for those who live in extreme poverty (Cañizares et al., 2019). In Zambia, it might be difficult to recruit qualified instructors and medical personnel for remote areas without access to power. Everything is impacted by a shortage of energy, from the equipment accessible in schools to the absence of light for pupils to complete their schoolwork. The health of women and children is also negatively impacted by the lack of access to clean energy for cooking, which causes them to spend more time gathering firewood than studying or engaging in other activities. With electricity, homes, schools, clinics, irrigation systems and water purifiers can all be powered, transforming entire towns. Safe, dependable, economical and renewable energy is a significant element in raising the life expectancy of children, increasing school enrolment and increasing the number of people who can read and write (Catholic Agency for Overseas Development, 2017). Finally, absence of electricity may cause lack of access to information and communication technology. During power cuts, people may not be able to use computers and electronic devices, and the use of smartphones and telephones can also be impeded since telephone towers may not be installed with generators (TargetStudy, 2018).

4.4 Economic challenges

Lack of power has a significant impact on the prospects accessible to those living in rural villages in Zambia. The ability of farmers and small businesses to expand their productivity and income is constrained by a lack of electricity. The majority of families, as well as commercial and industrial consumers nationwide, frequently faced eight or more hours of daily power outages in 2015 and 2016. As a result, the Zambian economy has been struggling since the middle of 2015, and growth in the years that have followed has slowed to about 3 per cent (Cardenes and Cooke, 2020). With a national average poverty rate of 54 per cent and a rural poverty rate of 77 per cent, economic progress has not been fairly distributed and poverty rates have remained persistently high. In addition, Zambia continues to fall short on a number of SDGs, especially those that target severe poverty and infant and maternal mortality. The mining industry, which accounts for 77 per cent of exports, is very important to the economy. The nation must therefore make an urgent investment in economic diversification. The COVID-19 led Zambia to be the first country in the COVID-19 era to default on its debt repayments. Only around 8 per cent of rural families are connected to the grid, compared to about 67 per cent of urban households, making access to electricity a major development concern, especially for rural areas (Cardenes and Cooke, 2020).

As an illustration of how Zambia faces economic hardship due to power shortages, droughts in the country in 2014 and 2015 necessitated the expensive purchase by the government of emergency power. Research conducted by the Government of Zambia reveals that GDP growth slowed during the drought period and the ensuing blackouts, this adding to the direct costs of purchasing emergency electricity. Mines, which use 60 per cent of the nation's electricity, were instructed to reduce their electricity consumption by 30 per cent during the severe drought of 2015. This caused the Zambian currency to weaken sharply and the GDP growth rates in the country to drop by about 6 per cent to a low of 2.6 per cent (from levels exceeding 10 per cent only five years earlier). This demonstrates the tremendous impact drought may have on economic growth, even if the drop in Zambia's growth rates had additional causes (Cardenes and Cooke, 2020).

Other economic challenges exist that make it difficult to exploit renewable energy technologies in Zambia, such as high investment costs and non-cost-reflective tariffs. Financial instruments that allow for bankability of such projects are also lacking in the Zambian market; this being coupled with the high cost of capital, it is difficult for local developers to participate in the space.

4.5 Environmental challenges

Climate change is already affecting Zambia's electricity sector through reduced and delayed rainfall, as experienced over the last eight years. This has led to declining water levels in the Kariba dam, which is the single biggest power source for Zambia and neighbouring Zimbabwe. The droughts of 2014 and 2015 led to a 50 per cent decline in the country's hydroelectric generation. It resulted in extended load-shedding (many customers experienced blackouts lasting more than eight hours a day) aimed at preserving water and avoiding a complete shutdown of generating plants and was the start of a power deficit that is becoming increasingly difficult to manage.

Non-availability of electricity also raises environmental concerns. During such periods people begin cutting down trees, killing and poaching animals, ruining primitive farming, removing vegetation, and other activities in order to satisfy their needs. And this has occurred on a large scale, leaving nature no time to recover. Furthermore, since viable options are lacking, governments may allow activities that are detrimental to the environment in order to finance their expenses, for example by granting licences for the killing of animals and allowing the cutting down of trees for the purposes of furniture making (TargetStudy, 2018).

The environmental issues associated with Zambia's lack of electricity are extensive. For instance, those without access to electricity are compelled to utilize other energy sources such as kerosene lamps or wood-burning stoves, which over time can lead to indoor air pollution and respiratory issues. The National Strategy to Reduce Deforestation and Forest Degradation states that an estimated 250,000 to 300,000 hectares of forest are lost in Zambia each year. Wood fuel, increased agricultural production, mining, timber exploitation, bushfires and infrastructural development are all factors that contribute to deforestation. However, many people rely on the forests for their livelihood and survival, particularly in rural areas (Phiri, 2021). This is an extremely high rate of deforestation and is unsustainable (Gonzalez, 2020). Out of the 38 forest reserves in Central Province, Chibombo District has the most encroachment and depletion, primarily as a result of charcoal manufacturing. This indicates a strong demand for and consumption of this energy source and also reflects the fact that its production is the primary land-use system in forests close to urban areas. The majority of the charcoal generated in Chibombo District is transported to the market in Lusaka, where it sells at good profit. This is a situation that many rural villages in Zambia experience, when demand comes from nearby densely populated town and metropolitan centres rather than from within the community itself. Due to the increased demand for wood fuel, many wood fuel companies have implemented non-species-selective cutting regimes, which has led to the catastrophic depletion of forest ecosystems and an ensuing land degradation. The indicated condition is one in which forest destruction persists regardless of tree size, species or quality because rural communities can no longer find fertile land or afford the expenses of agricultural inputs (Mulombwa, 1998).

Chapter 5. Energy landscape

Even though Hydro power contributes to most of the electricity generation of the country, new sources of renewable energy are needed due to the aforementioned challenges.

5.1 An overview of technologies and regulation

The energy landscape in Zambia is predominantly characterized by hydroelectric power, which accounts for 83 per cent of the country's total energy capacity, as shown in table V. 1. Beyond hydroelectricity, non-renewable energy sources collectively contribute 13.8 per cent. Therefore, renewable energy sources other than hydropower predominantly hinge on solar, representing 3.2 per cent of the nation's energy capacity.

Zambia's energy roadmap integrates diversification, affordability, climate and financial resilience.

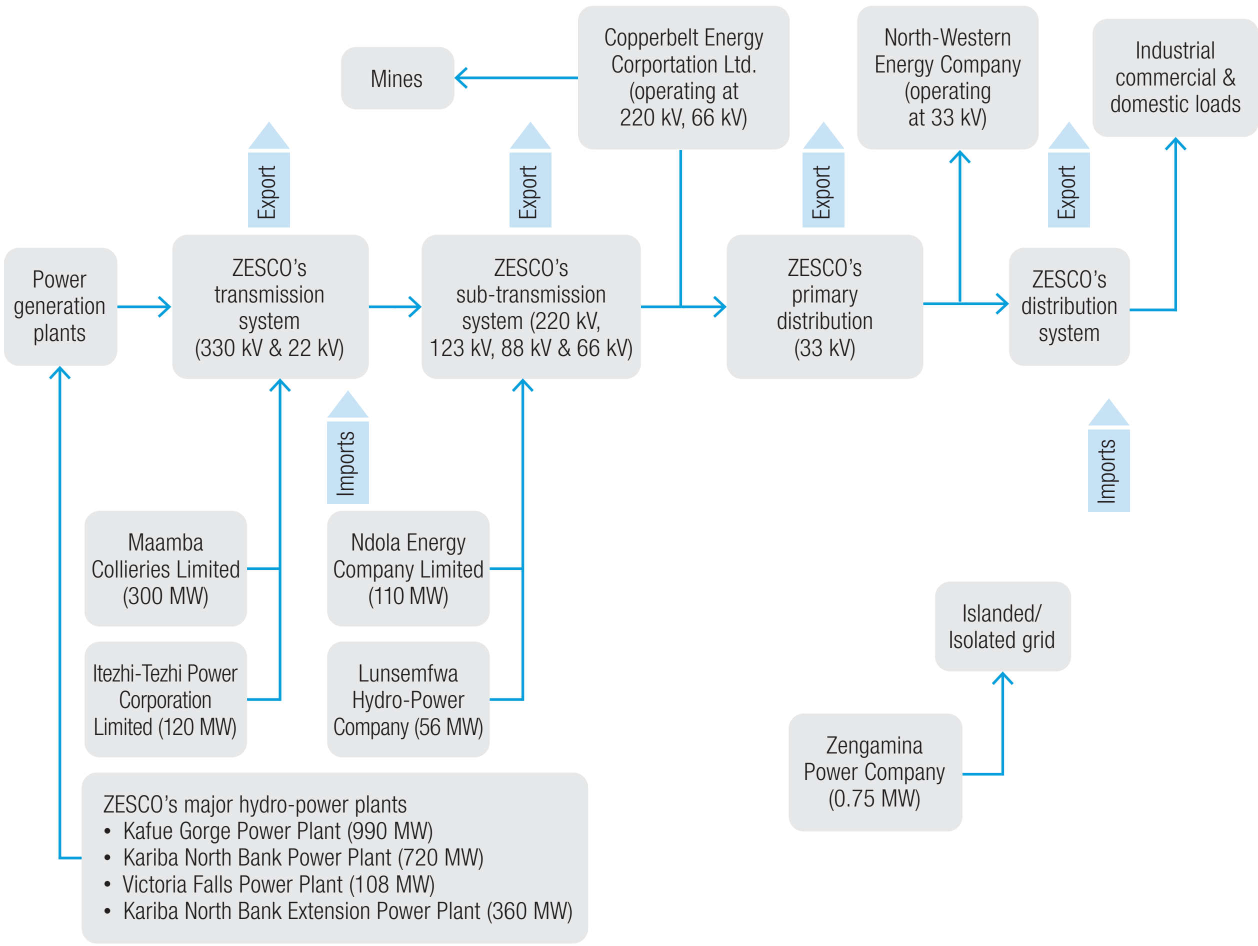
Table V. 1
Energy technology generation in Zambia

Energy technology	Capacity (MW)	National contribution (%)
Hydro	3,152	83.0
Coal	300	8.7
Solar	122	3.2
Diesel	116	2.2
Heavy fuel oil	105	2.9

Source: Energy Regulation Board (2023).

Although there are pockets of private-sector activity in generation, transmission and distribution, the vast majority of power in Zambia is operated by ZESCO, the vertically integrated state-owned utility. However, the sector is opening up to new independent power producers (IPPs) for on-grid and off-grid transactions. At present, over 1,000 MW is generated by IPPs. In addition, Zambia has a privately owned transmission network owned by Copperbelt Energy Corporation (CEC), a utility that had long enjoyed exclusivity in supplying power to the mining industry in the rich mineral province of Copperbelt. In Southern Africa, Zambia has made some of the greatest strides in liberalizing the energy sector as can be seen by the number of IPPs. Zambia also has an off-grid distribution company, Zengamina, that generates power from a 750 kW hydro plant and has its own distribution network supplying a small town in the North-western Province called Ikelenge. Figure V. 1 shows a summary of the structure of the Zambian power sector.

Figure V. 1
Structure of the Zambian power sector



Source: Author.

Excluding hydropower, only 3.2 per cent of the country's energy capacity derives from renewable sources.

The energy sector is regulated by the ERB, a quasi-government institution established by an act of parliament with the MoE providing oversight on matters related to energy policy. In addition to ZESCO making efforts to increase access to electricity, the Rural Electrification Authority (REA) also plays a critical role in increasing access to electricity in rural areas. REA does this by extending the grid to far-flung areas and setting up mini grids for self-generation using a rural development fund and budgetary allocation of funds by the central government. REA's generation projects are small and usually do not exceed 2 MW. It must be noted that Zambia does not have wind generation at present. Given the large hydro resource and significant presence of sunlight for solar in Zambia, wind has not been a priority and not much work on resource mapping has been done. However, some studies have been carried out more recently, such as the Energy Sector Management Assistance Programme, which contains interim wind resource statistics at the eight masts and preliminary energy production forecasts for wind farms around the masts. These studies have determined a promising wind resource. At present, two advanced projects exist in developing wind power in the Central and Eastern Provinces that have a chance of reaching commercial operations within the decade. Table V. 2 shows the power generation plants in the country and the ownership of each plant.

Table V. 2
Power generation plants in Zambia

Power station	Capacity (MW)	Generation type	Ownership
Kafue Gorge Upper	990	Hydro	ZESCO
Kafue Gorge Lower	750	Hydro	ZESCO
Kariba North Bank	720	Hydro	ZESCO
Kariba North Bank Extension	360	Hydro	ZESCO
Victoria Falls	108	Hydro	ZESCO
Itezhi Tezhi Power Corp.	120	Hydro	ZESCO/Tata Power
Lunzua	14.8	Hydro	ZESCO
Lusiwasi	15	Hydro	ZESCO
Chishimba Falls	6	Hydro	ZESCO
Musonda Falls	10	Hydro	ZESCO
Shiwang'andu	1	Hydro	ZESCO
Lunsemfwa Hydro	56	Hydro	IPP
Zengamina	0.75	Hydro	IPP
Kasanjiku	0.64	Hydro	REA
Ndola Energy Corp.	105	Heavy fuel oil	IPP
Maamba Collieries	300	Coal	IPP
Dangote Cement	30	Coal	IPP
Bangweulu	54	Solar	IPP
Ngonye	34	Solar	IPP
CEC Solar (Riverside)	35	Solar	IPP
Muhanya Solar	0.03	Solar	IPP
Solera Power	0.01	Solar	IPP
Standard Microgrid	0.02	Solar	IPP
Mugurameno	0.01	Solar	IPP
Samfya	0.06	Solar	REA
ZESCO Diesel Generation	4.8	Diesel	ZESCO
CEC gas turbine alternators	80	Diesel	CEC

Source: Energy Regulation Board (2023).

5.2 The role of the National innovation system in the energy sector

This refers to the network of institutions, organizations, policies, and resources within a country that interact and collaborate to generate, diffuse and utilize knowledge and innovation for economic and social development. It represents the collective and coordinated efforts of various actors involved in innovation, including government agencies, research institutions, universities, industry sectors and other stakeholders. In Zambia, the basic elements of an NIS exist and are to a certain extent well developed (Chaminade et al., 2018) although there are major weaknesses (UNCTAD, 2022a).

The strength and effectiveness of an NIS depend on the quality of interactions and linkages of the components mentioned above. A well-functioning NIS fosters an environment conducive to innovation, promotes competitiveness and drives economic growth by leveraging knowledge, technology and creativity. UNCTAD (2022a) provides a comprehensive review of the NIS, STI capabilities and harnessing STI for sustainable development.

In the Zambian context, some of the main factors that impede a proper functioning of the system include:

a) The persistence of a "silo" mentality where institutions tend to work in isolation without collaborating with each other;

b) The exclusion of key actors in the innovation discussions, such as technology and trade institutes where crafts and practical training are offered;

c) Outdated curricula that do not allow for increase in knowledge in new technologies and innovations;

d) The weak linkage between universities, research and technology organizations on the one hand and the private sector on the other, driven largely by the lack of collaboration and weak legal and institutional frameworks that are not dealt with by the responsible ministries;

e) Public research organizations and higher education institutions have inadequate provisions for technology transfer;

f) Inadequate visibility of innovation support providers, such as the National Technology Business Centre (NTBC), Citizens Economic Empowerment Commission, Zambia Development Agency and the Technology Development and Advisory Unit (University of Zambia);

g) Low private participation in R&D through mechanisms such as public–private partnerships (PPPs);

h) Low innovation culture in the country due to a lack of sensitization of stakeholders and training of researchers on innovation;

i) Platforms that encourage networking of innovators are lacking (Hahn et al., 2010).

The will for technology transfer in Zambia does exist, as witnessed by the institutions that have been established to aid this. However, successful technology transfer is not straightforward and presents various challenges that need to be overcome. The major barriers to successful technology transfer include:

a) The availability of adequate skills in the institutions charged with technology adoption and adaptation;

b) The willingness and availability of skills in the recipient communities to take up the technology;

c) The availability and lack of understanding of industry players to take up and commercialize the technology;

d) Very low interest from the government, funding agencies and civil societies, among others;

e) Very few to no demonstration projects for communities and the public sector at large (Kunkuta and Musesha, 2011).

In the case of biogas, while some local knowledge exists related to the construction of biodigesters, significant steps need to be undertaken to enhance technology transfer and local mastery of biogas energy to allow the technology to thrive long after the imported technology has been implemented. These include:

a) Training a cadre of skilled engineers, technologists and technicians who will be responsible for the development, adoption and adaptation of the technology;

b) Improving government support to technology transfer activities in respective institutions;

c) Promoting biogas energy technologies in the local communities and industry;

d) Deliberate policies to compel consultants and other international stakeholders to prove technology transfer before project or programme completion (Shane et al., 2014).

There are nonetheless examples of past successful technology transfers and collaborations. The National Institute for Scientific and Industrial Research (NISIR) has been one of the major players in technology transfer projects in Zambia. For instance, a NISIR energy project in collaboration with the Japan International Cooperation Agency that involved the introduction of biogas technology as a pilot project in schools in Central Province, as well as coal briquetting and improved cooking stoves, was successful to some extent but further commercialization of the technologies was hindered due to a lack of industry uptake and local skills in the communities. A programme run by Stichting Nederlandse Vrijwilligers (Foundation of Netherlands Volunteers) called Agriculture for Energy was also a successful programme that utilized biogas technology in particular, but scalability remains an issue (Stichting Nederlandse Vrijwilligers, 2021).

Technology transfer and the development of capabilities to adopt and diffuse energy technologies to the communities is primarily the function of the NTBC, an institution under the MoTS. However, its effectiveness is hampered by weak linkages with the other institutions and industry in general, as well as its reliance on government funding. To be able to transfer energy technology knowledge, Zambia needs to develop a critical mass of skilled expertise in multiple energy technologies by offering programmes in higher education institutions, and research and technology organizations need to improve capabilities in developing and adapting these technologies to the local environment. In addition, capacity-building at the vocational and institutional levels with demonstration projects is essential. It is important for Zambia to develop its own capabilities to introduce and adapt technologies in energy, as any new technology introduced requires capabilities to support its development, adoption, adaptation and more importantly maintenance for sustainability. Without these capabilities, the technology risks becoming obsolete after a few years when the imported technical support departs.

Multiple stakeholders, including government, academia, industry and local communities can collaborate to facilitate technology transfer and build national technological capabilities. Collaboration starts with constructive dialogue to share information and knowledge on the benefits of the technology, expectations, and the roles of each stakeholder. Open communication together with demonstration of the benefits of the technology by project proponents assist to facilitate technology transfer.

5.3 Energy roadmap for Zambia

Given the social, economic and environmental challenges listed in the preceding chapters, it is clear that a solution for energy relating to heating, lighting and cooking is required for Zambia. Candidate technologies are highlighted below that allow for a movement away from the traditional ways of generating energy.

The Integrated Resource Plan (IRP) is a power-sector plan for the next 30 years. Zambia's energy roadmap integrates diversification, affordability, climate and financial resilience to provide high-quality service to customers countrywide. The IRP comprises an assessment of Zambia's future energy needs and a plan to meet those future needs. It is "integrated" in that it examines both demand-side resources (conservation, energy efficiency and the like) as well as supply-side resources (generation/ power plants, transmission lines and the like) in making its recommendations on how best to meet future energy needs in the country.

As indicated previously, over the last two decades, Zambia has seen its environment increasingly altered by the effects of climate change. This has had an impact on Zambia's energy sector which is hydro dependent, leading to power shortages. In addition, the sector faces financial challenges owing to inadequate revenues.

Therefore, the IRP seeks to address four main challenges faced by the energy sector:

a) **Dependency on hydro generation**: Traditionally, Zambia has relied on hydropower to meet the electricity consumption needs of both commercial and non-commercial consumers. Hydropower accounts for 83 per cent of Zambia's total electricity output. Over the last decade, however, Zambia's hydropower sources have become increasingly susceptible to climatic changes leading to shortages of power supply across the country. Through the IRP, Zambia's energy sector will have the opportunity to investigate the viability of alternative sources of energy, particularly those in the renewables space such as wind and solar power generation.

b) **Climate risk**: In Zambia, the last decade has seen an increase in climatic variability, which has negatively impacted the capacity of the country's two largest hydropower stations to produce sufficient power to meet the nation's consumption patterns. The risk from climate change is compounded by increasing competition for available water resources for agriculture, industry and human consumption. In developing an IRP, the Zambian government will not only provide for alternative sources of energy, but plan for and mitigate the future climate change impacts likely to be faced by the country.

c) **Financial sustainability**: Sector arrears to IPPs have accrued over the past five years in part due to power procurements made at a significantly higher cost than power from existing hydro generation sources. The increased cost of power production has not been sufficiently factored into end-user tariffs, resulting in the accumulation of arrears under power purchase agreements. The IRP will provide a road map for sector financial sustainability, and thereby build confidence with investors and lenders to support priority investments in power generation, transmission and distribution in Zambia in the years ahead.

d) **Grid readiness**: The last three decades have seen a steady increase in Zambia's population as well as an expansion in new areas of economic activity away from the capital city of Lusaka and the mining towns of the Copperbelt and North-western provinces. This has caused an increase in Zambia's energy demand. However, eight of the country's ten provinces remain underserved with restricted and unstable grid connectivity. To meet this rising demand, Zambia must extend the grid to connect emerging areas of economic activity and population centres, as well as to parts of the country that have promising renewable energy resources. A strategy for addressing these grid management challenges is a key component of the IRP.

The key outcomes expected from the implementation of the IRP include:

a) Growth in Zambia's generation capacity by identifying alternative energy sources other than hydropower;

b) Improvement of the long-term reliability, affordability, efficiency and security of electricity supply;

c) Reduction of the short- and long-term costs of delivering electricity services;

d) Creation of local economic and social benefits from electricity-related projects, activities and programmes, including power generation projects;

e) Reduction to a minimum the environmental, climatic and other social, cultural and economic impacts of electricity supply and use.

Overall, implementation of the IRP will improve access to clean, reliable and affordable electricity for all at the lowest total environmental, social, economic and financial cost.

The IRP will ensure that the energy sector is able to play its role to advance economic growth, job creation and investment in the economy, and to extend energy access to the whole of Zambia's population (Zambia, MoE, 2021).

Chapter 6

The biogas technology

Chapter 6.
The biogas technology

Despite its challenges including high up front costs, limited expertise and policy gaps, biogas technology has the potential to address sustainable energy needs of Zambia.

6.1 Production of biogas

As described in IEA (2020), biogas is a mixture of methane, carbon dioxide, sulphur dioxide and small quantities of other minor gases that is obtained from organic waste. In particular, biogas is produced through an anaerobic process in which organic materials such as agricultural waste, animal waste, wastewater biosolids and food wastes are broken down by bacteria. This biological process requires optimal conditions of inputs such as temperature, water and feedstock, and it may also necessitate and bacterial inoculation in larger-scale production (FAO, 2020). The specific composition of biogas varies depending on the type of feedstock and the production method. Among the various production methods, IEA (2020) identifies three main such technologies:

- **Biodigesters**: These are sealed systems, such as containers or tanks, where organic material mixed with water is decomposed by naturally occurring microorganisms. Biodigesters come in two main types: fixed dome with a stationary gas holder atop the digester and floating drum with a movable gas holder (FAO, 2020).
- **Landfill gas recovery systems**: Biogas is generated through the anaerobic decomposition of municipal solid waste at landfill sites. Pipes and extraction wells, along with compressors, are used to capture and transport the biogas to a central collection point.
- **Wastewater treatment plants**: These facilities can be equipped to recover organic matter, solids, and nutrients like nitrogen and phosphorus from sewage sludge. Through additional treatment, sewage sludge can serve as a feedstock for biogas production in an anaerobic digester.

6.2 Benefits and challenges

The benefits of biogas have been widely documented in literature on biogas. For instance, a study by Surendra et al. (2014) underscores the potential of biogas technology in developing nations. It emphasizes how access to affordable energy services is vital for sustainable development, linking energy availability to improvements in education, health, employment, and overall quality of life. Biogas technology offers opportunities for waste management improvement, clean energy production, workload reduction (especially for women and children), and local employment creation. Additionally, it highlights the economic viability of utilizing renewable feedstocks like animal manure and crop residues for biogas production. Furthermore, the study also suggests that widespread adoption of biogas technology could reduce greenhouse gas emissions and create opportunities for carbon trading, generating revenue for further research and development. Reports from the Food and Agriculture Organization (FAO) and the International Energy Agency (IEA) highlight

Biogas could help transform Zambia's sustainable energy future.

Biogas could provide more than 3 million households with energy for cooking and lighting.

the potential of biogas in meeting the needs of rural communities (FAO ,2020, and IEA, 2020). These communities rely heavily on agriculture and livestock farming as their main source of livelihood, and therefore generate significant amounts of biomass waste. Biogas production offers interesting possibilities for rural communities, such as nutrient recycling through digester products for agricultural production, reduced deforestation and time spent collecting firewood, and increased job opportunities in low-income communities. As universal supply of electricity cannot be attained in the medium term, biogas energy may be sufficient to address the communities' energy needs as they primarily consist of cooking and lighting. Therefore, biogas offers a sustainable way to meet community energy needs, particularly when access to grid electricity is unavailable or significant heating needs are required to be met quickly. In fact, this technology has already been adopted on a small scale, and some communities in Zambia are already addressing their energy needs through biogas, thanks to readily available feedstock and trained personnel. Therefore, biogas is poised for transforming Zambia's sustainable energy future.

Although biodigesters are commonly associated with household-level needs in Zambia, the IEA recognizes the critical role that biogas is likely to play in the energy transition, especially in developing countries (IEA, 2020). The increasing population of Zambia and economic growth invariably lead to a society that produces increasing amounts of waste that can be used to produce cleaner energy with high potential for sustainable development. In turn, biogas supports a circular economy that yields benefits from reduced carbon emissions and deforestation, improved waste management and enhanced agricultural production. Additionally, the upgrading of biogas to biomethane, also known as renewable natural gas, is also considered a potential source of future growth. In sub-Saharan Africa, Zambia has fallen behind other countries in the adoption and usage of biogas, despite research on the fuel and its implementation having begun as early as the 1980s, as described in Shane et al. (2015). Studies found that crop leftovers and animal dung have a potential of high annual biogas production. The fuel could provide more than 3 million households with enough energy for cooking and lighting.

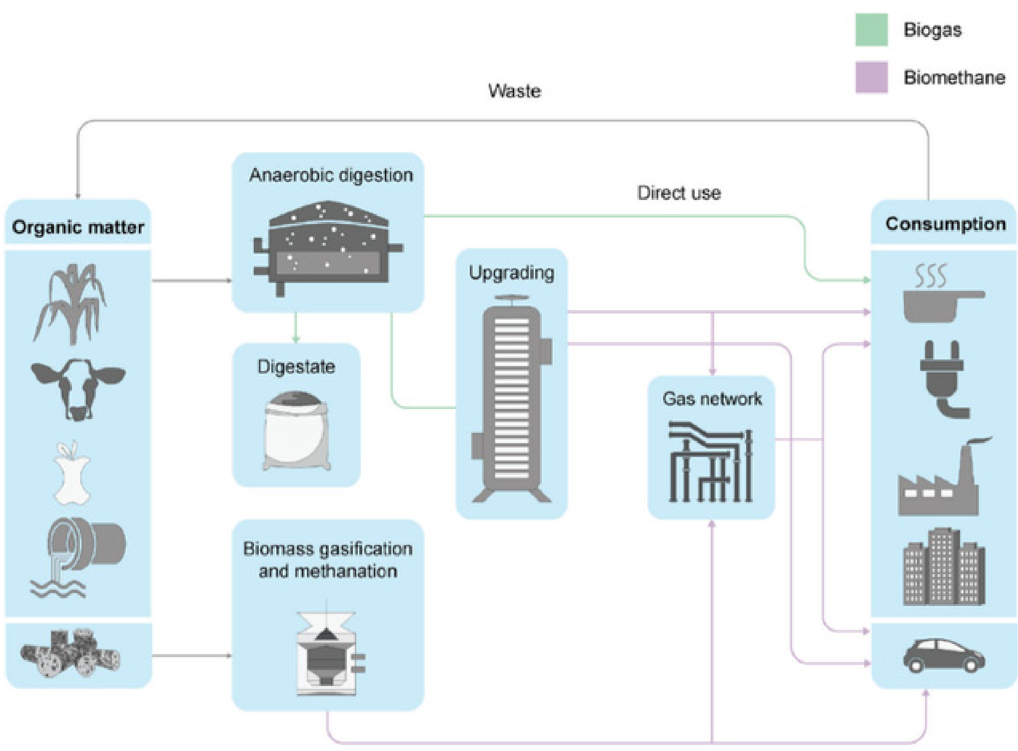
Besides the various potential benefits, studies have also identified various challenges for the adoption of biogas. Surendra et al. (2014) finds that, despite its many benefits, biogas technology faces barriers to widespread adoption in rural communities of developing countries, including high installation and maintenance costs, a preference for fossil fuels over renewables in many economies, and a lack of expertise in constructing and maintaining biogas plants. Additionally, energy receives limited attention in policy debates and technical education, hindering its implementation. Management challenges and water scarcity further impede biogas project success, while unsuitable temperatures in certain regions pose additional obstacles to biogas production. Patinvoh and Taherzadeh (2019) report that, in developing countries, biogas holds great potential as a clean energy solution, yet its widespread adoption is impeded by inadequate infrastructure, lack of capital, and ineffective policies. Focusing on Zambia, Shane et al. (2015) maintains that the lack of finance, lack of regulations, lack of strategies, a lack of interest from investors, a general lack of expertise and lack of knowledge about the advantages of biogas technology among leaders, financial institutions and the general public have adversely affected the implementation of biogas. In addition, a resistance to change based on local customs and culture, especially in the rural areas, the high installation and maintenance costs of biogas digesters, a lack of incentives and social equity, the complexity of the carbon market, and poor management and oversight of installed digesters are also contributing factors. Furthermore, inadequate R&D adds to the difficulties that have prevented Zambia from adopting and sustainably implementing domestic biogas production.

Figure VI. 1 shows the construction of a domed biogas digester in Zambia. The diagram in figure VI. 2 shows the biogas ecosystem.

Figure VI. 1
Construction of a biogas digester in Zambia

Source: Stichting Nederlandse Vrijwilligers – Netherlands Development Organisation (2021).

Figure VI. 2
Biomass gasification



Source: IEA (2020).

Chapter 7. Actor and stakeholder mapping and engagement

Collaboration among various actors and stakeholders is key for the successful implementation of biogas projects in Zambia.

7.1 Actor mapping

Actors are persons, groups or organizations acting within a system of interest. They are directly involved in the process and responsible for outputs and implementation of a particular project. Actors can also be partners who provide financial and technical support and are usually important with significant influence on the outcome of a project.

For the biogas TA that is the subject of this report, the actors detailed in table VII. 1 will need to collaborate, interact and contribute to the development and implementation of biogas projects, whether for electricity or agricultural uses such as the production of fertilizer. Effective coordination and collaboration among them are essential to the successful adoption and expansion of biogas technologies in the country. Therefore, stakeholder engagement is crucial for understanding biogas adoption dynamics. The actors in table VII. 1 are categorized into developers of biogas technology projects in Zambia (those actors which support implementation of projects), regulators of biogas projects and adopters, those adopting the use of biogas technology.

A RACI matrix is useful to clarify and define the roles and responsibilities of different actors. It also helps to identify the level of involvement and participation of each actor in a specific task or decision-making process. For biogas energy in the Zambian context, the RACI matrix is shown in figure VII. 2.

In this context, groups or individuals falling under “Monitor” typically exhibit low interest and influence in the project, but their involvement is necessary to oversee developments that might impact their specific areas of interest. Conversely, those under “Keep informed” are actively engaged in the project, regularly updated on task progress or deliverables, and demonstrate a high level of interest. “Keep satisfied” refers to stakeholders whose approval of project activities is essential, given their significant influence on the project’s outcome. Lastly, “Manage Closely” designates groups or individuals deeply invested in the project, possessing both a high level of interest and influence, necessitating close consultation due to their direct involvement in shaping the project’s ultimate success.

Stakeholder engagement is crucial for understanding biogas adoption dynamics.

Table VII. 1
Biogas technology actors

Actors		
Developers of biogas projects in Zambia	**Regulators**	**Adopters**
Ministry of Energy (MoE)	Energy Regulation Board (ERB)	Rural communities
Ministry of Technology and Science (MoTS)	Ministry of Agriculture (MoA)	Farmers
MoA	Ministry of Green Economy and Environment (MoGEE)	Grid-connected power users
Ministry of Fisheries and Livestock (MoFL)	National Science and Technology Council (NSTC)	Schools
Ministry of Lands and Natural Resources (MoLNR) (Forestry Department)	Zambia Environmental Management Agency (ZEMA)	Health centres
Ministry of Health (MoH)		Municipalities
MoEd		Women
Ministry of Green Economy and Environment (MoGEE)		
Municipalities		
ZESCO Ltd		
Rural Electrification Authority (REA)		
Farmers		
Engineering companies		
Academia and research Institutions		
Technology companies		
Equipment manufacturers		
Banks		
Microfinance institutions		
Biofuels Association of Zambia (BAZ)		

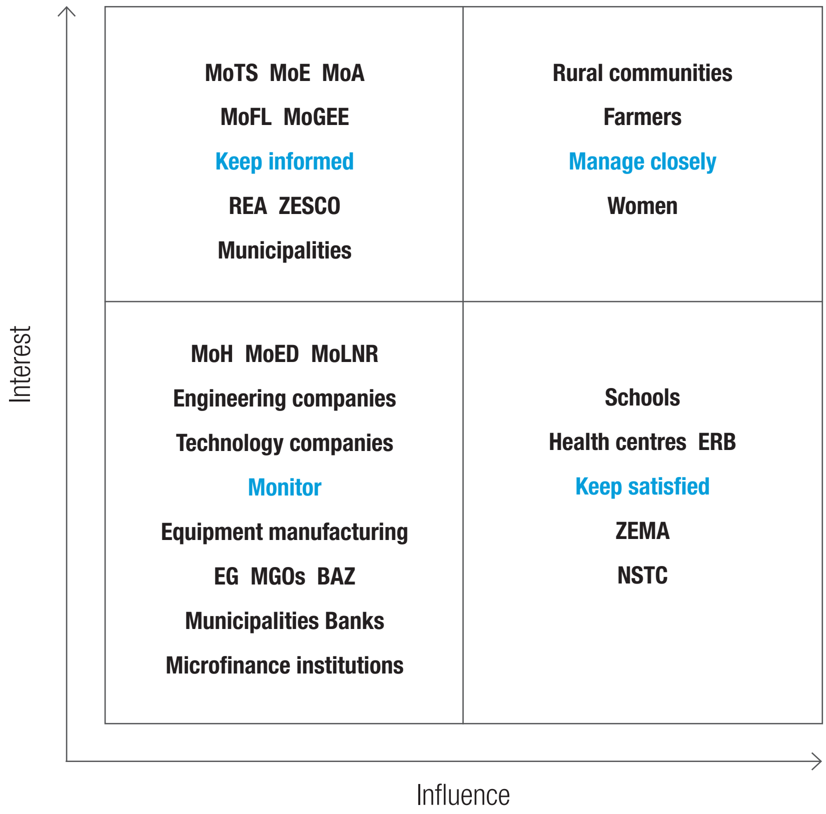
Source: Zambia TA Expert Group.

7.2 Stakeholder mapping

A stakeholder is a person, group or organization that is affected by, interested in or can affect the project.

It is important to understand that the specific impacts of biogas on stakeholders may vary depending on factors such as geographic location, socioeconomic context and the scale of biogas implementation. Biogas technology in Zambia has the potential to impact multiple stakeholders. Some key stakeholders that may be affected are shown in table VII. 2.

Figure VII. 1
Actor RACI matrix



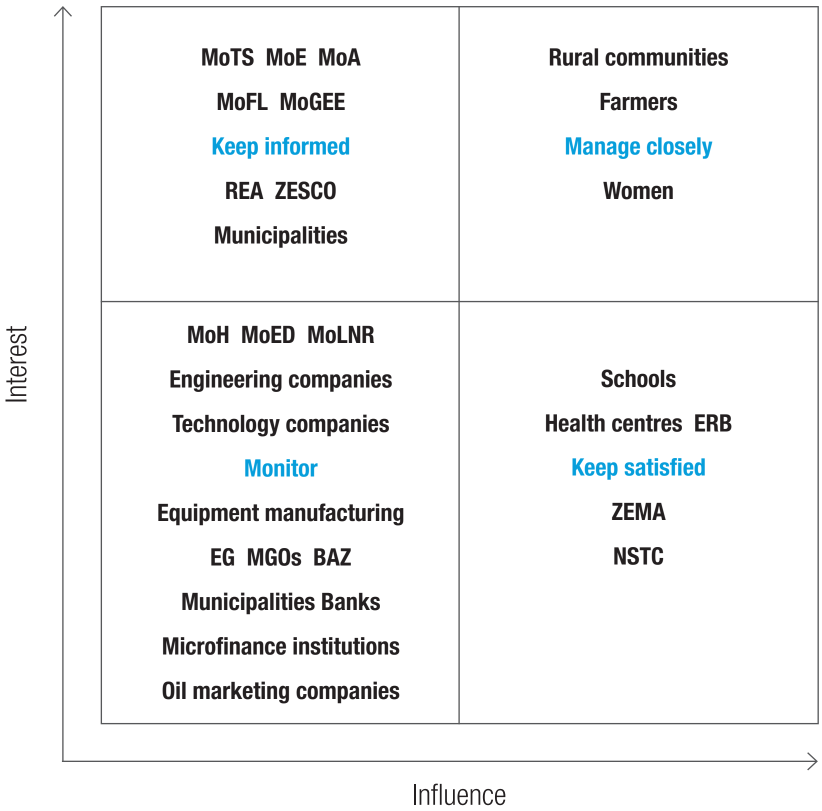
Source: the authors.

Table VII. 2
Biogas technology stakeholders

Stakeholders	
Banks	MoH
BAZ	MoLNR (Forestry Department)
Equipment manufacturers	MoTS
Farmers	Non-governmental organizations (NGOs)
Microfinance institutions	Oil marketing companies
Ministry of Local Government (MoLG)	REA
MoA	Rural communities
MoE	Technology developers
MoEd	Universities
MoFL	Zambia Environmental Management Agency
MoGEE	ZESCO Ltd

Source: Zambia TA Expert Group.

Figure VII. 2
Stakeholder RACI matrix



Source: the authors.

7.3 Stakeholder engagement methodology

Developing an evidence base for a TA on small-scale biogas in Zambia required a comprehensive approach that combined a survey and FGDs. The survey was designed to capture a holistic understanding of the current landscape, knowledge, attitudes, challenges and opportunities associated with biogas adoption in the country. In addition, actors and stakeholders were encouraged to participate in FGDs to provide further insight and elaborate on survey responses.[2]

[2] The survey and the guiding questions used in the FGDs are provided in Appendices A and B.

7.3.1 Characteristics of the survey and FGDs

The survey and the guiding questions of the FGDs had the following characteristics:

a) **Objective clarity**: The survey clearly defined objectives, outlining the specific aspects of biogas technology to be assessed. This included features, risks, opportunities, awareness levels and potential barriers.

b) **Multidimensional question design**: Questions covered multiple dimensions, including knowledge about biogas, perceptions of its benefits and risks, current usage or willingness to adopt and awareness of available support or incentives.

c) **Quantitative and qualitative elements**: The survey incorporated a mix of quantitative and qualitative questions. Closed-ended questions with predefined response options provided quantifiable data, while open-ended questions in the FGDs allowed for qualitative insights and nuanced responses.

d) **Local context consideration**: Questions were contextualized to the local conditions in Zambia, considering factors such as geographical variations, cultural aspects and economic considerations that have an impact on the adoption of biogas.

e) **Safety and environmental concerns**: Given the nature of biogas technology, the survey included questions addressing safety concerns during installation and usage, as well as perceptions of its environmental impact.

f) **Awareness and education levels**: Assessing the awareness levels and educational needs related to biogas technology were a crucial component. This involved questions about the sources of information, preferred communication channels and perceived gaps in understanding.

g) **Perceived barriers and opportunities**: Participants were asked about the perceived barriers hindering biogas adoption and the opportunities they saw in embracing this technology. This included financial considerations, technical know-how and policy-related factors.

h) **Government and policy awareness**: Questions were included to gauge respondents' awareness of government policies and incentives related to biogas, as well as their opinions on the role of government in promoting its adoption.

i) **Ethical considerations**: The survey adhered to ethical guidelines, ensuring participant confidentiality, informed consent and responsible data-handling practices.

The survey questionnaire and FGD guiding questions are attached as appendixes B and C, respectively.

7.3.2 Data analysis of survey results and FGDs

Data analysis followed a systematic approach, as valuable insights were derived from the survey results, contributing to a deeper understanding of the current landscape and informing strategies for promoting biogas technology in Zambia. This also allowed the identification of patterns and conclusions to be drawn from the data gathered. Results from the survey and FGDs were analysed by:

a) **Quantitative analysis**:
For closed-ended questions with quantitative responses, descriptive statistics to summarize key metrics such as proportions. In addition, visual representations of the data to facilitate easy interpretation were created.

b) **Qualitative analysis**:
For open-ended questions, thematic analysis to identify recurring themes and patterns in participants' qualitative responses were performed. The responses were then categorized into meaningful groups to extract insights on common sentiments or concerns.

c) **Subgroup analysis**:
Subgroups within the data set, such as those who were already familiar with biogas versus those who were not, were analysed to assess variations in responses based on the participants' characteristics.

d) **Synthesis and reporting**:
Key findings were synthesized into a cohesive narrative, highlighting major trends, insights and patterns.

e) **Recommendations**:
Recommendations based on the analysis were provided, suggesting actionable steps for addressing identified challenges for the implementation of biogas. Recommendations also considered implications for policy, awareness campaigns and future research.

Chapter 8. Analysis of the findings

Zambia faces varying levels of awareness and knowledge about biogas technology, indicating the need for targeted educational strategies. Despite the positive view of biogas as a sustainable energy solution driven by concerns about climate change, technical challenges, knowledge gaps, and the lack of supportive policies hinder widespread adoption. Government intervention through policies and incentives is crucial for scaling up biogas adoption. Additionally, there are diverse perceptions and concerns among stakeholders, emphasizing the need for comprehensive strategies and collaboration to promote biogas technology effectively.

The survey data and FGDs tell a story of varying levels of awareness and knowledge about biogas technology across different demographics, sectors and regions in Zambia. While there is a foundation of awareness, especially among certain sectors and age groups, there are clear opportunities to broaden and deepen this understanding across the board. The gender disparity in awareness, regional differences in knowledge levels and sector-specific gaps in awareness point to the need for targeted educational and promotional strategies. By addressing these disparities, stakeholders can foster a more inclusive and informed dialogue around the adoption and implementation of biogas technology in Zambia, potentially leading to more sustainable energy solutions and agricultural practices.

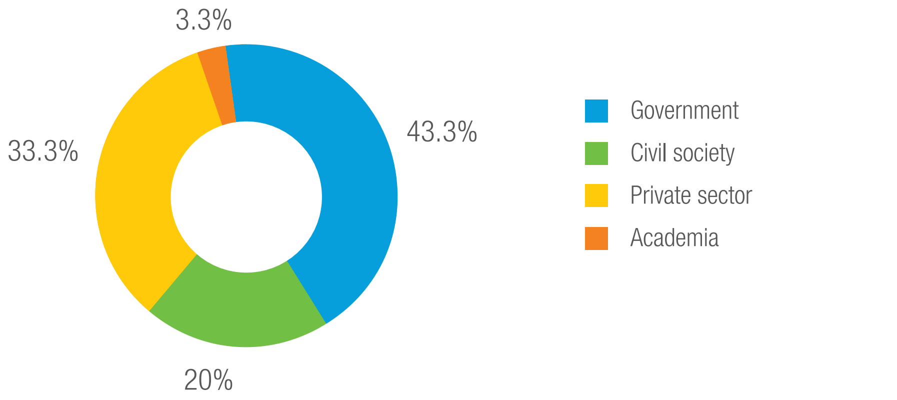
This narrative underscores the importance of tailored communication and outreach efforts to ensure that the benefits of biogas technology are understood and accessible to all segments of the population, thereby supporting Zambia's energy access and sustainability goals.

8.1 Survey findings

The survey results are based on a sample of 30 respondents of which 6 were women 16 were youths ranging between the ages 18–34. Respondents represented different groups, with 13 respondents representing the government or a government-related entity and with 10 respondents representing the private sector, as shown in figure VIII. 1. Within civil society, six respondents were identified, representing NGOs addressing diverse issues such as poverty and marginalization, rural development, women's rights, and sustainable resource management, among others. Finally, one respondent represented the academia.

Concerns about climate change are crucial to motivating biogas adoption.

Figure VIII. 1
Stakeholder groupings

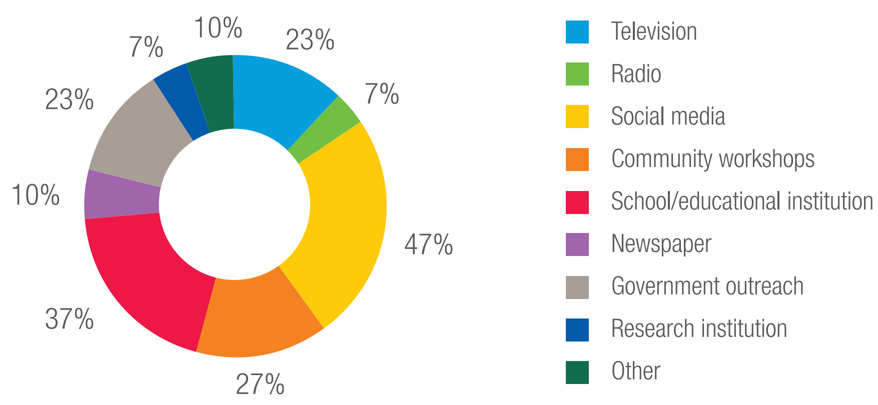


47 per cent of the respondents reported receiving information about biogas on social media.

Although all respondents were aware of biogas technology, the respondents reported receiving information on biogas from a variety of sources, as shown in Figure VIII. 2. It is noteworthy that 47 percent reported receiving information about the technology through social media. Another significant source of information for 37 percent appear to be schools or educational institutions. Moreover, community workshops, television, and government were each cited by approximately one-fourth of respondents as sources of knowledge.

A key aspect of why the survey was conducted was to understand how respondents saw biogas as a potential energy source. Noting the agricultural

Figure VIII. 2
Source of knowledge on biogas



benefits of biogas, the survey needed to show whether energy for the time being was also the most important aspect for stakeholders to be considered in the development of the technology. In addition, if respondents deemed it to be a potential energy source, it was crucial to ascertain which aspects of the country's energy challenges they believed biogas could effectively tackle. Figures VIII. 3 and VIII. 4 show that respondents clearly see biogas as a source of sustainable and cleaner energy that also assists in diversifying the energy mix.

Figure VIII. 3
Survey results on features of biogas

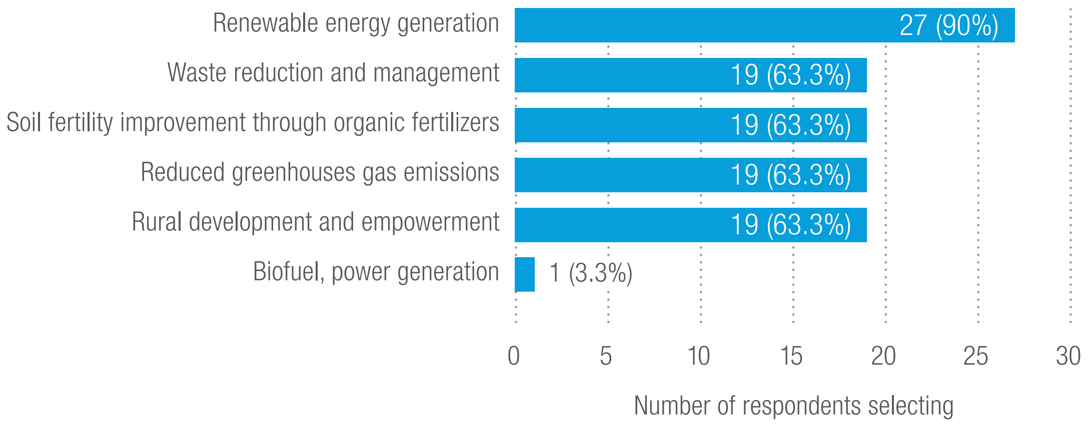
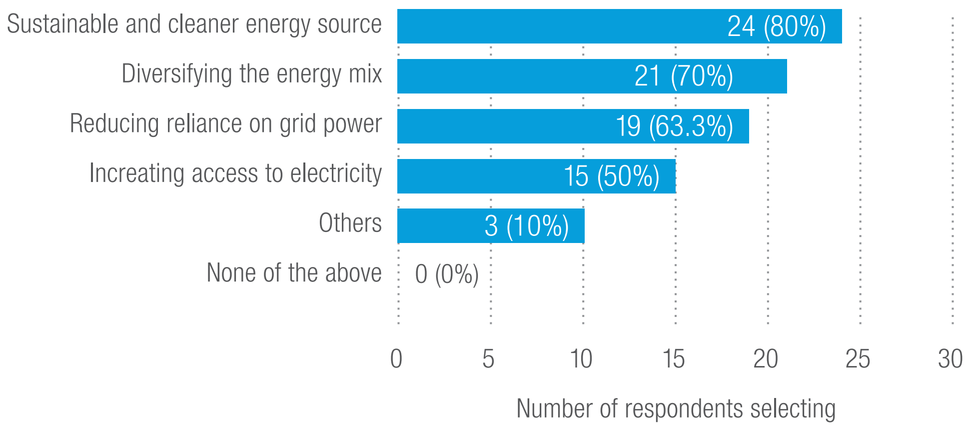
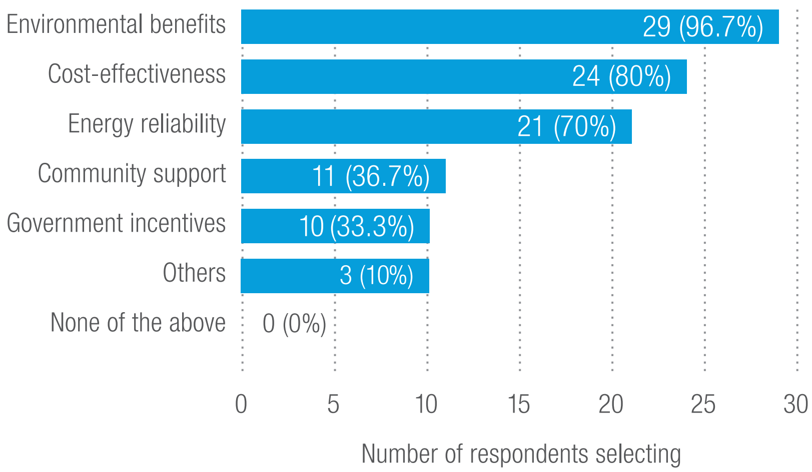


Figure VIII. 4
Survey results on biogas addressing energy challenges



The survey included questions to explore what would encourage them to adopt biogas technology. Most respondents (96.7 per cent) stated that environmental benefits would be the major reason for them to adopt biogas technology, followed by cost-effectiveness (80 per cent) and energy reliability (70 per cent) as shown in figure VIII. 5. The high ranking of environmental considerations as a reason for adopting biogas shows high awareness of climate change and willingness to adopt alternative energy methods for the sake of the environment.

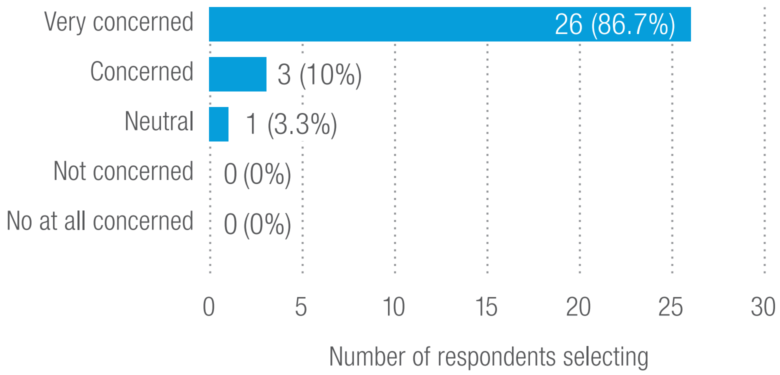
Figure VIII. 5
Motives for adopting biogas



The vast majority of respondents were also concerned about the negative effects of the traditional sources of energy such as wood and charcoal on the environment, with 96.7 per cent of respondents stating that they are very concerned or concerned about the environmental impact of these traditional sources. This suggests that concerns about climate change are crucial to motivating biogas adoption. None of the respondents stated that they were not concerned about the impact of charcoal and wood, which shows that people are generally aware of the problems arising from use of these fuels, as shown in figure VIII. 6.

Figure VIII. 6

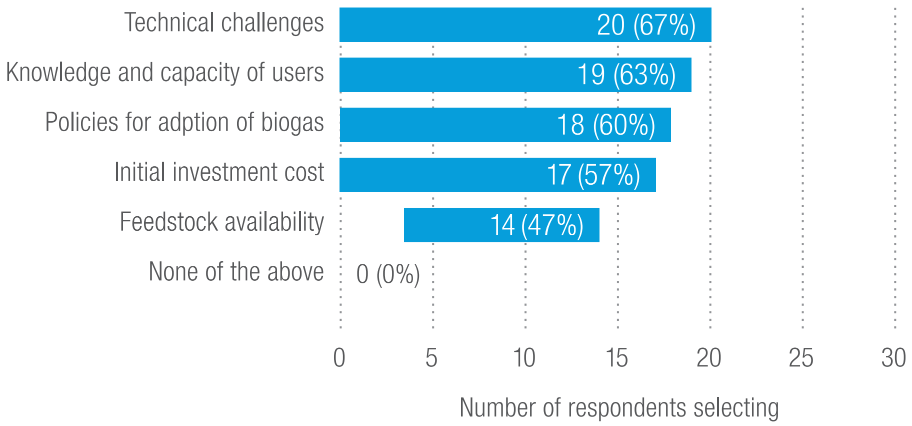
Survey results about concerns on environmental impact of traditional energy sources



The survey also sought to determine the perception of stakeholders regarding potential challenges or risks associated with the widespread adoption of biogas technology in Zambia. Biogas systems require appropriate design, construction and maintenance, and technical challenges can arise if systems are not well managed, potentially leading to reduced energy production or system failures. In addition, the success of biogas systems relies on a consistent and adequate supply of organic feedstock, such as animal manure and crop residues. Inconsistent feedstock availability can hinder biogas production and setting up biogas systems can require significant upfront investment in infrastructure and equipment. This can be a barrier for individual farmers or communities with limited financial resources. Respondents noted that the biggest challenges to the widespread adoption of biogas were technical ones related to design, construction and maintenance (67 per cent). This was followed by knowledge and capacity of users, and policies that encouraged the adoption of the technology at 63 per cent each and 60 per cent, respectively, as shown in figure VIII. 7.

Figure VIII. 7

Survey results for potential challenges or risks associated with the widespread adoption of biogas technology in Zambia



Zambia has a significant agricultural sector and biogas technology can help make productive use of agricultural residues, enhancing energy diversification and farm sustainability. However, for the technology to be scaled up significant government support will be required. Zambia's government has the opportunity to promote biogas adoption through supportive policies, incentives and regulations, driving the growth of the biogas sector. Given that, respondents were asked what role the government should play in promoting the adoption of biogas technology in Zambia. Most respondents stated that developing supportive policies, capacity-building and public awareness campaigns are the most important roles that the government can play in promoting biogas technology, as shown in figure VIII. 8.

Noting the role that government would need to play in the adoption and implementation of biogas technology, stakeholders were asked to state what support mechanisms or incentives the government could provide that would eventually lead to policy recommendations. Respondents stated that technical assistance, community engagements and low interest loans would incentivize the adoption of biogas technology. Other mechanisms that were supported were demonstration projects and tax benefits as shown in figure VIII. 9.

Figure VIII. 8

Survey results for government role in implementing supportive policies

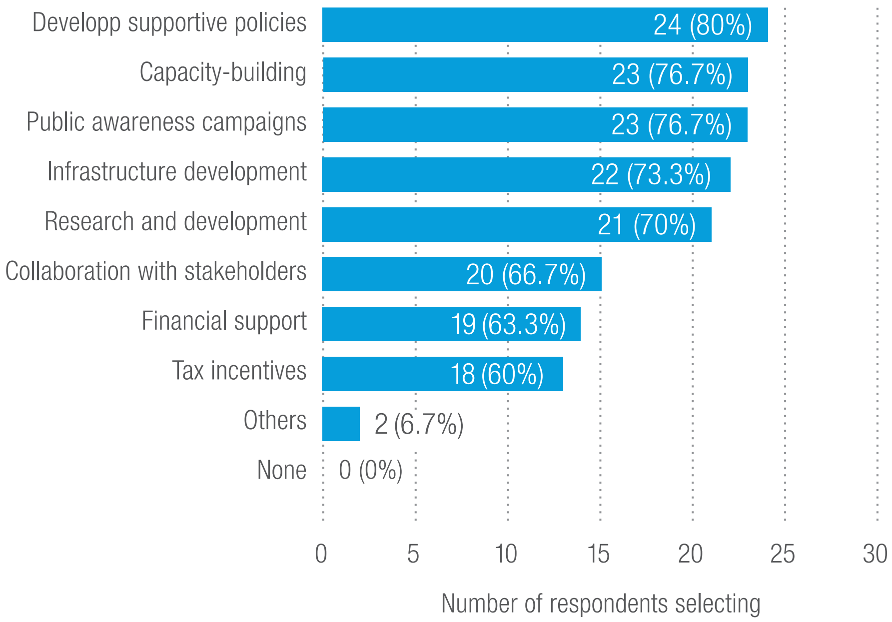


Figure VIII. 9

Survey results for incentives or support mechanisms to encourage adoption of biogas technology

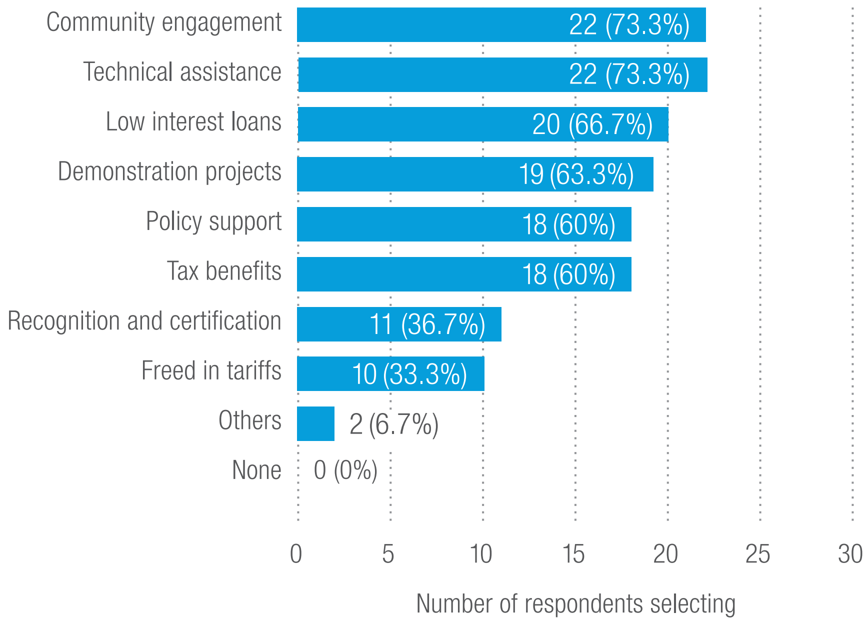


Figure VIII. 10 illustrates the levels of knowledge about biogas technology among the primary stakeholder groups. The data reveals that while there are pockets of knowledgeable individuals within the government regarding biogas, overall, the vast majority of government representatives have only a moderate level of understanding. Particularly noteworthy is the private sector's high level of knowledge compared to other groups. Conversely, respondents from the civil society exhibit a more evenly spread range of knowledge.

Figure VIII. 10
Knowledge of biogas technology across stakeholder groups

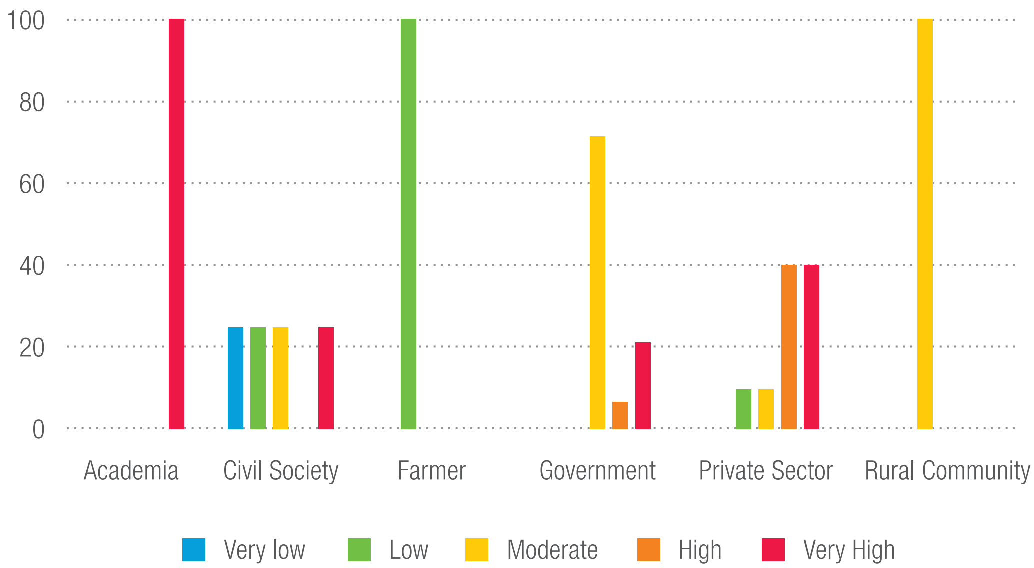
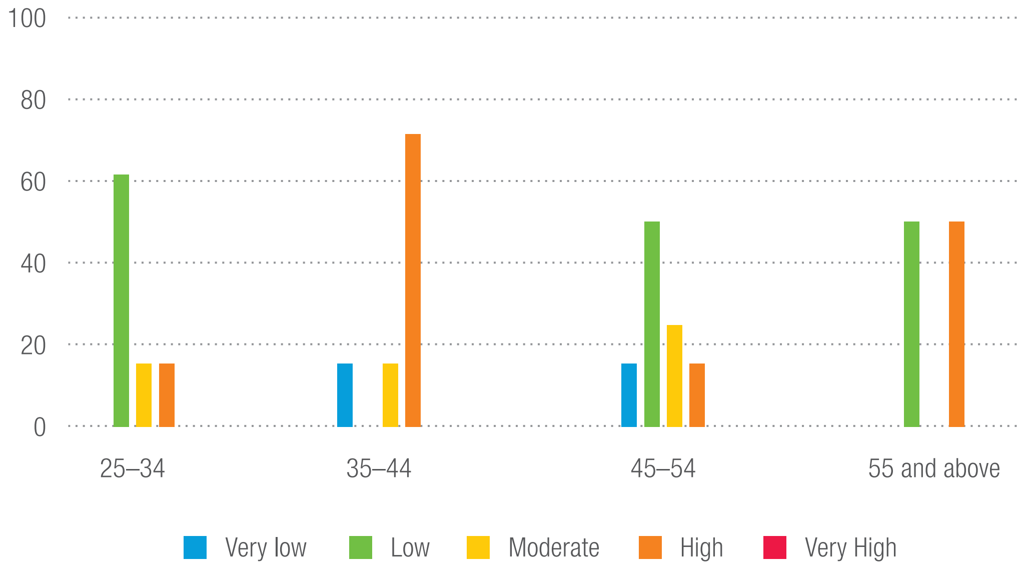


Figure VIII. 11 depicts the knowledge levels regarding biogas technology across different age ranges. Interestingly, younger individuals between 25–34 years old exhibit the lowest level of knowledge, with the vast majority of respondents falling within the "low" to "moderate" knowledge range. In contrast, those aged 35–44 demonstrate a significant shift towards higher levels of knowledge. Respondents aged 45–54 show a more spread level of knowledge, although half report a "low" level of knowledge. Interestingly, respondents aged 55 and above display a polarized pattern.

These findings suggest that there are indeed differences in responses based on sector and age group, with certain sectors and age groups showing higher awareness and knowledge levels about biogas technology. This highlights the need for targeted educational and promotional strategies to address gaps in awareness and knowledge across different sectors and age groups.

Figure VIII. 11
Knowledge of biogas technology across age ranges



8.2 Focus group discussion results

The FGDs were broken down into four topics: (a) knowledge of biogas; (b) risks and challenges of biogas; (c) opportunities and benefits of biogas; (d) future considerations and government support. Respondents were asked questions under each topic as shown in appendix B and a thematic analysis was performed on each topic.

8.2.1 Knowledge of biogas

Respondents showed varying degrees of familiarity with biogas technology, ranging from being very familiar to somewhat familiar. While biogas technology is widely known in the western world, it remains unknown and largely a novel technology in Zambia. Many rural communities and farmers who produce waste that is useful for this technology have never heard of it. In some cases, where the technology is known, there has been negative perceptions of it given that some have deemed it unsafe and toxic. Exposure to knowledge of biogas often occurred through work, social media, education or community projects. Several respondents learned about biogas through specific projects, training sessions or research initiatives. The sources of information included bilateral grant calls, workshops, social media, documentaries and personal connections. Respondents also stated that the MoEd, REA and various NGOs were actively engaged in biogas-related initiatives, including research, demonstrations and school projects. The findings underscore the importance of education, community engagement and coordinated efforts across sectors to promote sustainable and inclusive biogas initiatives. Table VIII. 1 summarizes the responses from respondents on the questions asked regarding knowledge of biogas.

Table VIII. 1
Summary of participants' responses to questions on knowledge of biogas

Question	Response
Interaction and utilization of biogas technology	Some participants, particularly from research institutions and NGOs, reported personal interaction with biogas technology. This included setting up small systems for processing kitchen waste, conducting research and demonstrations in schools, and converting septic tanks into biodigesters. Positive experiences were shared, highlighting the lack of unpleasant odours when using biogas and the potential for community-level projects.
Attitudes towards biogas	Overall, there was a positive attitude towards biogas technology among the general population who were aware of it, but this varied across demographics, regions and educational levels. The positive perception was attributed to the benefits of biogas, such as reducing air pollution, providing sustainable energy solutions and offering alternatives to depleted fuels. Negative attitudes were noted, particularly in urban areas, where scepticism, fear of explosions and concerns about maintenance and safety were prevalent. Challenges included overcoming fear, addressing negative perceptions, changing mindsets and disconnecting biogas from political affiliations.
Reliability and efficiency of biogas	Participants acknowledged the reliability and efficiency of biogas when best operating procedures were followed. The reliability was associated with using various feedstocks, such as animal, kitchen and human waste. The lack of awareness about different feedstocks was identified as a challenge, emphasizing the need for education and awareness campaigns. Challenges were noted in terms of community beliefs, politics, safety concerns and misconceptions, which had an impact on the acceptance and reliability of biogas technology.
Challenges and strategies for awareness	Challenges to awareness included lack of information, fear of technology, scepticism, cost concerns and lack of clarity on benefits. Strategies to address these challenges involved leveraging carbon credits, providing incentives, using communication strategies, collaborating between ministries, conducting workshops and training, and engaging with community leaders. Suggestions included developing a clear regulatory framework, engaging the private sector, involving the media, leveraging social media and organizing demonstrations in communities.

8.2.2 Risks and challenges of biogas

The thematic analysis highlights the multifaceted concerns and considerations surrounding the adoption of biogas in Zambia, taking into account economic, environmental, social and cultural dimensions. Addressing these concerns and barriers requires comprehensive strategies and collaboration among various stakeholders as shown in table VIII. 2.

Table VIII. 2

Summary of respondents' responses concerning risks and challenges of biogas

Question	Response	Description of response
Potential risks associated with biogas systems in Zambia	Installation and technical challenges	**High initial investment**: Concerns about the significant upfront costs associated with the installation of biogas systems. **Lack of knowledge**: Limited awareness and knowledge about biogas systems among the population. **Technical support**: Worries about the absence of technical support and expertise post-installation. **Tool availability**: Challenges related to the lack of proper tools for installation and maintenance. **Information gaps**: Concerns about inadequate information on production and optimization of installation and usage. **Feedstock availability**: Risks associated with the availability of feedstock.
	Environmental risks	**Natural disasters**: Potential impacts from natural disasters like flooding and erosion on the structural integrity of biogas systems. **Air pollution**: Risk of air pollution due to gas leakages. **Impact on land use**: Concerns about reduced agricultural land use if effective management practices are not in place. **Soil pollution**: Risks associated with feedstock leakages into the soil, causing pollution in built biodigesters.
	Health and safety	**Diseases**: Potential health risks from waste produced depending on the feedstock. **Fire injuries**: Risks of injuries by fire if not properly managed. **Groundwater**: Risk of groundwater contamination causing diseases or death.
	Social and cultural risks	**Community acceptance**: Concerns about community acceptance, particularly regarding choices of feedstocks like urine and human waste that may face resistance.

Table VIII. 2. (continued)

Summary of respondents' responses concerning risks and challenges of biogas

Question	Response	Description of response
Barriers and challenges to biogas technology adoption	Economic and resource challenges	**High installation costs**: Economic barriers due to the high cost of installation and the need for special equipment. **Lack of resources**: Challenges arising from inadequate resources and information. **Social norms**: Influence of social norms affecting adoption. **Lack of awareness**: Limited awareness of the benefits of biogas compared to other energy sources. **Information barriers**: Challenges associated with information access. **Efficiency concerns**: Perceived inefficiency of energy produced compared to other sources. **Access to improved technology**: Difficulty in accessing improved biogas technology. **Infrastructure challenges**: Lack of proper infrastructure, including delivery roads and distribution challenges. **Standards and commercial barriers**: Lack of standards and commercial barriers affecting adoption. **Knowledge distribution**: Challenges in the effective distribution and adoption of current technological advancements.
	Technical support	**Government and stakeholder support**: The need for support from the government and stakeholders, including the reduction of regulatory barriers, and incentives and subsidies. **Provision of infrastructure**: Importance of providing infrastructure to support biogas adoption.
Gender-, youth-, marginalized group-specific impacts on biogas adoption	Women	**Tailored messaging**: The importance of tailored messaging to women, acknowledging their central role in cooking. **Time and effort savings**: Recognition that women can save time and effort by using biogas instead of traditional fuels.
	Youth	**Adaptability to technology**: Youths are seen as more adaptable to technological advancements. **Business opportunities**: Recognition of business opportunities for youths in biogas-related ventures. **Time efficiency motivation**: The motivation for youths is seen in the time efficiency offered by biogas.
	Marginalized groups	**Rural benefits**: Recognition that rural areas would benefit from biogas, especially where grid electricity is not prevalent. **Commercial opportunities**: Acknowledgment of commercial benefits, such as the production of biofertilizers and community electricity sales. **Health improvements**: The potential for improved health in marginalized groups due to a cleaner environment and air with the use of a renewable energy source.

8.2.3 Opportunities and benefits of biogas

The thematic analysis reveals a wide range of economic, environmental and social benefits associated with the development and promotion of biogas technology in Zambia. These benefits extend to local communities, sustainable goals and economic opportunities across various sectors. The analysis emphasizes the potential of biogas technology to address energy challenges, promote sustainability and contribute to economic growth (table VIII. 3).

Table VIII. 3

Summary of respondents' responses concerning opportunities and benefits of biogas

<table>
<tr><th>Question</th><th>Response</th><th>Description of response</th></tr>
<tr><td rowspan="3">Benefits of biogas technology to local communities in Zambia</td><td>Economic opportunities</td><td>Selling of gas: Income generation through the sale of biogas.
Selling of bio slurry: Commercial opportunities by selling bio slurry as organic fertilizer.
Entrepreneurship: Support for entrepreneurial ventures related to biogas.
Employment opportunities: Job creation in installation, maintenance, feeding and technical support.
Youth empowerment: Opportunities for youth empowerment through involvement in the biogas sector.</td></tr>
<tr><td>Energy-related benefits</td><td>Lighting: Access to clean energy for lighting.
Cooking: Clean and efficient cooking methods using biogas.
Increase in productivity: Improved productivity with water pumps running on biogas.
Energy independence: Reduced reliance on external energy sources, contributing to energy independence</td></tr>
<tr><td>Health and environmental benefits</td><td>Health benefits: Improved health due to the use of a cleaner energy source.
Empowerment of marginalized communities: Inclusion and empowerment of marginalized communities through access to biogas technology.</td></tr>
<tr><td rowspan="4">Contributions of biogas technology to sustainable development and energy access in Zambia</td><td>Environmental sustainability</td><td>Use of locally made materials: Support for sustainability by utilizing locally made materials.
Bio slurry benefits: Environmental benefits from bio slurry as an organic fertilizer, improving soil health.
Waste management: Addressing animal and human waste management issues.</td></tr>
<tr><td>Knowledge transfer and skill development</td><td>Knowledge transfer: Facilitation of knowledge transfer to address existing knowledge gaps.
Skill development: Opportunities for skill development in the field of biogas technology.</td></tr>
<tr><td>Energy access and cost-efficiency</td><td>Alternative to expensive grid power: Cost-effective alternative to increasingly expensive grid power.
Mobile set-up: Mobility of biogas systems, enabling set-up anywhere and reducing reliance on grid power.</td></tr>
<tr><td>Sustainable practices</td><td>Conversion of septic tanks: Conversion of septic tanks to biogas systems, promoting self-reliance in homes.</td></tr>
</table>

Table VIII. 3 (continued)

Summary of respondents' responses concerning opportunities and benefits of biogas

Question	Response	Description of response
Economic opportunities from the development and promotion of the biogas sector	Agricultural and food production	**Savings on fertilizer**: Cost savings in agriculture due to organic fertilizer production. **Fish feed production**: Production of fish feed from bio slurry. **Organic food production**: Scalable production of organic food using biogas by-products.
	Job creation and industrial benefits	**Job opportunities**: Creation of jobs in installation, maintenance, feeding and technical support. **Manufacturing sector benefits**: Benefits to the manufacturing sector in the production of biogas system components.
	Financial innovation	**Funding opportunities**: Emergence of financial innovation to fund biogas system development.

8.2.4 Future considerations and government support

Participants expressed varying levels of awareness, ranging from being aware of policies but without specific details to a clear awareness of policy and strategy. Common themes across the responses included:

- **Awareness**: Respondents acknowledge the importance of raising awareness for the success and adoption of biogas technology.
- **Financial accessibility**: Strategies to make biogas financially accessible should include seeking alternative funding, offering incentives and engaging with global donors.
- **Incentives**: Various incentives, such as tax exemptions and rebates, were highlighted to encourage the adoption of biogas.
- **Educational integration**: Suggestions were made to include biogas in the school curriculum to increase awareness and understanding.
- **Infrastructure development**: Emphasis was placed on investing in infrastructure to support the growth and adoption of biogas technology.

These themes collectively highlight the multifaceted nature of considerations and strategies necessary for the successful promotion and adoption of biogas technology as seen by the respondents. Table VIII. 4 summarizes the responses of respondents on the questions asked.

Table VIII. 4

Summary of respondents' responses concerning future considerations and government support

Question	Response
Addressing financial constraints	Strategies to address financial constraints include: **High cost of investment**: Respondents emphasized the need to address the high initial cost of investment. **Alternative financing**: Exploring alternative sources of financing to make biogas projects more accessible. **Infrastructure investment**: Investing in infrastructure to support the development and adoption of biogas. **Support for entrepreneurs**: Providing support for biogas entrepreneurs to encourage their involvement. **Incentives**: Offering incentives for investments in biogas, including financial incentives and public funds. **Credit risk perception**: Recognizing challenges in obtaining bank loans due to being perceived as a credit risk. **Financial mechanisms**: Advocating for the establishment of financial mechanisms specifically for lending to biogas producers. **Marketing and sensitization**: Marketing biogas to stakeholders, reducing interest rates and sensitizing lenders about biogas projects. **Global donor engagement**: Engaging bilateral and global donors for financial support.
Incentivizing adoption of biogas	Various factors were identified to incentivize individuals and companies to adopt biogas, including: **Tax exemptions**: Offering tax exemptions to promote adoption. **Alternative funding exploration**: Exploring other sources of funding beyond traditional channels. **Infrastructure development**: Building necessary infrastructure to facilitate adoption. **Sensitization**: Emphasizing the need for sensitization to increase awareness. **Tax rebates and certification**: Introducing tax rebates, licensing and certification to encourage adoption. **Global green climate funding**: Seeking funding from global green climate initiatives. **Eliminating subsidies for non-renewable energy**: Incentivizing the shift from non-renewable energy by eliminating subsidies. **Incentives for charcoal alternatives**: Providing incentives to alternatives to charcoal burners to discourage tree cutting.
Future evolution of biogas	Diverse perspectives were discussed on the future evolution of biogas, which include: **Success over tisme**: Expectations of success in the next 5, 10 or 15 years. **Awareness raising**: Emphasis on the need to raise awareness to drive biogas adoption. **Educational integration**: Advocating for the inclusion of biogas in the school curriculum. **Development of small-scale biogas**: Anticipation of the development of small biogas projects. **Grid integration**: Foreseeing biogas contributing to the grid. **Industrial scale in 10 years**: Aspirations for biogas to reach an industrial scale within a decade. **Mass production and reduced prices**: Expectations of mass production leading to reduced prices. **Interministerial strategy**: Calls for coordinated strategies involving multiple ministries (MoTS, MoE, MoA).

Chapter 9

Conclusions and policy recommendations

Chapter 9. Conclusions and policy recommendations

Zambia's electricity access challenges require sustainable solutions like biogas adoption. Despite its benefits, many challenges remain, necessitating policy interventions. This chapter outlines ten policy recommendations to address this.

Access to electricity remains one of the biggest challenges that the Government of Zambia wishes to address in the country. In order to do this, both on-grid and off-grid solutions need to be considered and undoubtedly STI with regards to energy technologies will be vital in trying to achieve this. While Zambia is endowed with fossil fuels such as coal, the likelihood of financing such an energy technology over the long term remains slim. It is clear that any alternative technology must be renewable in nature. Furthermore, any technology to be implemented should provide fuel to local communities at the least possible cost. Developing an expensive technology for local communities would disincentivize individuals in impoverished communities to move away from traditional methods of cooking and heating that are not environmentally sustainable.

In addition, since Zambia has suffered load-shedding in the past and most likely will face load-shedding in the future too, there is a need to adopt energy technologies that reduce power deficits for already connected on-grid customers, a problem that policymakers grapple with today. Given the background and the country context, it is clear that biogas technology in the long run:

a) Can improve access to electricity;
b) Can improve security of supply and address the power needs of the population;
c) Is renewable in nature;
d) Can reduce the power needs for those already connected to the grid or mini-grids;
e) Can have an impact on the social, economic and environmental challenges currently faced by the government.

However, despite these obvious benefits, it appears from the survey and FGDs that awareness of biogas technology remains low in the wider population and perceptions about it remain overall negative. In addition, the government has not yet adequately incentivized citizens to move away from the traditional methods of cooking and heating to safer, cleaner and more efficient methods such as biogas. Based on the responses from stakeholders, in order to initialize actions that lead to the increase of knowledge, development and implementation of biogas technology in Zambia it is crucial to formulate and implement policies that address various aspects of the biogas sector. Ten policy recommendations are provided to address the challenges identified in this assessment. These policy recommendations are the direct result of the TA process and the input provided by the various stakeholders that took part in it. The recommendations aim to create an enabling environment for the growth of biogas technology in Zambia, fostering knowledge, development and widespread implementation across all relevant sectors.

Zambia needs inclusive policies for women, youth and marginalized groups.

9.1 Educational and training programmes

Many of the respondents to the survey and the FGDs were clear that knowledge and attitudes towards biogas in the general population remains poor. As such, educational and training programmes will be essential to effectively equip individuals with the knowledge and skills needed to contribute to the sustainable development and widespread adoption of biogas. Such programmes should include:

- Developing policies to integrate biogas technology education into the national curriculum at schools, colleges, and universities;
- Organizing events for increasing public awareness of biogas technologies and provide forums for the exchange of experiences;
- Development and implementation of training programmes that are specially adapted to the needs of different population groups, including "training of trainers" measures to reach a wide population in a short time;
- Key metrics: Tracking the number of individuals trained, including geographical distribution and their subsequent involvement in biogas projects.

Table IX. 1 lists the requirements for the development of such educational and training programmes.

Table IX. 1
Educational and training programme requirements

Item	Requirement
Needs assessment	Conduct a comprehensive needs assessment to understand the specific requirements of the target audience. Identify existing knowledge gaps, skill levels and the scope of training needed.
Stakeholder engagement	Involve relevant stakeholders, including government agencies, educational institutions (including technical and vocational education and training (TVET) colleges), industry experts, NGOs and community representatives (among them women, youth and marginalized groups) in the planning and design of educational programmes. Collaborate to ensure a holistic approach.
Curriculum development	Develop a well-structured and practical curriculum that covers the fundamentals of biogas technology, including the science behind it, system design, installation, operation, maintenance and safety measures. Ensure alignment with industry standards and best practices.
Incorporate practical training	Design programmes that include hands-on, practical training sessions. This can involve setting up small-scale biogas systems, troubleshooting common issues and practical demonstrations of system components.
Training facilities	Establish dedicated training facilities equipped with the necessary infrastructure for hands-on training. This may include demonstration biogas systems, laboratories and simulation tools.
Online learning platforms	Develop online courses and learning platforms to reach a broader audience especially for multipliers who have access to the Internet, e.g. NGOs, schools, vocational schools, etc. Online modules can include instructional videos, interactive simulations and quizzes to enhance learning experiences.
Train-the-trainer programmes	Conduct train-the-trainer programmes to build a pool of skilled educators who can, in turn, train others. This helps create a sustainable model for continuous education.
Integration into formal education	Work with educational institutions to integrate biogas technology into formal curricula, ensuring that students are exposed to sustainable energy concepts early in their academic journeys.
Customized training for different audiences	Tailor training programmes for different target audiences, such as students, technicians, engineers, farmers and entrepreneurs. Consider their specific needs and skill levels when designing the content.
Certification programmes	Implement certification programmes to formally recognize individuals who have successfully completed the training. Certification adds credibility to the skills acquired and encourages participation.
Monitoring and impact assessment	Implement a robust monitoring and impact assessment system to track the success of training programmes. Assess the number of individuals trained, their success in applying learned skills and the overall impact on communities and industries.

9.2 Research and development incentives

Literature review on biogas has revealed that while biogas technology was explored in the early 1990s in Zambia, R&D initiatives have slowed down largely due to a lack of funding and weaknesses in the country's NIS. Given this, it is imperative that a focus be placed on R&D initiatives to enhance the use and adoption of the technology. This can be achieved by:

- Organizing international knowledge and technology exchanges on good practices of biogas usage; for example, within the Southern African Development Community (SADC);
- Providing financial incentives, grants or tax breaks for research institutions and businesses involved in biogas technology R&D;
- Encouraging collaboration between research institutions, government agencies and the private sector to promote the development of linkages that support innovation in biogas technology;
- Key metrics: Monitoring the number of research projects, publications and innovations related to biogas from various education and research institutions.

Table IX. 2 details the requirements for R&D initiatives to promote the adoption of biogas technology.

Table IX. 2
Requirements for establishing R&D incentives on biogas

Item	Requirement
Establish research grants	Introduce government-funded research grants to support academic institutions, research organizations and businesses involved in biogas technology R&D. Grants can be targeted towards specific research areas, such as efficiency improvements, feedstock optimization or technological innovations.
International knowledge and technology exchange	Organize platforms for the exchange of knowledge and technologies related to biogas; for example, within the SADC.
PPPs	Facilitate collaborations between government agencies, research institutions and private companies. PPPs can leverage resources, expertise and funding from both sectors to accelerate R&D efforts.
Tax credits and incentives	Offer tax credits or other financial incentives to companies engaged in biogas R&D. This can include tax deductions for eligible R&D expenses, reducing the financial burden and encouraging businesses to invest in innovation.
Technology incubators and accelerators	Establish technology incubators and accelerators focused on biogas technology. These entities can provide start-ups and researchers with the necessary infrastructure, mentorship and funding to bring innovative ideas to market.
Innovation challenges and competitions	Organize innovation challenges and competitions to incentivize researchers, start-ups and businesses to develop groundbreaking solutions in biogas technology. Prizes, recognition and opportunities for further funding can drive participation.
Technology transfer offices	Establish technology transfer offices to facilitate the transfer of research findings and technologies from academia to industry. These offices can streamline the commercialization process and support start-ups in bringing biogas innovations to market.
Continuous funding streams	Ensure sustained funding for biogas R&D by incorporating it into long-term government budgets or creating dedicated funds. Consistent funding enables researchers to pursue comprehensive and multi-year projects.
Incentives for sustainable practices	Tie R&D incentives to sustainable practices in biogas technology. Projects that focus on environmental sustainability, waste reduction and social impact could receive additional incentives to promote responsible innovation.
Monitoring and evaluation	Implement a robust monitoring and evaluation framework to assess the impact of R&D incentives. Regular evaluations can inform policymakers about the effectiveness of the incentives and guide adjustments for optimal outcomes.
Monitoring and impact assessment	Implement a robust monitoring and impact assessment system to track the success of training programmes. Assess the number of individuals trained, their success in applying learned skills and the overall impact on communities and industries.

9.3 Research and development incentives

Participants in the survey and FGDs indicated that not a lot of financial incentives or mechanisms exist for the adoption of biogas systems. This was determined as relevant because setting up and installing biogas systems has a high upfront cost that small-scale farmers and the rural population find it difficult to afford. Noting this, it was stated that financial support mechanisms driven either by the government or private-sector institutions could assist with the adoption of biogas systems. This financial support could include:

- Establishing financial support mechanisms, such as subsidies, low-interest loans or grants to facilitate the adoption of biogas technology among farmers, businesses and communities (see chapter 4.8 on creating incentives);
- Encouraging financial institutions to develop tailored loan products for biogas projects;
- Key metrics: Monitoring the uptake of incentives and their impact on biogas system installations.

Table IX. 3 details suggested requirements for financial support mechanisms.

Table IX. 3
Financial support mechanisms to promote biogas adoption

Item	Requirement
Government subsidies and grants	Establish financial mechanisms that offer soft loans and low-interest financing options for biogas projects. This can involve collaborating with financial institutions to create dedicated funds or special loan programmes for biogas entrepreneurs.
Soft loans and low-interest financing	Facilitate the inclusion of biogas projects in carbon credit programmes. By generating carbon credits through reduced GHG emissions, biogas projects can access additional revenue streams through carbon trading.
Carbon credits and trading	Explore the availability of international funds for the diffusion of biogas equipment; for example, from programmes to reduce deforestation and GHG emissions.
International finance	Provide training and capacity-building programmes for financial institutions to enhance their understanding of biogas technology and its financial viability. This can improve the assessment and approval processes for biogas-related loans.
Capacity-building for financial institutions	Establish funds dedicated to supporting the development phase of biogas projects. These funds can cover feasibility studies, environmental impact assessments and other initial project costs.
Project development funds	Introduce matching grants and challenge funds where the government matches contributions made by private investors. This approach encourages private-sector participation and increases the overall funding pool.
Matching grants and challenge funds	Provide incentives for manufacturers of biogas equipment to reduce costs and make technology more affordable. This can include tax breaks, R&D grants or subsidies for local production.
Incentives for equipment manufacturers	Explore community-based financing models, such as crowdfunding or cooperatives, to mobilize funds for biogas projects. This decentralized approach can involve local communities in the development and ownership of biogas initiatives
Community financing models	Establish a robust monitoring and evaluation framework to assess the impact of financial support mechanisms. Regular evaluations can help refine strategies and ensure that funds are effectively allocated to projects with positive outcomes.
Monitoring and evaluation framework	Implement a robust monitoring and evaluation framework to assess the impact of R&D incentives. Regular evaluations can inform policymakers about the effectiveness of the incentives and guide adjustments for optimal outcomes.
Monitoring and impact assessment	Implement a robust monitoring and impact assessment system to track the success of training programmes. Assess the number of individuals trained, their success in applying learned skills and the overall impact on communities and industries.

9.4 Policy framework for feedstock management

One of the risks discussed in the FGDs concerned the availability of feedstock to keep biogas systems running effectively. It was highlighted that, given the high upfront cost of biogas systems, it would be regrettable if users did not operate them regularly due to challenges linked to feedstock availability, which was sometimes far away from where the system was installed, and related logistical challenges. As such, for a biogas system to be used successfully and demonstrate its usefulness, it will require sufficient feedstock and a system of assuring feedstock provision will be essential. This could be achieved by:

– Developing a comprehensive policy framework for the sustainable management of feedstocks used in biogas production, addressing issues such as waste management, agricultural residues and energy crops;

– Key metrics: Evaluating the number of effective policies, strategies and action plans developed and their impacts.

The requirements for this are detailed in table IX. 4.

Table IX. 4

Requirements for a policy framework for feedstock management

Item	Requirement
Feedstock classification and guidelines	Develop clear classifications for different types of feedstocks suitable for biogas production. Establish guidelines for their collection, handling and processing to ensure optimal utilization.
Regulatory standards and compliance	Enforce regulatory standards for feedstock quality, ensuring that materials meet specified criteria for biogas production. Implement compliance mechanisms and penalties for non-compliance.
Identification of suitable feedstock sources	Identify and assess suitable feedstock sources based on regional availability and characteristics. Consider organic waste from agriculture, food processing, municipal solid waste and sewage as potential sources.
Community engagement and awareness	Engage communities in the identification and collection of suitable feedstocks. Implement awareness programmes to educate the public on the importance of proper feedstock management for biogas production.
Integrated waste management policies	Integrate feedstock management policies into broader waste management frameworks. Coordinate efforts with relevant government agencies responsible for waste management to ensure a cohesive approach.
Financial incentives for feedstock producers	Provide financial incentives for agricultural and industrial producers to supply feedstocks for biogas production. This can include subsidies, tax credits or revenue-sharing mechanisms.
Monitoring and reporting	Establish monitoring and reporting requirements for feedstock management. Develop a system for tracking the quantity and quality of feedstocks supplied to biogas facilities, promoting transparency and accountability.
Capacity-building for farmers and producers	Provide training programmes for farmers and other feedstock producers on sustainable practices, waste separation and collection techniques. Enhance the capacity of producers to supply high-quality feedstocks.
Public awareness and educational campaigns	Launch public awareness and education campaigns to inform citizens about the importance of waste separation, recycling and responsible disposal practices. Encourage participation in feedstock supply chains.

9.5 Grid connection policies

The IRP, see chapter 1.3.3.1, is intended to change the energy sector to become more diversified, resilient to climate change, financially secure and able to offer consumers across the nation high-quality, reasonably priced services. If this is the case, biogas at a larger scale could play a major role in the future for electricity production and mechanisms of its integration into the grid must begin to be discussed today. Grid connection policies for future connections would need to be implemented and may be attained by:

- Formulating policies that enable the integration of biogas systems into the national energy grid, allowing for the sale of excess biogas-generated electricity. Off-grid policies must also be considered for areas that are far from the national grid;
- Defining feed-in tariffs and regulatory frameworks to incentivize grid-connected biogas projects. International experiences, for example within SADC, with feed-in systems and tariffs should be analysed to shorten learning processes;
- Key metrics: Determining the criteria and requirements for integrating biogas systems into the existing electricity grid.

The requirements for successful grid connection policies are detailed in table IX. 5.

Table IX. 5
Requirements for grid connection policies

Item	Requirement
Technical standards and interoperability	Develop technical standards for biogas systems to ensure compatibility and interoperability with existing grid infrastructure. Establish guidelines for equipment certification to guarantee safety and reliability.
Net metering policies	Implement net metering policies that allow biogas producers to feed surplus electricity into the grid. Establish fair compensation mechanisms for excess energy supplied to encourage grid-connected biogas systems.
Tariff structures for biogas electricity	Establish a tariff structure that reflects the value of biogas-produced electricity. Consider factors such as the environmental benefits, reliability and distributed generation contributions to the grid.
Connection application process	Simplify and streamline the grid connection application process for biogas facilities. Define clear procedures, timelines and documentation requirements to facilitate efficient connections.
Grid capacity planning	Incorporate biogas projects into grid capacity planning processes. Assess the potential impact on the grid and plan upgrades or expansions accordingly to accommodate increasing biogas contributions.
Grid stability and power quality	Establish requirements for biogas systems to maintain grid stability and power quality. Define limits on voltage fluctuations, harmonics and other factors to ensure a reliable and stable electricity supply.
Off grid policies	Implement off-grid policies for biogas by designing strategies and regulations to facilitate the deployment and sustainability of biogas systems in areas not connected to the centralized electricity grid.

9.6 Community engagement and awareness

As household biogas systems used predominantly for lighting and cooking would target local communities, community engagements and awareness of these systems will be essential, including among women, youth and marginalized groups. As has been determined from the survey and FGDs, awareness of these systems and their benefits remains low. This is largely driven by the unavailability of information and the lack of deliberate programmes to disseminate information. The following procedures could help promote awareness:

- Develop policies to promote community engagement and awareness programmes on the benefits of biogas technology;
- Establish community-driven initiatives to encourage the adoption of small-scale biogas systems at the household and community levels;
- Create deliberate programmes to disseminate information on TV, radio and social media platforms;
- Key metrics: Measure the increase in public knowledge through surveys, workshops, media (TV and radio), social media and awareness campaigns.

Table IX. 6 details the requirements for such procedures to be put in place.

Table IX. 6
Requirements to promote community engagement and awareness

Item	Requirement
Stakeholder mapping	Identify and map key stakeholders in the community, including local leaders, community groups, women, youth, educational institutions, the differently abled and businesses. Understand their interests, concerns and potential roles in promoting biogas awareness.
Community needs assessment	Conduct a thorough needs assessment to understand the energy needs, preferences and challenges of the community. Tailor the biogas awareness campaign to address specific local requirements.
Local languages and cultural sensitivity	Develop communication materials and campaigns in local languages to ensure effective communication. Consider cultural sensitivities and customs to enhance acceptance and understanding of biogas technology.
Community workshops and training sessions	Organize community workshops and training sessions to provide hands-on experience and knowledge about biogas technology. Include practical demonstrations, allowing community members to see and understand the benefits first-hand.
Establish community-based organizations	Facilitate the formation of community-based organizations focused on renewable energy, including biogas. These organizations can serve as platforms for ongoing engagement, information dissemination and support.
Demonstration projects	Implement biogas demonstration projects within the community. Showcase successful installations in public spaces, schools or community centres to provide tangible examples of biogas applications.
Awareness campaigns	Launch targeted awareness campaigns using a variety of media, including posters, pamphlets, radio broadcasts and social media. Clearly communicate the environmental, economic and health benefits of biogas technology.
Participatory planning	Involve the community in the planning and decision-making processes related to biogas projects. Seek input on project design, location and potential applications to ensure local needs are considered.
Community champions programme	Identify and empower community champions who are passionate about biogas technology. Train them to become advocates and educators within their communities, promoting awareness through peer influence.

9.7 Quality standards and certification

The FGDs revealed that the private sector has moved significantly faster than the relevant government agencies in the development of biogas systems and that quality standards, regulation and certification have lagged behind. This is largely a result of the small-scale nature of these systems that generate quantities of energy that fall below those normally regulated. However, as these systems are becoming more popular and manufacturers and installers increasing in number, quality standards and certification are essential. As such, the following is recommended:

- Implement policies to establish quality standards and certification processes for biogas systems and components through relevant ministries and regulators, such as Zambia Bureau of Standards (ZABS);
- Ensure that certified systems meet safety, efficiency and environmental standards;
- Key metrics: Establish criteria and benchmarks to ensure the reliability, safety and efficiency of biogas production and utilization.

Table IX. 7 details the requirements for quality standards and certification procedures to be put in place.

Table IX. 7
Requirements to establish biogas quality standards and certification

Item	Requirement
Industry collaboration	Facilitate collaboration among industry stakeholders, including government agencies, technology developers, research institutions and industry associations. Establish a working group to collectively define quality standards and certification criteria.
Regulatory framework	Work with relevant government bodies to develop a regulatory framework for biogas technology. Establish clear guidelines, standards and certification requirements that align with national and international norms.
Standardization organizations	Engage with standardization organizations, both national and international, to contribute to the development of specific standards for biogas technology. Collaborate with bodies such as ZABS and the International Organization for Standardization (ISO) to ensure global compatibility.
Technical committees	Form technical committees consisting of experts in biogas technology, safety, environmental science and related fields. These committees can contribute to the development and periodic review of quality standards.
Performance metrics	Define performance metrics related to the efficiency, reliability and safety of biogas technology. Establish criteria for gas production rates, methane content, system reliability and overall performance under different operating conditions.
Quality assurance protocols	Develop comprehensive quality assurance protocols that cover the entire life cycle of biogas systems. Include protocols for design, manufacturing, installation, maintenance and decommissioning to ensure consistent quality.
Testing and verification procedures	Establish standardized testing and verification procedures to assess the performance and safety of biogas systems. Define testing protocols for components, subsystems and integrated systems.
Training programmes	Implement training programmes for technicians, installers and operators to ensure that they are familiar with quality standards and certification requirements. Training should cover installation best practices, safety protocols and system maintenance.
Compliance database	Create a centralized database of certified biogas systems, manufacturers and installers. This database can serve as a public resource for consumers and regulators to verify compliance with quality standards.

9.8 Incentives for agricultural-sector integration

As the survey and the FGDs revealed, biogas plays a dual role in energy and agriculture. While the focus of the present TA is energy, it became evident that there are significant benefits to the agricultural sector and this fact could play a huge role in the development of biogas. The largest contributor to feedstock for biogas systems is the agricultural sector and as such it should follow naturally that by encouraging integration of biogas systems in the agricultural process a higher adoption of biogas systems will be achieved. Agricultural-sector integration with biogas systems could be done by:

– Introducing incentives for farmers to integrate biogas technology into their agricultural practices, emphasizing the benefits of waste management, soil enrichment and reduced dependency on traditional energy sources and fertilizers;

– Key metrics: Designing measures to encourage farmers and agricultural businesses to adopt biogas technology.

Requirements for this to be achieved are detailed in table IX. 8.

Table IX. 8
Incentives for agricultural-sector integration

Item	Requirement
Technical support and training	Enhance agricultural extension services to include training and technical support for farmers in adopting biogas technology. This may be done by conducting workshops to educate farmers on the benefits, installation and maintenance of biogas systems.
Government procurement preferences	Consider implementing government procurement policies that give a degree of preference to agricultural products and services produced using biogas technology. This would create a market for biogas-enabled agricultural products.
Tax credits	Allow accelerated depreciation for biogas infrastructure, enabling farmers to recover their investment more quickly. In addition, implementation of tax credits for farmers who integrate biogas technology into their agricultural practices would be another incentive. This could include credits for system installation costs and ongoing operational expenses.
Financial incentives and grant programmes	Provide financial subsidies for the installation of biogas systems on farms to alleviate the initial capital investment burden and introduce grant programmes that offer financial support for farmers adopting biogas systems, particularly for smaller-scale operations.
Infrastructure development	Create community-based biogas hubs that allow multiple farmers to share a centralized biogas facility, reducing individual investment costs.
Awareness and outreach campaigns	Launch targeted awareness campaigns to educate farmers about the benefits of biogas technology in agriculture, including improved waste management and energy independence.
Demonstration farms	Establish demonstration farms where farmers can witness first-hand the successful integration of biogas systems.
Market access and product differentiation	Provide support for farmers to access markets that value environmentally friendly and sustainable agricultural practices, creating demand for biogas-enabled products. Introduce labelling or certification schemes that differentiate and promote products originating from agricultural systems that incorporate biogas technology.
Promotion of private-sector participation	Encourage private-sector participation in the biogas value chain by creating a conducive business environment, offering incentives and facilitating partnerships that could lead to an increase in its use in the agricultural sector.

9.9 Capacity-building for government agencies

One of the intended outcomes of the TA process is to build capacity among policymakers and government agencies to be able to carry out TA processes in other relevant sectors in the economy. FGDs revealed that government institutions may not be fully equipped with information related to biogas, especially concerning the regulation and promotion of the technology. Capacity-building initiatives should thus not only include how to carry out a TA exercise but should also build capacity for the proper adoption and implementation of the biogas technology. This could be achieved by:

– Providing training and capacity-building programmes for government agencies responsible for regulating and promoting biogas technology;

– Ensuring that regulatory frameworks are conducive to the growth of the biogas sector;

– Key metrics: Conduct pre- and post-training assessments to quantify the increase in knowledge and understanding of biogas technology, policies and regulations.

Requirements for this to be achieved are detailed in table IX. 9.

Table IX. 9
Requirements for capacity-building within government agencies

Item	Requirement
Training programmes	Develop customized training modules that cover various aspects of biogas technology, including its benefits, installation, maintenance, policy frameworks and regulatory compliance. This should include offering both technical training for engineers and non-technical training for policymakers, regulators and support staff. Institutions that could benefit from this training include MoE, MoTS, ERB, NISIR, NTBC, MoA, ZABS and universities, among others.
Access to experts and consultants	Bring in experts and consultants in the field of biogas technology to conduct specialized training sessions, answer queries and provide insights based on practical experiences.
Policy and regulatory training	Conduct workshops focused on developing and updating policies related to biogas technology, ensuring that regulations align with industry standards and best practices. In addition, provide training on regulatory compliance and enforcement, equipping government officials with the knowledge needed to ensure safe and efficient biogas operations.
Integration into performance appraisals	Include measures related to biogas knowledge and project implementation in the performance appraisals of relevant government officials. This incentivizes continuous learning and application of acquired skills.
Feedback mechanisms	Conduct regular feedback sessions to gather input from government officials on the effectiveness of capacity-building initiatives. Use this feedback to refine and improve training programmes.
International collaboration	Facilitate international collaboration and partnerships to access knowledge, expertise and funding for the development of biogas projects. This may include participation in regional and international forums to share experiences and best practices. This could allow for the exploration of opportunities for international cooperation in R&D, for example within the SADC, or with countries with advanced capacities in biogas technology (for example, Brazil).

9.10 Inclusion of women, youth and marginalized groups

Literature review and the outcomes of the survey and the FGDs all show that women, youth and marginalized groups are often excluded when new technologies are introduced. Products in the sector are not designed with these groups in mind as such and adoption becomes difficult. Zambia needs inclusive policies for women, youth and marginalized groups, as well as for fostering sustainable development, gender equality and social equity. This could be achieved by:

- Developing policies that promote the adoption of biogas in Zambia among women, youth and marginalized groups, focusing on inclusivity, accessibility and empowerment;
- Key metrics: Measure the proportion of women, youth and marginalized individuals actively participating in biogas projects and initiatives.

Requirements to achieve inclusion of these groups are detailed in table IX. 10.

Table IX. 10

Inclusion of women, youth and marginalized groups in the adoption of biogas technology

Item	Requirement
Inclusive financing mechanisms	Establish microfinance programmes specifically designed for women, youth and marginalized groups to facilitate access to affordable loans for biogas system installation. Further, provide subsidies or reduced interest rates on loans for biogas projects initiated by women, youth and marginalized communities to overcome financial barriers.
Tailored marketing strategies	Develop gender-sensitive marketing strategies that highlight the practical benefits of biogas technology for women in terms of time savings, health improvements and income-generating opportunities. Also, design campaigns that resonate with the interests and aspirations of youth, emphasizing the environmental and economic advantages of biogas.
Support for women-led enterprises	Establish support programmes specifically for women entrepreneurs interested in entering the biogas sector, including mentorship, access to markets and networking opportunities. This can be coupled with allocating seed funding to encourage the initiation of women-led biogas projects.
Flexible repayment schemes	Implement flexible repayment schemes for loans taken by women, youth and marginalized groups, taking into account seasonal variations in income and economic challenges.
Partnerships with NGOs and civil society	Collaborate with NGOs and civil society groups that specialize in women's and youth empowerment to jointly implement biogas adoption programmes.
Research on gender and social dynamics	Conduct gender impact assessments to understand the specific needs and challenges faced by women in adopting biogas technology, informing policy adjustments accordingly.
Policy advocacy and representation	Ensure representation of women, youth and marginalized groups in biogas policymaking bodies to advocate for their unique needs and perspectives.

These recommendations will necessitate further elaboration in terms of strategic planning, programmatic prioritization and regulatory initiatives. Further actions fall within the remit of the executive and legislative branches of the policy system. They can nevertheless be seen as a possible structure for a subsequent policy road map that can be developed by relevant government agencies.

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Appendix A. Methodology for the selection of the technology

To select the technology, the TA expert group began by referring to the Zambian NEP 2019 and listing the energy technologies and sources that are envisaged in the document. The listed energy technologies and sources were then marked against ten areas based on the criteria outlined in table A. 1. The following nine technologies and sources were listed:

(1) Hydro
(2) Wind
(3) Solar
(4) Geothermal
(5) Biomass (firewood)
(6) Biogas (waste to energy)
(7) Coal
(8) Nuclear
(9) Petroleum

Table A. 1
Areas and criteria employed for the selection of the technology

Areas	Criteria
a) Resources	Does the country have sufficient natural resources for the energy technology?
b) Policy	Is the energy technology supported by government policy?
c) Practicality	Can the energy technology be practically assessed in nine months?
d) Skills	Do the skills exist should the energy technology be developed?
e) Green	Is the energy technology clean and renewable?
f) Need	Does it meet the energy needs of the population?
g) Politics	Can the energy technology be a source of conflict locally or internationally?
h) Maturity	Has the technology been adopted elsewhere and can evidence of its impact can be drawn?
i) Impact locally	Is the impact of the energy technology known locally?
j) Impact externally	Is the impact of the energy technology known externally?

Source: Author.

The expert group brainstormed, discussed and provided arguments for and against each criterion for each technology as the basis for elimination, thus reducing the number of technologies selected. The following three technologies met the criteria for possible consideration:

(1) Wind
(2) Geothermal
(3) Biogas

To determine the most suitable technology of the three, the expert group then subjected these technologies to an additional criterion of assessment by the application of a point system, as follows:

a) Solution to energy problem – 0 if it had no capacity to solve the energy problem, 1 if it had the capacity to do so;

b) Cost-efficiency – 0 if it was an extremely expensive technology to implement, 0.5 if it was semi-expensive to implement, 1 if the technology was cost-effective to implement;

c) Assessment time – 0 if an assessment could not be carried out on the technology in nine months, 1 if an assessment could be carried out in 9 months;

d) Capacity – 0.5 for a capacity factor less than 80 per cent, 1 for a capacity factor equal to or greater than 80 per cent;

e) Time for development post financial close – 0 for long term (over five years), 0.5 for medium term (one to five years), 1 for short term (under one year);

f) Grid connection possibility – 0 for inability to connect to the grid, 1 for ability to connect to the grid;

g) Off-grid connection possibility – 0 for inability for off-grid connection, 1 for ability for off-grid connection;

h) Resource availability – 0 if the natural resource is not available in the country, 0.5 if the availability of the resource was limited, 1 if the resource was widely available.

After allocating points to each energy technology using the criteria listed above, wind and biogas obtained the highest scores and were tied. The expert group then subjected the two technologies to a vote and biogas technology was selected as the subject of the TA exercise.

Appendix B. Survey questionnaire

Introduction

The purpose of this survey is to evaluate stakeholders' understanding, knowledge and attitudes towards small-scale biogas technology in Zambia. In addition, it seeks to understand the perceptions and considerations by individuals related to small-scale biogas technology in Zambia. All responses to the survey will be treated as confidential and will only be used for the purposes of the study. By responding to the survey, you will have provided consent for the use of the information for the purposes of the study.

Chapter 1: Demographics

1. What is your age range?
- ☐ 18–24
- ☐ 25–34
- ☐ 35–44
- ☐ 45–54
- ☐ 55 and above

2. What is your gender?
- ☐ Male
- ☐ Female
- ☐ Other

3. In which region of Zambia do you currently reside?
- ☐ Lusaka
- ☐ Copperbelt
- ☐ Central
- ☐ Eastern
- ☐ Western
- ☐ Northern
- ☐ Southern
- ☐ North-Western
- ☐ Luapula
- ☐ Muchinga

4. What area do you reside in?
- ☐ Urban
- ☐ Peri-urban
- ☐ Rural
- ☐ I'm not sure

5. What stakeholder grouping do you represent?
- ☐ Government
- ☐ Rural community
- ☐ Farmer
- ☐ Academia
- ☐ Private sector
- ☐ Civil society

Chapter 2: Knowledge of biogas technology

1. Have you ever heard about biogas technology before taking this survey?
- ☐ Yes
- ☐ No

2. How would you rate your current knowledge level and understanding about biogas technology?
- ☐ Very Low
- ☐ Low
- ☐ Moderate
- ☐ High
- ☐ Very high

3. If you have some knowledge, how did you learn about biogas technology? (Select all that apply.)
- ☐ Television
- ☐ Radio
- ☐ Social media
- ☐ Community workshops
- ☐ School/educational institution
- ☐ Newspaper
- ☐ Government outreach
- ☐ Other (please specify)

4. What do you think are the main sources of feedstock for biogas production? (Select all that apply.)
- ☐ Agricultural waste
- ☐ Animal manure
- ☐ Human waste
- ☐ Kitchen waste
- ☐ Other (please specify)

Chapter 3: Core features of biogas technology

1. Which of the following features of biogas technology do you find most appealing? (Select all that apply.)
   - ☐ Renewable energy generation
   - ☐ Waste reduction and management
   - ☐ Soil fertility improvement through organic fertilizers
   - ☐ Reduced greenhouse gas emissions
   - ☐ Rural development and empowerment
   - ☐ Other (please specify)

2. In your opinion, what role can biogas play in addressing energy access challenges in rural areas of Zambia? (Select all that apply.)
   - ☐ Increasing access to electricity
   - ☐ Diversifying the energy mix
   - ☐ Reducing reliance on grid power
   - ☐ Sustainable and cleaner energy source
   - ☐ Other
   - ☐ None of the above

3. Do you believe that biogas technology has the potential to contribute to sustainable agriculture in Zambia?
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Neutral
   - ☐ Disagree
   - ☐ Strongly disagree

Chapter 4: Attitudes towards biogas technology

1. What factors, if any, would encourage you to consider adopting biogas technology? (Select all that apply.)
   - ☐ Cost-effectiveness
   - ☐ Environmental benefits
   - ☐ Energy reliability
   - ☐ Government incentives
   - ☐ Community support
   - ☐ Lack of alternatives
   - ☐ Other (please specify)
   - ☐ None of the above

2. How concerned are you about the negative environmental impact of traditional energy sources, such as wood and charcoal?
   - ☐ Very Concerned
   - ☐ Concerned
   - ☐ Neutral
   - ☐ Not concerned
   - ☐ Not at all concerned

3. To what extent do you believe the adoption of biogas technology could positively impact agricultural practices in Zambia?
   - ☐ Significantly
   - ☐ Moderately
   - ☐ Slightly
   - ☐ Not at all

Chapter 5: Risks and challenges associated with biogas technology

1. What concerns, if any, do you have about the safety of biogas technology in terms of installation and usage? (Select all that apply.)
   - ☐ Gas leaks
   - ☐ Ventilation issues
   - ☐ Material compatibility for use in biodigester
   - ☐ Fire hazards
   - ☐ Exposure to toxic gas
   - ☐ Inadequate training
   - ☐ Lack of community awareness on biogas safety
   - ☐ None

2. How confident are you in the durability and longevity of biogas systems in different environmental conditions in Zambia?
   - ☐ Confident
   - ☐ Not sure
   - ☐ Not confident

3. In your opinion, what are the potential challenges or risks associated with the widespread adoption of biogas technology in Zambia? (Select all that apply.)
   - ☐ Technical challenges related to design, construction and maintenance
   - ☐ Feedstock availability
   - ☐ Initial investment cost
   - ☐ Knowledge and capacity of users
   - ☐ Policies that encourage adoption of biogas

4. Are you aware of any health or environmental risks associated with the use of biogas technology? If yes, please specify what the risks are.
   - ☐ Yes
   - ☐ No

Chapter 6: Opportunities and benefits of biogas technology

1. How do you think the adoption of biogas technology could positively impact the economy of Zambia? (Select all that apply.)
   - ☐ Agricultural residue utilization
   - ☐ Rural electrification
   - ☐ Health improvements due to cleaner cooking and lighting methods
   - ☐ Reduction in pollution
   - ☐ Job creation
   - ☐ Energy diversification
   - ☐ None of the above
   - ☐ Other (please specify)

2. In your view, what economic opportunities could arise for local communities through the development of the biogas sector? (Select all that apply.)
   - ☐ Employment opportunities
   - ☐ Entrepreneurship and small business
   - ☐ Organic fertilizer production
   - ☐ Skills development & training
   - ☐ Carbon credit generation
   - ☐ Access to funding and grants
   - ☐ None of the above
   - ☐ Other (please specify)

3. How can the integration of biogas technology contribute to environmental conservation efforts in Zambia? (Select all that apply.)
   - ☐ Reducing pollution
   - ☐ Conserving soil nutrients
   - ☐ Capturing methane emissions
   - ☐ Reduced deforestation
   - ☐ Improved air quality
   - ☐ None of the above
   - ☐ Other (please specify)

Chapter 7: Sources of information and education

1. How often do you come across information about biogas technology in your community?
   - ☐ Daily
   - ☐ Weekly
   - ☐ Monthly
   - ☐ Rarely
   - ☐ Never

2. Which sources do you find most reliable for obtaining information about biogas technology? (Select all that apply.)
   - ☐ Government announcements
   - ☐ Educational institutions
   - ☐ NGOs and community organizations
   - ☐ Media (TV, radio, newspapers)
   - ☐ Social media
   - ☐ Friends and family
   - ☐ None of the above
   - ☐ Other (please specify)

Chapter 8: Future considerations and support

1. Would you be interested in attending workshops or training sessions on biogas technology?
   - ☐ Definitely
   - ☐ Probably
   - ☐ Not sure
   - ☐ Probably not
   - ☐ Definitely not

2. In your opinion, what role should the government play in promoting the adoption of biogas technology in Zambia? (Select all that apply.)
   - ☐ Develop supportive policies
   - ☐ Capacity-building
   - ☐ Financial support
   - ☐ Research and development
   - ☐ Public awareness campaigns
   - ☐ Collaboration with stakeholders
   - ☐ Tax incentives
   - ☐ Infrastructure development
   - ☐ None of the above
   - ☐ Other (please specify)

3. How would you rate the affordability of biogas technology for an average household in Zambia?
   - ☐ Very affordable
   - ☐ Affordable
   - ☐ Neutral
   - ☐ Expensive
   - ☐ Very expensive
   - ☐ Not sure

4. Would you consider adopting biogas technology for your household if financial incentives were provided by the government or other organizations?
   - ☐ Yes
   - ☐ No
   - ☐ Maybe

5. How confident are you in the ability of users to maintain a biogas system?
   - ☐ Very confident
   - ☐ Confident
   - ☐ Neutral
   - ☐ Not confident
   - ☐ Not at all confident

6. Would you be willing to invest in or support community based biogas projects in Zambia?
   - ☐ Yes
   - ☐ No
   - ☐ Maybe

7. What types of incentives or support mechanisms do you believe would encourage individuals and businesses to adopt biogas technology? (Select all that apply.)
   - ☐ Low interest loans
   - ☐ Feed-in tariffs
   - ☐ Tax benefits
   - ☐ Technical assistance
   - ☐ Recognition and certification
   - ☐ Demonstration projects
   - ☐ Community engagement
   - ☐ Policy support
   - ☐ None of the above
   - ☐ Other (please specify)

8. How important is it, in your opinion, for educational institutions to incorporate information about biogas technology in their curricula?
   - ☐ Very important
   - ☐ Neutral
   - ☐ Not important

9. Do you think there is a need for increased awareness campaigns to inform the public about the benefits and risks of biogas technology?
   - ☐ Yes
   - ☐ Not sure
   - ☐ No

10. What additional information or support do you think would be helpful to increase awareness and positive attitudes towards biogas technology? (Select all that apply.)
    - ☐ Educational campaigns
    - ☐ Collaboration with religious and community leaders
    - ☐ Local language outreach
    - ☐ Financial literacy programmes
    - ☐ Interactive workshops and webinars
    - ☐ Policy advocacy
    - ☐ None of the above
    - ☐ Other (please specify)

11. Are there any experiences or examples from other countries that you believe Zambia can learn from in the development of its biogas sector? If yes, please specify what example.
    - ☐ Yes
    - ☐ No

12. What potential partnerships or collaborations do you think could enhance the implementation of biogas projects in Zambia? (Select all that apply.)
    - ☐ Government and local communities
    - ☐ Government and research institutions
    - ☐ NGOs and development organizations
    - ☐ Local communities and cooperatives
    - ☐ Media and communication partners
    - ☐ Donor agencies and financial institutions
    - ☐ Private-sector organizations and local communities
    - ☐ None of the above
    - ☐ Other (please specify)

Appendix C. Focus group discussions

The purpose of these focus group discussions will be to gather insights, opinions, perceptions and experiences of small-scale biogas technology in Zambia through group interaction. Participants will engage in group conversations by responding to set guiding questions, expressing their views and responding to each other's comments. Four (4) groups of eight (8) members each will discuss four (4) topics on **Knowledge of biogas; Risks and challenges of biogas; Opportunities** and **benefits of biogas and Future considerations and government support**. Groups will be rotated to allow the estimated total number of participants of 30 to each respond to the guiding questions provided below. Participants' consent will be requested in order to allow for recording of the discussion for accurate data analysis and an explanation of how the recordings will be used will be provided.

A. Knowledge of biogas

1. How familiar are you and your community with the concept of biogas technology?
2. Can you share any specific instances where you've come across information about biogas in Zambia?
3. Have you or anyone you know personally interacted with or utilized biogas technology?
4. What is your general attitude towards the use of biogas technology in Zambia?
5. How do you perceive the reliability and efficiency of biogas as an energy source compared to other alternatives?

B. Risks and challenges of biogas

6. What potential risks do you associate with the installation and usage of biogas technology in Zambia?
7. Are there safety concerns you believe are associated with biogas technology and how can they be mitigated?
8. From your perspective, what environmental risks or impacts might be associated with widespread biogas adoption?
9. What barriers or challenges do you think individuals and communities might face in adopting biogas technology?
10. Are there any gender-specific, youth-related or marginalized groups impacts/issues that should be considered related to biogas adoption and use? If yes, please specify which.

C. Opportunities and benefits of biogas

11. In what ways do you see biogas technology benefiting local communities in Zambia?
12. How can biogas technology contribute to sustainable development and energy access in Zambia?
13. Are there economic opportunities that could arise from the development and promotion of the biogas sector?

D. Future considerations and government support

14. Are you aware of any government policies or initiatives promoting biogas technology in Zambia?
15. How can financial constraints be addressed to make biogas technology more accessible?
16. What factors do you think would incentivize individuals and businesses to adopt biogas technology in the future?
17. How do you see biogas technology evolving in Zambia in the next 5, 10, 15 years?

Appendix D. Members of the steering committee and expert group

Steering Committee members

Mrs Jane M Chinkusu (Chair), Director Science and Technology, Ministry of Technology and Science, MoTS

Mr Mambo Banda, Agriculture Expert, Zambia National Farmers Union

Mr Sunday Chikoti, Director Industry, Ministry of Commerce Trades and Industry

Mr John Lukonde Chongo (focal point), Assistant Director Science and Technology, MoTS

Mr Stephen Chundama, Proxy Director Technical, Zambia Development Agency

Prof. Prem Jain, UNESCO Chair in Renewable Energy and Environment, Director Solar Energy Centre, Department of Physics, University of Zambia

Dr Henry Kambafwile, Director, National Institute for Scientific and Industrial Research

Mr Ackson Mwanza, Proxy Director, Zambia – Self Help Africa

Dr P Namwinga, Principal University Education Officer, Ministry of Education

Mr E Ngonga, Proxy Deputy Director, Energy Regulation Board

Dr Kabwe Puta, Provincial Fisheries and Livestock Coordinator, Ministry of Fisheries and Livestock

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Expert Group members

Dr Onesmus Munyati (Chair), Senior Lecturer, University of Zambia

Dr A Banda, Director, National Remote Sensing Centre

Dr Mwaba Kasese Bota, Director, Zambia Centre for Entrepreneurship and Innovation, Lusaka

Dr Patrick Chikoti, Chief Agriculture Research Officer, Zambia Agricultural Research Institute

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