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ZAMBIA

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION

PART II: BARRIER ANALYSIS AND ENABLING ENVIRONMENT

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Foreword

As a non-Annex I country to the UNFCCC, Zambia is not subject to binding greenhouse gas emission reduction commitments under the Kyoto Protocol. Our contribution to global greenhouse gas emissions is small in the energy sector but relatively high under agriculture and land use and forestry. Although not bound compulsory, as a country, vulnerable country to the impacts of climate change, Zambia takes its responsibilities seriously and it will continue to do its part in the global efforts to address climate change.

Climate variability and change has become major threats to sustainable development in Zambia. Evidence suggests that the country is already experiencing climate –induced hazards such as droughts, floods and extreme temperatures. Without urgent and coordinated action, climate change and related disasters could negate decades of development progress and undermine the efforts to attain MDGs which may eventually result in failure to sustain Zambia's recently attained low-medium income country status.

Zambia has had some success in mainstreaming climate change in its Sixth National Development Plan and in developing National Programme of Action (NAPA). Zambia has also developed a draft National Climate Change Response Strategy (NCCRS) focusing on capacity development for mainstreaming climate change into policies and programmes. However, most of the projects identified have not been implemented due to scarcity of detailed information and bankable proposals.

The Technology Needs Assessment initiative and its objectives of "(i) identifying and prioritizing through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities, (ii) identifying barriers hindering the acquisition, deployment, and diffusion of prioritized technologies, (iii) developing technology action plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitating the transfer, adoption, and diffusion of selected technologies in the participant countries, and present project ideas", has resulted in the development of concrete detailed action plans that can help decision makers to identify, create, and expand adaptation technologies and market for identified mitigation technologies.

This Technology Needs Assessment project considered several adaptation technologies related to water and agriculture, some of the most vulnerable sectors in Zambia, and developed concrete action plans to increase the resilience of these sectors in facing the expected adverse effects of climate change. Additionally, the TNA report has developed mitigation option in energy supply, energy efficiency, sustainable charcoal production and sustainable agriculture. The project ideas developed will serve as an input into development of bankable proposal for financing from various climate related funding under the UNFCCC and other bilateral and multilateral arrangement.

Minister of Lands, Natural Resources and Environmental Protection

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We would also like to express our gratitude and appreciation to the contributors of this report, participants of consultation meetings, experts assisting in document reviews, and input guidance from related projects draft Second National Communication, draft National Climate Change Response Strategy, Sixth National Development Plan, in addition to academic institutions, and private companies, whose proactive participation was fundamental to the completion of the Technology Needs Assessment report.

Last but not least, we would like to thank the main authors of these reports, Prof F D. Yamba and Dr. D Chiwele for their professionalism, friendship and patience throughout the project process.

The TNA Project Team(Mitigation and Adaptation).

Contents

ACKNOWLEDGEMENTS iv

ABBREVIATIONS viii

EXECUTIVE SUMMARY 10

CHAPTER I BACKGROUND 12

1.1 Technologies Identified 12

1.2 Objectives 12

1.3 Approach and Methodology 13

1.3.1 Market Analysis 14

1.3.2 Barrier Analysis 14

1.3.3 Enabling Environment – Measures to overcome barriers 15

1.3.4 Cost Benefit Analysis 15

2.0 BARRIER ANALYSIS OF GEOTHERMAL FOR ELECTRICITY GENERATION 16

2.1 Market Analysis 16

2.2 Identification of Barriers 17

2.3 Enabling Environment – Measures to overcome barriers 18

2.4 Cost Benefit Analysis 18

3.0 BARRIER ANALYSIS OF BIOMASS GASIFIER FOR ELECTRICITY GENERATION 19

3.1 Market Analysis 19

3.2 Identification of Barriers 20

3.3 Enabling Environment – Measures to overcome barriers 21

3.4 Cost Benefit Analysis 22

4.0 BARRIER ANALYSIS OF ENERGY MANAGEMENT SYSTEMS 23
4.1 Market Analysis 23
4.2 Identification of Barriers for Deployment of Energy Efficiency and Management Systems 24
4.3 Enabling Environment – Measures to overcome barriers 25
4.4 Cost Benefit Analysis 26
5.0 BARRIER ANALYSIS OF IMPROVED CHARCOAL UTILIZATION AND PRODUCTION 28
5.1 Market Analysis 28
5.2 Identification of Barriers for deployment of improved charcoal utilization (including firewood) and production 29
5.2.1 Improved Charcoal Production 29
5.2.2 Improved Charcoal/ Firewood Cookstoves 30
5.3 Enabling Environment: Measures to overcome barriers 31
5.3.1 Improved charcoal production (brick kiln) 31
5.3.2 Improved Charcoal/Firewood Cookstoves 32
5.4 Sustainable Charcoal Value Chain 32
5.5 Cost Benefit Analysis 34
6.0 BARRIER ANALYSIS FOR THE DEVELOPMENT OF BIOFUELS - BIODIESEL 34
6.1 Market Analysis 34
6.2 Identification of barriers for the deployment of biofuels – biodiesel 35
6.3 Enabling Environment: Measures to overcome barriers 36
6.4 Cost Benefit Analysis 37
7.0 BARRIER ANALYSIS FOR SUSTAINABLE AGRICULTURE 38
7.1 Market Analysis 38
7.2 Identification of Barriers 40
7.3 Enabling Environment: Measures to overcome barrier 40
7.4 Cost Benefit Analysis 41
LIST OF REFERENCES 42

List of stakeholders involved and their contacts 43
Annex I: Geothermal 44
Annex II: Biomass Gasifer for off grid 46
Annex III: Energy Efficiency and Management systems 48
Annex IV: Charcoal production 50
Annex V: Improved cookstoves 52
Annex VI: Biofuels from Jatropha 54
Annex VII: Sustainable Agriculture 57
Annex VIII: Results of Cost Benefit Analysis 60

ABBREVIATIONS

BAZ	Biofuels Association of Zambia
CBA	Cost Benefit Analysis
CDM	Clean Development Mechanism
CEEEZ	Centre for Energy, Environment and Engineering Zambia Ltd
CFL	Compact Fluorescent Lights
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
COP	Conference of the Parties
CSP	Concentrated Solar Power
DOE	Department of Energy
EE	Energy Efficiency
ERB	Energy Regulation Board
FD	Forest Department
FNDP	Fifth National Development Plan
GART	Golden Valley Research Institute
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse gas
HFCs	Hydrofluorocarbons
IRR	Internal Rate of Return
LFA	Logical Framework Analysis
MDG	Millenium Development Goals
MCA	Multi-Criteria Analysis
MFI	Micro Financial Institution
MLNREP	Ministry of Lands, Natural Resource and Environmental Protection
NAMA	Nationally Mitigation Actions
N_2O	Nitrous Oxide
NGO	Non Governmental Organisation
NMVOC	Non Methane Volatile Organic Compounds
NO	Nitrogen Oxide
NPV	Net Present Value
PV	Photo voltaic
R&D	Research and Development
RTSA	Road Transport and Safety Agency
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SNC	Second National Communication
SNDP	Sixth National Development Plan
SO_2	Sulphur Dioxide
TAP	Technology Action Plan
TFS	Technology Factsheet
TNA	Technology Needs Assessment
UNCED	UN Conference on Environment and Development
UNEP DTIE	UNEP Division of Technology, Industry and Economics
UNFCCC	United Nations Framework Convention on Climate Change
URC	UNEP Risoe Centre
UNZA	University of Zambia

WCED	World Commission on Environment and Development
ZARI	Zambia Agriculture Research Institute
ZACCI	Zambia Chamber of Commerce and Industry
ZEMA	Zambia Environmental Management Agency
ZENGO	Zambia Environment and Energy Organization *(*ZENGO*)*
ZNFU	Zambia National Farmers Union

EXECUTIVE SUMMARY

Objectives and Approach

The main objective of barrier analysis after prioritization of technologies is to identify and analyze barriers, and determine measures to overcome barriers aimed at facilitating technology transfer and diffusion. The approach used to set up the framework for deployment of identified technologies involves; market analysis, barrier analysis, enabling environment, and cost benefit analysis

Barrier Analysis

Barrier analysis for deployment of identified technologies was set up through the use of logical framework analysis with help of a logical tree. Barrier analysis comprises of the following steps; (i) Identification of barriers from studies experience and brain storming and organization of the barrier into broad categories, namely: economic and financial, market failure, policy, legal and regulatory, information and awareness, etc (ii) screening of barriers to identify key barrier and known key barriers based on multi criteria analysis approach, (iii) decomposition of barriers at four levels namely broad category, e.g. economic and financial, barriers within a category e.g. high cost of capital, and elements of barriers, e.g. high interest rate

Enabling Environment: Measures to overcome barriers

Measures to overcome barriers involve the following steps; (i) process of identifying and describing measures, (ii) formulate problems to solution in logical problem analysis(through reformulating all the problems as positive statements about the future situation in which the problems are solved, (iii) assessment and categorization of the measures identified aimed at identifying measures with significant impacts, which then feed into a wider enabling framework for the transfer and diffusion of identified technologies.

Results of Barrier Analysis and Enabling Environment

(i) Geothermal for electricity generation

The main barrier arising from the consultations with expert groups is lack of adequate financing, in particular availability funds to support fully exploratory activities to include: identification, hydrochemistry, geophysics, remote sensing and drilling leading to results with reduced risks, aimed at avoiding prospective targets being relinquished. Geothermal exploration and development with its own unique characteristic can be slowed down due to lack of policy on legal framework for supervision and financing. During operation phase, geothermal electricity generation has relatively higher levelised costs compared to baseline (hydro).

Measures identified to enhance deployment for electricity generation are: (i) framework for provision of financing for geothermal exploration and development, (ii) capacity development on specialized skills on geothermal exploration and development, (iii) formulation of support policies through provision of fiscal incentives and public finance and (iv) establishment of appropriate legal and regulatory framework for geothermal exploration and development.

(ii) **Biomass gasifier for off grid electricity generation**

The barriers identified inhibiting deployment of biomass gasifier for electricity generation include:(i) Inadequate information, (ii) high cost of capital, (iii) inadequate information on resource cost and (iv) absence of plans and programs.

Measures identified for enhancing deployment of biomass gasifier for electricity are: (i) awareness and information program for small scale project developers and entrepreneurs for off-grid systems including biomass gasifier, (ii) techno-economic assessment of off-grid systems, (iii) resource assessment and their logistics and (iv) implementation program and support policies for biomass gasifier.

(iii) Energy efficiency and management

The barriers identified inhibiting deployment of energy efficiency and management include:(i) Lack of awareness and information regarding EF, (ii) Lack of investment in EF, (iii) Lack of technical knowledge on energy efficiency and management (iv) Absence of EF policy at industrial, households/commercial and service entities.

The measures identified for deployment for EF and management include; (i) awareness and information program for industrial and commercial entities and municipalities, (ii) provision of financial mechanisms and incentives,(iii) introduction of energy management program to industrial and commercial entities and municipalities and (iv) formulation of a national energy efficiency and management policy, strategy, and action plan

(iv) Sustainable charcoal value chain

Charcoal production

The barriers identified inhibiting deployment of charcoal production kiln(brick) include:(i) technical constraints (ii) social culture and behavioral biases (iii) inadequate human skills (iv) high cost of capital and inadequate access to financial resources and (v) no targeted and comprehensive charcoal or wood biomass policy

The measures identified for deployment of improved charcoal production (brick kiln) include; (i) Development of the brick kiln technology pack. (ii) awareness and information on business opportunities of brick kiln and development of business plan,(iii) innovative financing mechanism

Improved cooking stoves

The barriers identified inhibiting deployment of charcoal production kiln(brick) include:(i) technical constraints (ii) social culture and behavioral biases (iii) inadequate human skills (iv) high cost of capital and inadequate access to financial resources and (v) no targeted and comprehensive charcoal or wood biomass policy.

The measures identified for deployment of improved charcoal/firewood cookstoves; (i) innovative financing mechanism (ii) awareness and information program, (iii) provision of a technical pack for improved cookstoves.

(v) Biofuels development – biodiesel

The barriers identified inhibiting development of biofuels/biodiesel (i) lack of benchmark pricing, high capital cost and inadequate access to financial resources (ii) inadequate knowledge on resource cost, (iii) weak network connectivity between feedstock producers and biofuels plant operators, and (iv) lack of comprehensive, legal and regulatory framework.

The measures identified for development of biofuels-biodiesel; (i) benchmark pricing, awareness program to financial institutions and specific investment framework (ii study on cost effectiveness of feedstocks for biofuel-biodiesel productions and associated logistics for supply chain, and (iii) comprehensive legal and regulatory framework

(vi) Sustainable agriculture

The barriers identified inhibiting practicing conservation agriculture (i) high resource development costs (ii) tedious work due to lack of equipment and (iii) social cultural and behavioral biases.

The measures identified for sustainable agriculture; (i) provision of development resources (ii introduction of appropriate machinery for ease of conservation agriculture application. (iii) awareness and information program to highlight the benefits and technologies for sustainable agriculture

CHAPTER I BACKGROUND

1.1 Technologies Identified

As part of the technology needs assessment and multi-criteria analysis undertaken in Part I, the following technologies were prioritized for elaboration under barrier analysis and enabling environment: (i) geothermal for electricity generation, (ii) biomass gasifier for off grid electricity, (iii) energy efficiency management systems, (iv) sustainable charcoal value chain, (v) biodiesel – biofuels development, (vi) sustainable agriculture.

1.2 Objectives

The main objective of barrier analysis after prioritization of technologies is to identify and analyze barriers, and determine measures to overcome barriers aimed at facilitating technology transfer and diffusion. The main steps of identifying and analyzing barriers and of developing measures to overcome them include:

- Organize the process;
- Identify all possible barriers through literature survey, interview and/or workshop brainstorms;
- Screen the gross list of barriers to select the most essential;
- Classify the remaining key barriers into a hierarchy of categories;
- Analyze the causal relationships between the barriers;
- Develop measures to overcome barriers by translating barriers into solutions;
- Access the costs and benefits of measures and incentives to determine weather they comply with policy objectives;
- Determine who shall take action and who shall pay;

1.3 Approach and Methodology

The approach used to set up the framework for deployment of identified technologies involves; market analysis, barrier analysis, enabling environment, and cost benefit analysis as elaborated in figure 1.1(II).

Figure 1.1(II): Framework for deployment of identified technologies

Phase I: TNA Report

	Description	***Tools***
Market analysis	• Brief description of identified technologies • Identification of key stakeholders, market chain actors and the linkage between them • Assessment of the supply market	Market mapping
Barrier analysis	• Identification and classification of barriers to the deployment of the prioritized technologies, including financial, policy, legal, market failures, and institutional analysis	• Key stakeholders and expert consultations in order to identify their views and incentives to participate • Information collected from studies, experience and brainstorming
Enabling framework	• Identification of measures to the deployment of the prioritized technologies • Set up an enabling framework for the prioritized technologies based on the identified measures	
Cost benefit analysis	• Assess the costs and benefits of identified technologies incentives for technology deployment success.	Cost benefit analysis

Phase II: TAP Report	Technology action plan and project proposals	• Develop a Technology Action Plan (TAP) outlining the essential elements of the enabling framework, and consisting of a detailed plan of actions to implement the proposed measures and estimate the need for external assistance to cover implementation costs. • Develop project proposal for the prioritized technologies for future funding.	TAP

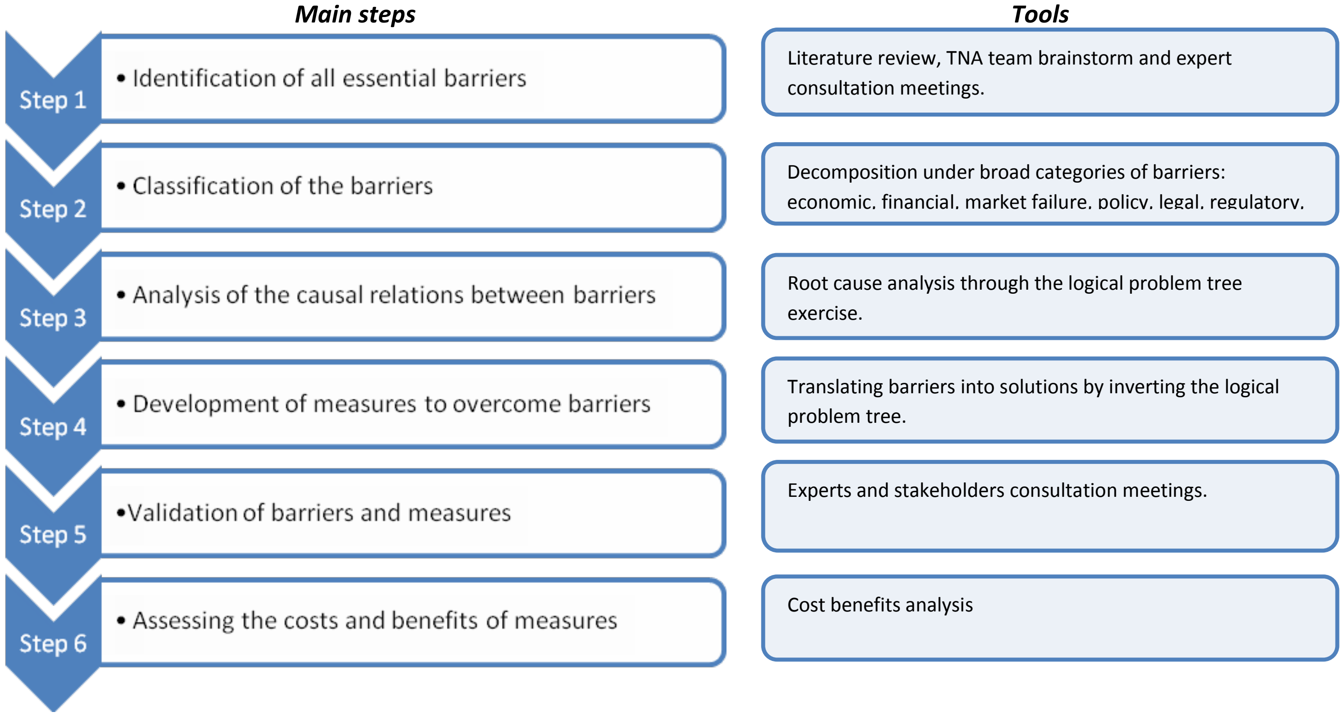
1.3.1 Market Analysis

Market analysis involves brief description of identified technology and market mapping followed by support services. Market mapping is analytical framework for understanding market systems and approach to market development that is both systemic and participatory. The market approach is a very useful way to conceptualize, visual represent and communicate knowledge about the entire commercial and institutional environment in which specific market chains operate. The tool helps to explore who the market actors for the technology are, what support services are available to them and the nature of the enabling business environment. The map has three components namely: (i) central component (market chain comprising of economic actors as producers to final consumers), (ii) second component (enabling business environment describing the critical factors and trends that influence the business), and third component (input and service providers that support the market chain).

1.3.2 Barrier Analysis

Barrier analysis for deployment of identified technologies was set up through the use of logical framework analysis with help of a logical tree. Barrier analysis comprises of the following steps; (i) Identification of barriers from studies experience and brain storming and organization of the barrier into broad categories, namely: economic and financial, market failure, policy, legal and regulatory, information and awareness, etc (ii) screening of barriers to identify key barrier and known key barriers based on multi criteria analysis approach, (iii) decomposition of barriers at four levels namely broad category, e.g. economic and financial, barriers within a category e.g. high cost of capital, and elements of barriers, e.g. high interest rate. Figure 1.2(II) elaborates the steps above together with corresponding tools to achieve required step.

Figure 1.2(II): Elaboration of barrier analysis steps and corresponding tools



In the case of Zambia, three groups were identified to cover both barrier analysis and measures to overcome barriers for the following technology groups. Group one: Energy based covering geothermal, biomass gasifier and energy efficiency and management, group two: improved methods of charcoal production (brick kiln) and improved cook stoves, group three: covering sustainable agriculture and biodiesel from agriculture. List of the experts is provided in Annex IV.

1.3.3 Enabling Environment – Measures to overcome barriers

Measures to overcome barriers involve the following steps; (i) process of identifying and describing measures, (ii) formulate problems to solution in logical problem analysis(through reformulating all the problems as positive statements about the future situation in which the problems are solved, (iii) assessment and categorization of the measures identified aimed at identifying measures with significant impacts, which then feed into a wider enabling framework for the transfer and diffusion of identified technologies.

1.3.4 Cost Benefit Analysis

Cost Benefit Analysis (CBA) is a technique for assessing the monetary costs and benefits of implementing a technology over a given time period. There are generally two routes for assessing cost benefit analysis namely; financial and social economic. Financial analysis involves estimation of Internal Rate of Return (IRR) and Net Present Value (NPV) with input data of investment costs, and operation and maintenance cost of a given technology and is normally used for ascertaining financial viability of capital based projects. On the other hand, CBA based on social economic analysis involves estimating the costs and benefits of each identified measure, apply a discount rate and calculate NPV of selected measure, and normally used for non capital goods. In the case of Zambia both approaches were used.

2.0 BARRIER ANALYSIS OF GEOTHERMAL FOR ELECTRICITY GENERATION

2.1 Market Analysis

Geothermal energy is thermal energy in the form of hot water and steam generated and stored in the earth. This energy can be used to generate electricity using technologies such as dry steam power plants, flash steam power plants and binary cycle power plants.

Zambia's electricity supply mix is predominantly hydro at 99.0%. Recent studies have indicated that runoff is expected to be affected in the future due to variations in climate change affected by drought in some critical years(RESAP 2012).This will lead to interruptions in the electricity supply. For example, in the drought year of 1991/1992, there was immense load-shedding of electricity in the country which affected the economic well being. Further, electricity demand in Zambia is projected to increase at 4% per annum. This will lead to exhaustion of the electricity potential estimated at 6000MW in the year 2030. In view of the aforegoing, it is important that Zambia starts integrating renewable energy into the national grid aimed at broadening the energy mix and enhance it to make it more secure.

Efforts to integrate geothermal technology in Zambia's energy system either as on grid or off grid are ongoing. The main actors in this development are a private company and Zambian Government on one hand, and professional entities providing services such as hydrochemistry laboratory testing and reporting, remote sensing and drilling. Kalahari GeoEnergy Ltd, a currently self-funded private company, entered into an agreement with Government of Zambia in March 2011. Under this agreement the Company would undertake geothermal research, exploration and development. The Company has conducted field reconnaissance including hydrochemistry on all identified geothermal targets, geophysics on the more prospective sites. Having formulated a conceptual model, the Company will conduct preliminary drilling in early 2013 at its first target, a low enthalpy system in a shallow sedimentary setting. It is anticipated that reservoir modelling and a test well will be completed during 2013 and a feasibility study in 2014.

The Company reports to a Committee comprising representatives of the relevant Government ministries and stake-holders; thus ensuring that progress and challenges are regularly reviewed. The Company follows mining industry international best practice in its exploration program; it commissions peer reviews of data and interpretation at each key stage, which has provided the confidence to fast track the primary target.

By targeting low-enthalpy geothermal systems, the Company expects to be able to define a number of commercially viable geothermal targets across Zambia, which would on the one hand provide both on-grid and off-grid power production capability, thus potentially benefiting both established users and rural electrification and industrialisation programme. Whilst on the other hand, by using modular binary power plants, feasible targets could be brought into production more quickly for a lower capital cost than large direct steam fed turbines.

2.2 Identification of Barriers

Barrier analysis work was carried out through a root – cause analysis presented in annex V-I. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is high upfront costs due to the need to drill exploration, pre-production and production wells and construct power stations and associated risks.

- *The main barriers:*

    - Technical risks
    - Market risks
    - Environmental impacts
    - Lack of financing

- *The different root-causes for different kinds of barriers whether it could be economic, financial, technicaland and social will include but not limited to* exploration and technology risks, high tariffs, and lack of in house trained personal, appropriate legal framework and funding for exploration phase

Decomposition of identified barriers is summarized in Table 2.1(II)

Table 2.1(II): Decomposition of identified barriers categories to deployment of geothermal for electricity generation

Barrier categories	Sub Barrier	Elements contributing to barrier
Economic and financial	Lack of financing	Lack of funding for exploration phase to include: Identification, hydrochemistry, geophysics, interpretation and exploration, and pre-production drilling.
Technical	Exploration and technology risks	Risks related to need to correctly determine temperature and fluid flow rates and most particularly, drilling risks and associated high costs.
Market failure	Market risks	Relatively higher tariffs from geothermal electricity production compared to baseline (hydro) and hence unable to have return on investment.
Policy legal and regulatory	Lack of appropriate legal framework.	Lack of policy on legal framework for supervision and financing of geothermal exploratory activities in view of its unique characteristics.

The main barrier arising from the consultations with expert groups is lack of adequate financing, in particular availability funds to support fully exploratory activities to include: identification, hydrochemistry, geophysics, remote sensing and drilling leading to results with reduced risks, aimed at avoiding prospective targets being relinquished. Geothermal exploration and development with its own unique characteristic can be slowed down due to lack of policy on legal framework for supervision and financing. During operation phase, geothermal electricity generation has relatively higher levelised costs compared to baseline (hydro).

2.3 Enabling Environment – Measures to overcome barriers

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-I. The measures for deployment for geothermal for electricity generation are summarized on Table 2.2 (II)

Table 2.2(II): Measures for deployment for geothermal for electricity generation

Category	Measures	Elaboration of measures
Economic and financial	Framework for provision of financing for geothermal exploration and development.	Provision of financing to support exploration phase to include: Identification, hydrochemistry, geophysics, interpretation and exploration, and pre-production drilling, from different sources including Government.
Technical	Capacity development on specialized skills on geothermal exploration and development.	Develop capacity to reduce risks related to correctly determination of temperature and fluid flow rates, identification of correct techniques, independent review of results and interpretation.
Market failure	Formulation of support policies through provision of fiscal incentives and public finance.	Requires support policies (grants, rebates, tax credit, equity investments and feed in tariff) to leverage relatively higher tariffs from geothermal electricity production compared to baseline (hydro) and hence unable to have return on investment.
Policy legal and regulatory	Establishment of appropriate legal and regulatory framework for geothermal exploration and development.	Institutional framework for supervision and financing of geothermal exploratory activities in view of its unique characteristics.

Measures identified to enhance deployment for electricity generation are: (i) framework for provision of financing for geothermal exploration and development, (ii) capacity development on specialized skills on geothermal exploration and development, (iii) formulation of support policies through provision of fiscal incentives and public finance and (iv) establishment of appropriate legal and regulatory framework for geothermal exploration and development.

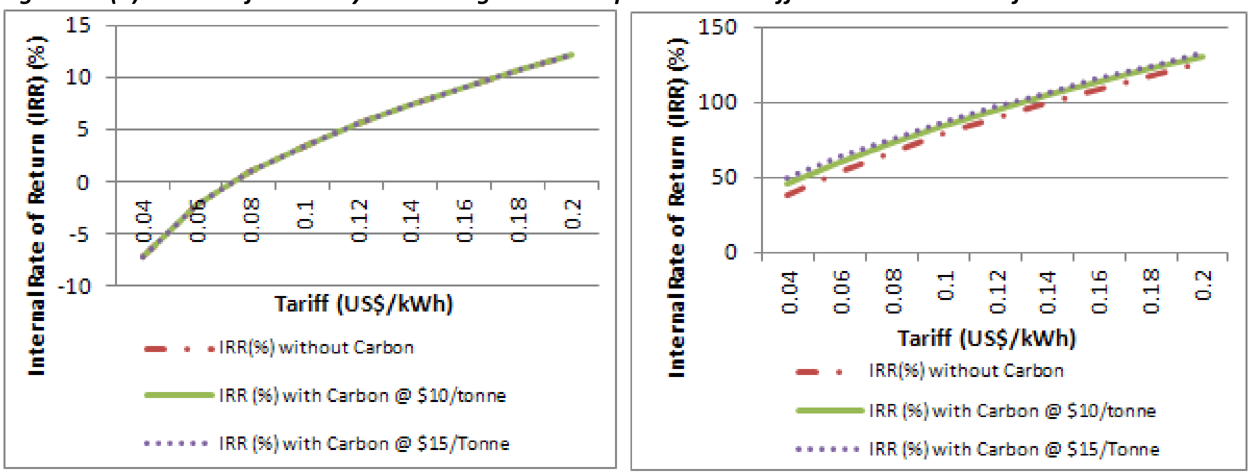
2.4 Cost Benefit Analysis

Cost Benefit analysis assessment was undertaken first on general cost characteristics for geothermal electricity generation from literature, and this was followed by specific financial analysis of setting up a 50 MW plant based on preliminary findings of geothermal resource assessment currently underway.

Typical investment costs, O+M costs and levelised costs are relatively competitive depending on the design. Geothermal flash (1800-3600 US$/kW, 150-190 US$/kW, and 4.5-13.0 US$ cents/kWh): Geothermal Binary Cycle (2100-5200 US$/kW, 150-190 US$/kW, and 4.9-17.0 US$ cents /kWh). Both technologies are commercially viable. This compares with the hydro with typical investment costs, O+M costs and levelised costs (1000-3000 US$/kW, 25-75 US$/kW, and 2.4-15.0 US$ cents/kWh)(SRREN, 2011). It is clear from the comparison that levelised costs for development of new hydro has an advantage over geothermal but within reasonable limits. It should, however, be noted that current electricity tariffs in Zambia are between 4 to 6 US$ cents/kWh, and clearly they are not cost reflective.

Financial analysis of geothermal electricity generating plant of capacity of 20MW was undertaken using the COMFAR UNIDO model. The criterion for selection of the 20MW plant was based on preliminary resource assessment being undertaken. The analysis was undertaken considering revenue base from the sale of electricity and carbon credits under CDM arrangements. Figure 1.3(II) left shows results of the analysis showing relationship between tariff and Internal Rate of Return for the 20MW geothermal electricity plant. Whilst Figure 1.3(II) right shows the results for P.V utility.

Figure 1.3(II) Results of the analysis showing relationship between tariff and Internal Rate of Return



At IRR of 10%, the tariffs for hydro and wind are both 15 US$cents/kWh, biomass are US$8 Cents/kWh, and geothermal are US$ Cents 17/kWh. There is, however, a slight reduction in the tariff (averaging US$ 3 Cents/kWh) when revenue from carbon sales are taken into consideration. The results indicate that geothermal has the highest tariff, followed by hydro and wind, and lowest biomass. However, geothermal has a higher capacity factor (80%) as compared to hydro (60%), and wind (25%)(RESAP 2012)

3.0 BARRIER ANALYSIS OF BIOMASS GASIFIER FOR ELECTRICITY GENERATION

3.1 Market Analysis

Biomass gasifier is suited for off grid applications and involves production of gaseous fuel called producer gas used in gas engines and modified gasoline and diesel internal combustion engines for electricity generation. Producer gas can also be used to produce steam which is then expanded on a steam reciprocating internal engines to produce electricity. Besides providing electricity to isolated areas in rural areas, it has an advantage of creating associated additional employment for the feedstock providers who are mostly small and medium scale farmers and foresters.

The main actors for biomass gasifier implementations are small scale project developers and entrepreneurs, customer base consisting of households, clinics, schools, business houses and small scale industrial entities, on one hand. On the other hand, the other actors are service providers for provision of enterprise development services for preparation of bankable proposals for submission to financial institutions for project finance. Equally government is a key actor for policy support in the implementation of biomass project.

Biomass gasifier like other renewable energy, largely based on off-grid energy system can contribute to poverty reduction and assist addressing MDGs. This can be achieved through provision of modern energy services to unmet demand for cooking, lighting and other small electric needs, process motive power and water pumping.

Rural electrification rate in Zambia is relatively low estimated at 4%. Current efforts to increase rural electrification access focus on grid extension. Despite these efforts few of population living in rural areas of Zambia will be served by grid connections during the next decade Although, generally grid extension is possibly the lowest cost per kWh delivered for many remote populations grid extension becomes less cost effective due to longer distances and load loads prevailing in such locations. In such situations, RE is becoming increasingly more competitive. Some of the renewable energy technologies such as biomass gasifier can contribute to increase access in rural areas serving as off-grid systems.

The Sixth National Development Plan (SNDP) envisages increased access through Rural Electrification Authority which aims to provide electricity for all rural areas by 2030. The draft Second National Communication (SNC) to the United Nations Convention on Climate Change proposes development of rural biomass electricity generating facilities. In this connection therefore, biomass gasifier can play an important role in contributing to this goal.

3.2 Identification of Barriers

Barrier analysis work was carried out through a root – cause analysis presented in annex V-II. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is off- grid biomass gasifer not available and applied in Zambia
- *The main barriers:*
    - Inadequate information
    - High cost of capital
    - Technical-inadequate knowledge on resource cost
    - Economic and finance- financially not viable
    - Policy
- The different root-causes for different kinds of barriers whether it is economic, financial, technicaland and social will include but not limited to poor information dissemination, high interest rates, low affordability and lack of awareness at policy level.

Decomposition of identified barriers is summarized in Table 2.3(II)

Table 2.3(II): Decomposition of identified barriers to deployment of biomass gasifier for off-grid electricity generation

Barrier	Sub Barrier	Elements contributing to barrier
Awareness And Information	Inadequate information	Inadequate information due to lack of information on business opportunities and benefits to accrue through use of biomass gasifier for electricity generation.
Economic and finance	High cost of capital	Currently, biomass gasifier for electricity generation is perceived to be high due to on-grid tariffs which are not cost reflective. Besides, financial institutions perceive such projects as high risk investment.
Technical	Inadequate information on resource cost	Despite availability of biomass feed-stocks in form of agriculture and forest/sawmill wastes, their costs are not known and hence costs for generation of electricity using biomass gasifier are not known.
Policy legal and regulatory	Absence of plans and programs	Absence of plans and program inhibit attainment of goals set by REA of achieving rural electrification for all by 2030.

The barriers identified inhibiting deployment of biomass gasifier for electricity generation include:(i) Inadequate information, (ii) high cost of capital, (iii) inadequate information on resource cost and (iv) absence of plans and programs.

3.3 Enabling Environment – Measures to overcome barriers

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-II. The measures for deployment for biomass gasifier for off-grid electricity generation are summarized on Table 2.4 (II).

Table 2.4(II): Measures for deployment for biomass gasifier for off grid electricity generation

Category	Measures	Elaboration of measures
Awareness and Information	Awareness and information program for small scale project developers and entrepreneurs for off-grid systems including biomass gasifier.	Awareness and information program through provision of information on markets, technology and feedstock characteristics, and off-grid business opportunities for small scale project developers and entrepreneurs and financial institutions.
Economic and financial	Techno-economic assessment of off-grid systems.	Undertake techno-economic assessment aimed at ascertaining viability of off-grid systems including biomass gasifier, and their cost effectiveness and comparison with cost of on-grid extension.
Technical	Resource assessment and their logistics.	Undertake a study on resource assessment and logistics at promising sites to include their suitability for use in biomass gasifiers for electricity generation.

Policy legal and regulatory	Implementation program and support policies for biomass gasifier.	Develop implementation program for biomass gasifier dissemination and provision of support policies in terms of incentives and public finance for off-grid systems.

Measures identified for enhancing deployment of biomass gasifier for electricity are: (i) awareness and information program for small scale project developers and entrepreneurs for off-grid systems including biomass gasifier, (ii) techno-economic assessment of off-grid systems, (iii) resource assessment and their logistics and (iv) implementation program and support policies for biomass gasifier.

3.4 Cost Benefit Analysis

Cost effectiveness of off-grid systems based on biomass gasifier and compared to other off-grid RE technologies was assessed based on analysis of levelised costs. In addition, financial analysis of biomass gasifier was undertaken based a capacity of between 100 and kW400kW. Table 2.5(II) shows cost effectiveness of off-grid systems including biomass gasifier.

Table 2.5(II) Cost effectiveness of off-grid systems including biomass gasifier.

Technology	Capacity Factor (%)	Rated output (kW)	Average Levelised Cost (US$ Cents/kWh)
Diesel/gasoline generator	30	100	20
		5,000 (base load)	9.25
		5,000 (Peak load)	17.65
Solar PV	20	0.3	56.09
		25	51.43
		5,000	41.57
Wind	25	0.300	34.57
		100	19.71
PV /Wind Hybrid	25	0.300	41.78
		100	30.49
Biomass gasifier	80	100	8.96
Biogas	80	60	6.77
Pico/Micro Hydro	30	1.0	12.73
		100	11.01
Mini Hydro	45	5,000	6.95

Source: ESMAP, 2007; Technical and economic assessment of off-grid, mini grid and grid electrification technologies. ESMAP Technical Paper 121/07 December 2007.

Levelised generating cost for wind and PV/wind hybrid are in the range of 19-35 and 30-42 US $Cents/kWh respectively. Levelised generating cost for solar PV is still too high in the range of 40-56 US $Cent/kWh. It is clear that biomass gasifier and biogas, mini hydro, and Pico/Micro Hydro are promising and competitive RE which can be implemented in rural areas in the short term. Besides, biomass and biogas have relatively higher capacity factor (80%) compared even to pico/micro hydro (30%) and mini hydro (45%).

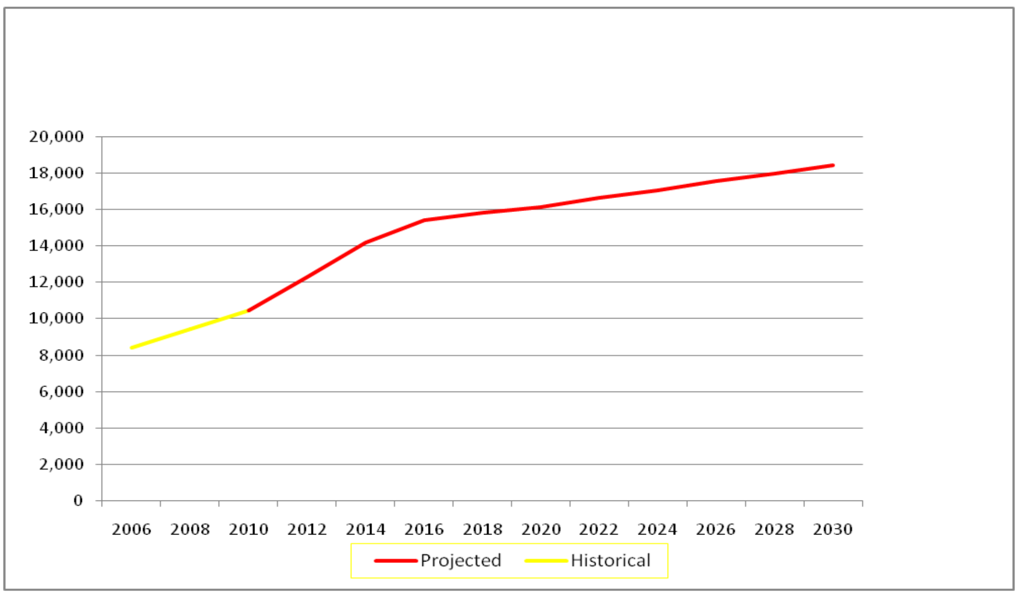
Financial analysis undertaken as part of this study in Part I for a 100kW biomass gasifier yielded a return on investment of 14% and payback period of 5 years at an investment cost of US$288,000 at the set tariff of US$0.15/ kWh. Against micro hydro of the same capacity, return on investment was negative indicating that biomass gasifier is competitive.

4.0 BARRIER ANALYSIS OF ENERGY MANAGEMENT SYSTEMS

4.1 Market Analysis

Zambia has an installed capacity of 1812MW, out of which 1300MW is available based on 2010 statistics, and maximum demand is 1500MW. In terms of energy supply/demand situation, demand has outstripped supply since 2008. The electricity generation/sales was given as 9631GWh and according to projections, it is forecasted that energy sales will increase to 16000GWh in the year 2020 and to 20000GWh in the year 2030. Figure 1.4(II) provides historical and projected electricity generation/sales from 2006 to 2030.

Figure 1.4(II): Historical and projected electricity generation/sales (GWh) from 2006 to 2030



The energy supply having outstripped demand has resulted in load shedding activities to all sectors of the economy to include: households, industry/commercial and to some extent mining which has resulted in inhibiting economic growth and development. On the other hand, efforts are underway to develop new energy infrastructure to meet growing demand which is increasing at an annual rate of 100MW per annum. Some of this infrastructure includes development of Kariba North Bank Extension (360MW), Itezhi-Tezhi (120MW), Kafue Gorge Lower (600MW), Kabompo (34MW), Kalungwishi (220MW). With an exception of Kariba North Bank and Itezhi-Tezhi which will come on stream within the next two years. The rest of the projects will take relatively longer to complete in the range of between 7 to 10 years(SAPP, 2010)

During this period, the energy supply deficit will continue since the expected capacity from Kariba North Bank Extension and Itezhi- Tezhi will quickly be taken up due to increased and stressed demand the country is currently facing. It is in this view that the country must seriously take advantage of energy efficiency and management which can go a long way in reducing the pressure on energy supply. The goal of energy efficiency from industrial, household/ commercial, and services entities, in the context of sustainable development, is to explore ways to reduce the amount of energy used to produce a desired service or unity of economic output.

One tool of enhancing energy efficiency is implementation of national energy management programs, in conjunction with legislation, incentives and policies and the institutional mechanisms for energy efficiency. Energy management influences organization and technical procedures, as well as behavioral patterns in order to reduce total energy consumption. A good range of energy efficiency technologies exist both from the supply side and end use and these include; supply side transformation, energy management, industrial and commercial end-use energy efficiency, and household end-use energy efficiency. Despite this potential, energy efficiency and management systems are not taken on board in various economic, social and industrial sectors of the economy due to a number of barriers.

4.2 Identification of Barriers for Deployment of Energy Efficiency and Management Systems

Barrier analysis work was carried out through a root – cause analysis presented in annex V-III. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is energy efficiency and management not widely practiced in Zambia
- *The main barriers:*
    - Lack of awareness and information
    - Lack of investment in energy efficiency and management
    - Lack of political will and policy
    - Lack of technical knowledge on energy efficiency and management
- The root-cause to some barriers will include resistance to change and no culture of saving, interest due to relatively lower electricity tariffs and lack of capital, EF policy and knowledge on EF characteristics and costs.

Decomposition of identified barriers is summarized in Table 2.6(II)

Table 2.6(II): Decomposition of identified barriers to deployment of energy efficiency and management

Classes of Barriers	Sub Barrier	Elements contributing to barrier
Awareness And Information	Lack of awareness and information regarding EF.	Limited awareness of the financial or qualitative benefits arising from energy efficiency measures, influenced by resistance to change and interest due to relatively lower electricity tariffs.

Economic and finance	Lack of awareness and information on investment in EF.	Capital constraints and corporate culture leading to more investments in new production capacities rather than energy efficiency and greater weight given to addressing upfront costs than recurring energy costs.
Technical	Lack of technical knowledge on energy efficiency and management.	Lack of knowledge on EF characteristic and costs. Further, management and engineers are more focused on production quality, waste reduction and labor cost than managing energy use.
Policy legal and regulatory	Absence of EF policy at industrial, households/commercial and service entities	Absence of support policy ;(i) Tax incentivizes(energy tax, pollution levies, public benefits); (ii) fiscal policies(loans including both public loans and a number of innovative loan funds, and tax relief foe purchaser of energy efficiency measure.

The barriers identified inhibiting deployment of energy efficiency and management include:(i) Lack of awareness and information regarding EF, (ii) Lack of investment in EF, (iii) Lack of technical knowledge on energy efficiency and management (iv) Absence of EF policy at industrial, households/commercial and service entities.

4.3 Enabling Environment – Measures to overcome barriers

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-III. The measures for deployment of energy efficiency and management are summarized on Table 2.7 (II).

Table 2.7(II): Measures for deployment of energy efficiency and management

Category	Measures	Elaboration of measures
Awareness And Information	Awareness and information program for industrial and commercial entities and municipalities	Awareness and information program through provision of information on EF opportunities and benefits, technology costs, standards and policies and financing mechanisms for industrial and commercial entities and municipalities.
Economic and finance	Provision of financial mechanisms and incentives	Provision of financial mechanisms and incentives focusing on financial benefits of EF to accrue to end users to include private equity/venture capital, self financing, debt financing, public funds from international financial institutions, innovative financing (carbon finance).
Technical	Introduction of energy management program to industrial and commercial entities and municipalities	Introduction of energy management program supported by policies and programs to include; (i) target setting voluntary agreements, (ii) industrial energy management standards, (iii) capacity building for energy management and energy efficiency services, (iv) delivery of EF products and services, (v) certification and labeling of EF performance, and (vi) financial mechanism on incentives.

Policy legal and regulatory	Formulation of a national energy efficiency and management policy, strategy, and action plan	Policy, strategy and action plan to include: (i) fiscal incentives and regulatory tools, (ii) vision and mission for EF strategy, (iii) strategic intervention measures, target objectives and activities, (iv) action plan, all for implementation of EF program.

The measures identified for deployment for EF and management include; (i) awareness and information program for industrial and commercial entities and municipalities, (ii) provision of financial mechanisms and incentives,(iii) introduction of energy management program to industrial and commercial entities and municipalities and (iv) formulation of a national energy efficiency and management policy, strategy, and action plan

4.4 Cost Benefit Analysis

As part of this assignment, analysis was undertaken to assess the impacts of implementation of selected energy efficiency measures based on selected penetration levels given in Table 2.8(II), and these include; (i) energy management system for mining and industry sector (efficient electric motors, load management, process control), (ii) energy management system for commercial services sector (efficient lighting, heating and cooling) (iii) energy for households (CFL and solar water heater). The assumptions for the penetration levels are provided in the same Table 2.8(II) for the years 2020 and 2030 and 2010 being the base year. The assumptions are based on electricity demand for mining and industrial, commercial/services, and household sectors. These assumptions are modest and conservative aimed at demonstrating the impact energy efficiency can have on energy demand if implemented.

For the household sector, measures include replacement of incandescent lamps (typically 50W) with CFL (15W) and electric geyser (2kW) with solar water heater. The penetrations levels of selected EE options on baseline energy supply scenarios are elaborated in Table 2.8(ii)

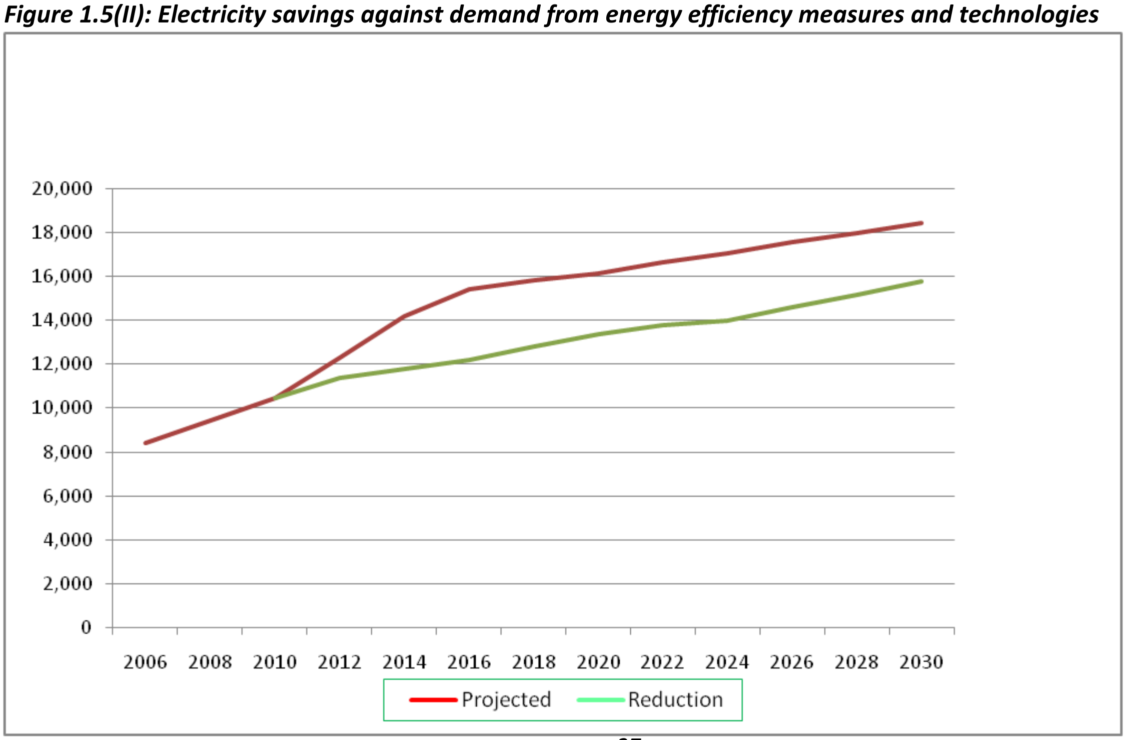
Table 2.8(II): Penetration levels of selected EE options on baseline energy supply scenarios

Technology	2020			2030		
	Assumptions	Sector Electricity Demand for (GWh)	Total Potential Savings (GWh)	Assumptions	Sector Electricity Demand for Sector(GWh)	Total Potential Savings (GWh)
Energy management system for industry and mining	10% of electricity energy demand	10,510	1,051	15% of electricity energy demand	13,029	1,954
commercial end-use energy efficiency (for commercial/industrial and mining)	10% of electricity energy demand	808	80.8	15% of electricity energy demand	1,002	150.3
CFL for households	20% of households (1,048,200) connected to	N/A	54	30% of households (1,878,100) connected to	N/A	144

Technology	2020			2030		
	electricity at 30% electricity rate for 2020 and 40% for 2030			electricity		
Solar Water Heater for households	10% of households (1,048,200) connected to electricity as above	N/A	230	15% of households (1,878,100) connected to electricity	N/A	617
Total			**1,416**			**2,865**
Avoided infrastructure investment (MW)			**200**			**412**
Avoided investment cost(US$ million) at US$ 3500/kW for hydro			**700**			**1,442**
Energy saving to end users(US$ million) at USS cents 6 for 2020 and 8 for 2030			**85**			**230**

Given in Figure 1.5(II) are electricity savings against demand from energy efficiency measures and technologies based on assumed penetration levels and assumptions elaborated in Table 2.8(II).

Figure 1.5(II): Electricity savings against demand from energy efficiency measures and technologies



From figure 1.5(II) and Table 2.8(II), it is clear that there is reasonable energy savings from the end users in the mining and industry, commercial/services and households sectors averaging 1,416 Gwh and 2,865 Gwh for the years 2020 and 2030, respectively. In terms of monetary savings, this translates to US$ 85 and 230 million dollars for the same target years. Avoided capital infrastructure development for electricity generation is estimated at 200 and 412MW and this translates into avoided investments of US$ 700 and 1,442 million dollars for the years 2020 and 2030, respectively. This avoided investment is quite significant for an economy like Zambia's and recognizing that EF measures been recommended are very modest and achievable as long as Zambia seriously implement recommended measures outlined in section 4.3.

The measures identified for deployment for EF and management include; (i) awareness and information program for industrial and commercial entities and municipalities, (ii) provision of financial mechanisms and incentives, (iii) Introduction of energy management program to industrial and commercial entities and municipalities and (iv) formulation of a national energy efficiency and management policy, strategy, and action plan

5.0 BARRIER ANALYSIS OF IMPROVED CHARCOAL UTILIZATION AND PRODUCTION

5.1 Market Analysis

Charcoal is an important energy source in Zambia. It ranks second to firewood in terms of primary energy supply. In 2000, it accounted 33% of total primary energy supply while fuelwood accounted for 43%, electricity and petroleum 10% each and coal 4%(SNC, 2010). In Zambia most of the charcoal is produced in earth-mound kilns of various sizes. Currently there is no standardized wood conversion fuel efficiency, but it is estimated to line between 10 to 20% depending on the source of reference (Mwitwa, 2012).

In the year 2008, total charcoal production was estimated at 1,000,000 tonnes, contributing to 10,000,000 tonnes of wood cultivated for purpose of charcoal production. Charcoal production is one of the drivers to deforestation and forest degradation, in addition to land clearing for agriculture, infrastructure development and timber harvesting. Between 2005 and 2010, annual deforestation rate was estimated to between 250,000 to 300,000 hectares per year (ILUA, 2005)

The charcoal chain involves production, distribution and marketing. The charcoal industry has primary and secondary stakeholders. Primary stakeholder comprises of the charcoal producer, trader, and transporter, end consumers, on one hand and traditional rulers and forestry department on the other. Secondary stakeholders include: District Council, Zesco, DoE, ZEMA, Charcoal Producers Association, Natural Resource Based NGOs and Council markets (Mwitwa, 2012)

Even though, there is no targeted and comprehensive charcoal or wood biomass policy, several strategies and legal frameworks such as the National Energy Policy, addressing the charcoal sector exist aimed at contributing to the conservation of forests and sustainable management of firewood and charcoal production. Further, the primary legal and policy framework - Forest Act No 39 of 1973 and Forest policy of 1998 promulgate how the forest sector will be administered through regulations. In view of the existence of several policies and strategies related to charcoal production, and various primary and secondary stakeholders involved, charcoal sector operates in a complex and multilayered institutional and legal context resulting, in unclear framework for stakeholders operating in the sector (Mwitwa, 2012)

Charcoal is predominately consumed in urban and peri-urban areas. An estimated 15% of charcoal is consumed in rural areas with urban areas accounting for 85%. The average annual household consumption in urban Zambia is 1046kg per household. Charcoal is mostly transported from production using trucks and pickups. The distance from production areas to demand centers varies from 30km to 200km with motor vehicles accounting for 99% of the charcoal transported. The rest is carried as head loads, wheel-burrows, bicycles and ox-carts. The charcoal is used in a device called “Mbaula” and its thermal efficiency is estimated low at 10%.

Fire wood on the other hand is used predominantly for cooking and heating in rural areas. The device used for cooking and heating is a three stone stove and the average consumption per household per year 4.5 tonnes per annum.

5.2 Identification of Barriers for deployment of improved charcoal utilization (including firewood) and production

5.2.1 Improved Charcoal Production

Barrier analysis work was carried out through a root – cause analysis presented in annex V-IV. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is brick kiln for improved charcoal production not readily available and used in Zambia and management not widely practiced in Zambia

- *The main barriers:*

    - Technical constraints
    - Social culture and behavioral
    - Inadequate human skill
    - Inadequate access to financial resources

- *The root-cause to somel barriers is* lack of knowledge of the brick kiln technology and skills to construct, consumer preferences and social biases and traditions and habits, high cost of capital and low affordability.

Decomposition of identified barriers is summarized in Table 2.9(II)

Table 2.9(II): Decomposition of identified barriers to deployment of improved charcoal production kiln (brick)

Barrier	Sub Barrier	Elements contributing to barrier
Technical	Technical constraints	Non availability of brick kiln technology and knowledge of it design.
Social culture and behavioral	Social culture and behavioral biases	Consumer preferences and social biases and traditions and habits, cheaper alternatives in the form of traditional earth kiln methods.
Human skills	Inadequate human skills	Lack of skills and experience in constructing and operating the brick kiln and knowledge of its operations.
Economic and financial	High cost of capital and inadequate access to financial resources	High cost capital of materials for construction of brick kiln and low income among charcoal makers to invest in brick kilns which is relatively more expensive than the traditional earth kiln.
Policy, legal and regulatory	No targeted and comprehensive charcoal or wood biomass policy	In view of the existence of several policies and strategies related to charcoal production, and various primary and secondary stakeholders involved, charcoal sector operates in a complex and multilayered institutional and legal context resulting, in unclear framework for stakeholders operating in the sector.

The barriers identified inhibiting deployment of charcoal production kiln(brick) include:(i) technical constraints (ii) social culture and behavioral biases (iii) inadequate human skills (iv) high cost of capital and inadequate access to financial resources and (v) no targeted and comprehensive charcoal or wood biomass policy

5.2.2 Improved Charcoal/ Firewood Cookstoves

Barrier analysis work was carried out through a root – cause analysis presented in annex V-V. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is limited use of improved cooking stoves in communities.
- *The main barriers:*
  - High upfront costs of improved stoves
  - Social culture and behavioral
  - Poor market infrastructure
  - Inadequate information
- *The root-cause to some barriers is* low affordability of the device by end users, consumer preferences and social biases and traditions and habits, absence of coordinated marketing program/plan and lack of information and awareness on improved stoves and availability.

Decomposition of identified barriers is summarized in table 2.10(II)

Table 2.10(II): Decomposition of identified barriers to deployment of improved charcoal / firewood cookstoves

Barrier	Sub Barrier	Elements contributing to barrier
Economic and financial	High upfront costs of improved stoves	Low affordability by most end users to purchase improved cooking stoves which are far much costly than the traditional stoves(Mbaula).
Social, culture and behavioral	Social, culture and behavioral biases	Social culture and behavioral biases due to cheaper alternatives in the form of traditional stoves(Mbaula) for charcoal and 3 stone for firewood), consumer preferences and traditions and habits.
Market failure/imperfection	Poor market infrastructure for marketing of improved stoves	Absence of coordinated marketing program/plan to elaborate awareness and information program.
Information and awareness	Inadequate information on improved stoves	Lack of market information on improved stoves due to limited information and awareness of ICS availability and usage.

The barriers identified inhibiting deployment of charcoal production kiln(brick) include:(i) technical constraints (ii) social culture and behavioral biases (iii) inadequate human skills (iv) high cost of capital and inadequate access to financial resources and (v) no targeted and comprehensive charcoal or wood biomass policy.

5.3 Enabling Environment: Measures to overcome barriers

5.3.1 Improved charcoal production (brick kiln)

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-IV. The measures for deployment of improved charcoal production (brick kiln) are summarized on Table 2.11(II).

Table 2.11(II): Measures for deployment of improved charcoal production (brick kiln)

Category	Measures	Elaboration of measures
Technical	Development of the brick kiln technology pack.	Development of brick kiln technology pack describing the design with drawings, size of kiln appropriate to Zambia's conditions, material specifications, capital costs and O&M costs.
Information and awareness	Awareness and information on business opportunities of brick kiln and development of business plan.	Develop awareness and information pack on business opportunities of brick kiln and development of business plan (market, technology description, financial analysis, financing including carbon financing, risks and mitigation measures) for charcoal SME and entrepreneurs
Economic and financial	Innovative financing mechanism	Provision of dedicated fund through the involvement of financial institutions including micro financial institutions to provide risk capital and development of business model.

The measures identified for deployment of improved charcoal production (brick kiln) include; (i) Development of the brick kiln technology pack. (ii) awareness and information on business opportunities of brick kiln and development of business plan,(iii) innovative financing mechanism.

5.3.2 Improved Charcoal/Firewood Cookstoves

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-V. The measures for deployment of improved charcoal/firewood cookstoves are summarized on Table 2.12(II).

Table 2.12(II): Measures for deployment of improved charcoal/firewood cookstoves

Category	Measures	Elaboration of measures
Economic and financial	Innovative financing mechanism.	Involvement of micro financial institution with a dedicated fund to provide end use micro credit to end users of improved stoves who are unable to buy outright, on one hand, and provision of loans to SME stove manufactures
Information and awareness	Awareness and information program	Awareness and information program through coordinated campaigns and improved market information to improved stoves end users
Technical	Provision of a technical pack for improved cookstoves	Provision of technical pack for improved cookstoves, specifying the design characteristics and specifications to ensure consistency of quality of the product for the SME and stove manufactures

The measures identified for deployment of improved charcoal/firewood cookstoves; (i) innovative financing mechanism (ii) awareness and information program, (iii) provision of a technical pack for improved cookstoves

5.4 Sustainable Charcoal Value Chain

Since charcoal production and use are interrelated, it is recommended that a holistic approach be developed involving sustainable charcoal value chain. Sustainable charcoal involves both sustainable forest management, and use of efficient improved kilns and stoves. The basic components of sustainable charcoal systems include supply and demand side interventions. Supply side interventions are aimed at managing forest resources for charcoal production to include: (i) agro forestry, (ii) woodlot management, (iii) controlled exploitation of forestry resources, (iv) improved carbonization skills and technologies. Demand side interventions include: promote use of improved cookstoves and briquetting, (ii) create awareness on energy conservation, and encourage use of eco-charcoal concept of certification

Achievement of sustainable value chain requires formulation of a holistic institutional, legal and regulatory framework aimed at formalizing the charcoal value chain business. Sustainable value chain framework requires development of pathways for sustainable production of charcoal and use as elaborated on figure 1.6(II)

Figure 1.6(II): Pathway for sustainable charcoal and use

Value	Data assessment	Actors
Forest resources and production	Forest management, regulation and enforcement; Forest area including land use change; Wood production systems including production costs, from natural forests, plantations, agro-forestry and afforestation.	Forest Department, ZEMA Local authorities, communities and civil society
Harvest/ Conversion	Mode of harvesting and charcoal production; Restrictions and regulations (permits, taxes); Types of charcoal kilns; Quantities produced; Efficiency costs	Forest Department, Ministry of Health, ZEMA, Charcoal producers associations, civil society
Packaging and harvesting	Standardization quantification policies	Bureau of standards, charcoal producers association, weights and measures
Transport	Modes of transport; restrictions and regulations; Average distances; Quantities; Transportation costs	Ministry of Transport, RTSA, Transport associations
Marketing	Mode of marketing (designation of charcoal trading sites) and proper storage/depots; Standards; Wholesalers and retailers; Resource availability; Prices	Local authorities, charcoal traders association
Consumption	Population size, number of households, average household size, average energy consumption per capita, availability and prices: types and standardization of cooking devices(Traditional or improved stoves), type of fuel(firewood, charcoal, crop residues, LPG, kerosene)	Bureau of standards, civil society, R&D community, artisans
Financing	Innovative financing throughout the value chain; micro financing for end users, carbon financing	MFIs, philanthropic financers, donor funding, dedicated fund

SUSTAIABLE FRAMEWORK

IMPLEMENTATION

5.5 Cost Benefit Analysis

Sustainable charcoal value chain has been found to be a powerful tool in increasing forest cover and reducing emissions (World Bank, 2011). The study has demonstrated that sustainable value chain increases the forest cover through intervention of supply and demand involving use of traditional kiln as a baseline and sustainable charcoal chain involving combined use of improved kiln and improved stoves as elaborated in figure 1.7(II)

Figure 1.7(II): Best practices to address charcoal as a driver of deforestation

	Year				
	1	5	10	20	Units
Forest Area under BAU Scenario					
	1,887,369	607,640	0	0	hectare
Forest Area with Policy Intervention					
A) Traditional Kiln					
Fuel Switch	1,887,369	838,982	0	0	hectare
Fuel Switch + Improved Stoves	1,887,369	886,701	0	0	hectare
B) Improved Kiln*					
Fuel Switch	1,887,369	1,474,745	921,141	0	hectare
Fuel Switch + Improved Stoves	1,887,369	1,508,616	1,215,381	0	hectare

*Applied Conversion Parameters	
Kiln Efficiency (traditional kiln)	10%
Assumed annual increase in kiln efficiency	20%
Maximum kiln efficiency assumed for improved kiln	15%
Conversion factor wood weight => Volume (ton => m3)	0.85

Assumed Forest Parameters Natural Forests (Miombo Woodland)	
Stock per hectare	10
Growth per hectare per year	2.5

Source: World Bank, 2011

6.0 BARRIER ANALYSIS FOR THE DEVELOPMENT OF BIOFUELS - BIODIESEL

6.1 Market Analysis

Zambia has a wide variety of crops suitable for bioenergy production due to its suitable climatic and soil conditions. The large areas of currently unutilised arable land places Zambia in a strategic position as a country with enormous potential for biofuels production. Of great importance is the need to address sustainability and cost effectiveness issues. Sustainability of feedstock production requires assessment of land availability and suitability which takes account of land requirement for food production and biodiversity.

Another important issue is that of development of standards and regulations for the biofuels industry. In the last few years, good progress has been made in the promotion of biofuels industry in the country. Biofuels industry has been added to a list of priority industry to benefit from incentives under Zambia Development Agency. At the regulatory level, biofuels has been allowed to be traded, and ethanol and biodiesel standards are now available. However, there still remain issues that need to be addressed including financing, cost effectiveness, sustainability issues, transportation and storage issues and pricing in particular.

6.2 Identification of barriers for the deployment of biofuels – biodiesel

Barrier analysis work was carried out through a root – cause analysis presented in annex V-VI. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is biodiesel is not sufficiently produced and used in Zambia for development of biofuels/ biodiesel
- *The main barriers:*
    - Economic and financial
    - Technical
    - Network failures
    - Policy, legal and regulatory
- *The root-cause to identified barriers is* lack of benchmark pricing, high upfront costs and inadequate access to financial resources. Others are lack of comprehensive policy, legal and regulatory framework and weak network connectivity between feedstock producers and plant operators

Decomposition of identified barriers is summarized in Table 2.12(II)

Table 2.13(II): Decomposition of identified barriers to development of biofuels-biodiesel

Barrier	Sub Barrier	Elements contributing to barrier
Economic and financial	Lack of benchmark pricing, high capital cost and inadequate access to financial resources	Lack of benchmark pricing has been caused by delayed negotiations between Government and BAZ due to lack of awareness and sensitization on the former. High capital costs is influenced by high interest rates and perceived investment risks by financial institutions leading to inadequate financial outlay to the biofuels sector.
Technical	Inadequate knowledge on resource cost.	Production and transportation costs not completely known and high cost of agriculture inputs can be a further barrier to resource costs
Network failures	Weak network connectivity between feedstock producers and biofuels plant operators.	There is currently lack of logistics for supply chains influenced by isolated feedstock supply points. There is also undefined material handling system

		from the factory to the outlet.
Policy, legal and regulatory	Lack of comprehensive, policy, legal and regulatory framework	Although progress has been made in implementing biofuel development in Zambia, there still policy legal and regulatory issues which need addressing to include issues that need to be addressed including financing, cost effectiveness, sustainability issues, transportation and storage issues and pricing in particular.

The barriers identified inhibiting development of biofuels/biodiesel (i) lack of benchmark pricing, high capital cost and inadequate access to financial resources (ii) inadequate knowledge on resource cost, (iii) weak network connectivity between feedstock producers and biofuels plant operators, and (iv) lack of comprehensive, legal and regulatory framework

6.3 Enabling Environment: Measures to overcome barriers

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-VI. The measures for development of biofuels -biodiesel are summarized on Table 2.14(II).

Table 2.14(II): Measures for development of biofuels - biodiesel

Category	Measures	Elaboration of measures
Economic and financial	Benchmark pricing, awareness program to financial institutions and specific investment framework	Conclude benchmark pricing for biofuels/biodiesel aimed at encouraging investment in the sector. Awareness programme to enable financial institutions realize opportunities for investment in the biofuel sector. Provision of specific investment framework and dedicated fund to provide risk capital to feedstock producers and plant operators
Technical	Study on cost effectiveness of feedstocks for biofuel-biodiesel productions and associated logistics for supply chain	Undertake study on cost effectiveness of biofuels feedstocks to include: Jatropha soybeans, sunflower, cotton seed and palm oil and associated costs for logistics and transportation.
Policy, legal and regulatory	Comprehensive legal and regulatory framework	Development of comprehensive framework taking account of marketing arrangements modalities, dedicated fund to support feedstock and biofuel production, land availability and suitability assessments and sustainable criteria development, and R&D of feedstock optimization

The measures identified for development of biofuels-biodiesel; (i) benchmark pricing, awareness program to financial institutions and specific investment framework (ii study on cost effectiveness of feedstocks for biofuel-biodiesel productions and associated logistics for supply chain, and (iii) comprehensive legal and regulatory framework.

6.4 Cost Benefit Analysis

Biodiesel is produced from oil bearing crops to include rape seed, soya beans, sunflower, and recently Jatropha. An analysis was undertaken for biodiesel to assess production cost of selected feedstocks (jatropha, soyabean and sunflower) based on resource and cost requirements for these feedstocks; Given in Table2.14 (II) and figure1.8 (II) are comparison of production costs of Jatropha, soyabean and sunflower against production diesel prices at different crude oil prices.

Table2.15 (II): Comparison of production costs of Jatropha, soyabean and sunflower against production diesel prices at different crude oil prices

		Jatropha	**Soya beans**	**Sunflower**
1	Biodiesel production(thousand tonnes/annum)	50	50	50
2	Biodiesel production(million litres /annum	55.6	55.6	55.6
3	Yield (tonone/hectare)	4	3	1.5
3	Oil Content (%)	40	18	40
4	Extraction Efficiency(%)	75	75	75
3	Seed requirements (tonne)	175,000	370,370	170,000
4	Land requirements (Hectares)	44,000	124,000	57,000
5	Unit Cost (US$)/tonne	120	780	330
7	Cost of raw materials(US$ millions)	21.70	289	56.1
8	O&M Cost plus depreciation (US$ millions)	29.5	294.5	61.6
9	Unit production (US$)	0.5	5.3	1.1
10	Gasoline Price at US$50/barrel	0.42	0.42	0.42
12	Gasoline Price at US$70/barrel	0.55	0.55	0.55
13	Gasoline Price at US$80/barrel	0.65	0.65	0.65
14	Gasoline Price at US$90/barrel	0.72	0.72	0.72
15	Gasoline Price at US$100barrel	0.78	0.78	0.78

Source: Biofuel framework development for Zambia, Ministry of Energy and Water Development, 2008

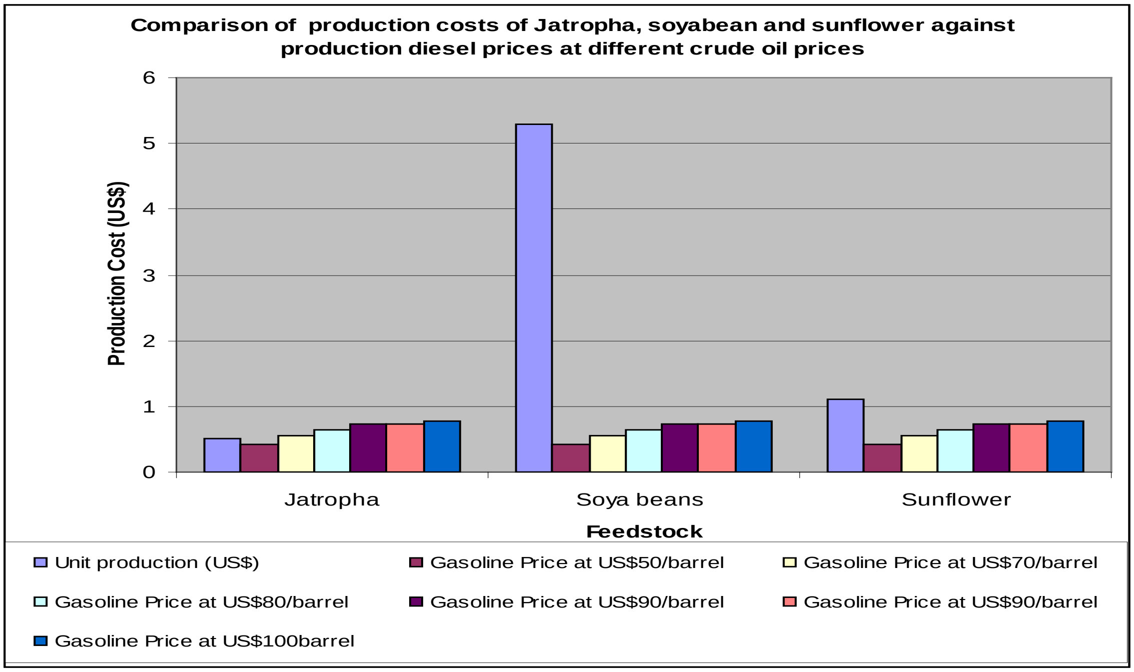


Figure 1.8(II) is comparison of production costs of Jatropha, soyabean and sunflower against production diesel prices at different crude oil prices

From the results displayed, unit production cost for jatropha, soya bean and sunflower have been calculated at US$0.50, 5.3 and 1.10 per litre, respectively. In terms of competitiveness, only Jatropha is mostly competitive (at more than US$ 60/barrel) and to a lesser extent (sunflower at slightly more than US$100/barrel). However, soyabean has been found to be totally uncompetitive at US$5.3 per litre mainly due to low oil content and high cost of raw material. In terms, of land requirements, Jatropha required 44,000, soya bean 124,000 and sunflower 57,000 hectares to produce 55.6 million litres of biodiesel per annum. Apart from being completive in production cost, Jatropha also requires less land compared to sunflower and worst of them all soya beans.

7.0 BARRIER ANALYSIS FOR SUSTAINABLE AGRICULTURE

7.1 Market Analysis

Agriculture in Zambia has the potential to enhance economic growth and reduce poverty. Good performance in the sector translates into overall improvement of the country's GDP, creates jobs and expands the tax base. This is mainly because the majority of Zambians depend on agricultural related activities for livelihood. Agriculture in Zambia's supports the livelihoods of over 70 of the population. Zambia's economy has grown steadily in real terms since 2000. However, the percentage contribution of agriculture sector to GDP had declined from 16% in 2001 to 12.6% in 2009.

Zambia is abundantly endowed with resources that are required to stimulate agricultural and rural development, in general and poverty reduction, in particular. The country has a land mass area of approximately 752, 000 square kilometres of which 12% is suitable for arable use. However, only 14% of arable land is presently cultivated. The country has a good climate, abundantly arable land, labour and plenty of water resources. The rainfall patterns are reasonably well and provides suitable characteristics for production of a diversity of crops, livestock and fish enterprises (PRSP, 2003).

There are three main categories of farmers in Zambian agriculture; small, medium and large scale. Small scale farming systems in Zambia are overwhelmingly dominated by single crop maize. In 2009/2010 81.72% of all small scale farmers grew maize, which is the staple food for the country. Yield for maize is below global average and is estimated at 1.2 tonnes per hectare. This low yield is attributed to no or less use of fertilizers by the majority of small scale farmers since most of them are unable to afford. Despite this low yield, they, produce about 50% percent of the total maize supply in the country. Although there is a Government program "Farm Input Support Program"which supports small scale farmers with fertilizer and seed, it does not cover the majority of small scale farmers. Some of the small scale farmers have increased yields to 2-3 tonnes per hectare. The intention of the program is to support small scale farmers once in a given season and stand on there on during the following farming season. However this has not been realized due to relatively low floor maize prices and in some cases poor management practices.

In view of the above short comings, the Government is encouraging sustainable agriculture which has an advantage of increasing the yield without the use of fertilizer and a relatively lower cost. Sustainable agriculture involves a number of practices to include; (i) development of green manure and cover crops for soil improvements (ii) conservation tillage (iii) use of organic manure (iv) application of lime, (v) control of weed.

The measure on development of green manure involves growing of green manure crop such as velvet beans, sunhemp, pigeon peas, and cowpeas in rotation with cereals. This measure leads to less use of mineral nitrogen leading to less loss of N_2O, nutrition protein food, and measure breaks soil pan leading to less run-off. The measure on conversation tillage involves minimum tillage such as basin planting and reap row planting. The measure leads to precise and less input application of fertilizer and lime leading to less N_2O and less CO_2 produced. The measure on use of organic fertilser involves use of sunhemp, pigeon peas, and compost. Measure leads to less application of fertilizer leading to less N_2O and reduced erosion. The measure on application of lime involves application of lime on crop production. This measure neutralizes acidity and sustainable use of land leading to reduction of shifting cultivation and hence less CO_2 produced. The measure on control of weeds involves rotation of legumes in rotation and intercropping. The measure leads to less production of CO_2 due minimum tillage and improves conservation of soil water leading to increased yields and hence increased CO_2 sequestration.

The project envisages supporting small scale farmers on sustainable agriculture, initially starting with a total of 1000 hectares, followed by 3000 hectares and stabilizing at 5000 hectares. The size of the farm will average 2 hectares and each farmer will be supported with fertilizer of 200kg of D-Compound and the same for urea per hectare which is the same input as baseline. As sustainable agriculture activities progress and beginning to take root, the amount of fertilizer will be reduced to 100Kgs for both in the second year and to 40kg in the third year, and thereafter there will be no need for fertilizer until the tenth year.

7.2 Identification of Barriers

Barrier analysis work was carried out through a root – cause analysis presented in annex V-VII. The main conclusions from the analysis undertaken is summarized as follows –

- *The starter problem* is conservation agriculture not extensively practiced in Zambia
- *The main barriers:*
    - Economic and financial
    - Technical
    - Social, culture and behavioral
- The root-cause to identified barriers include high resource development costs, tedious work due to lack of equipment, new technology and lack of knowledge.

Decomposition of identified barriers is summarized in Table 2.16(II)

Table 2.16(II): Decomposition of identified barriers for sustainable agriculture

Barrier	Sub Barrier	Elements contributing to barrier
Economic and financial	High resource development costs	Inadequate resources for crop research and training for improved management practices, extension services and working capital for herbicides and insecticides.
Technical	Tedious work due to lack of equipment	Tedious work involving pot holing requires more time since small scale farmers are unable to afford required equipment
Social, cultural and behavioral	Social cultural and behavioral biases	Social cultural and behavioral biases leading to resistance to change

The barriers identified inhibiting practicing conservation agriculture (i) high resource development costs (ii) tedious work due to lack of equipment and (iii) social cultural and behavioral biases.

7.3 Enabling Environment: Measures to overcome barrier

Measures to overcome barriers where identified based on logical problem analysis with inputs from expert groups and results are shown in annex V-VII. The measures for are summarized on Table 2.17(II).

Table 2.17(II): Measures for sustainable agriculture

Category	Measures	Elaboration of measures
Economic and financial	Provision of development resources	More Resources required for enhanced integrated crop research and conservation technologies training and outreach programs, extension services and working capital for herbicides and insecticides.

Technical	Introduction of appropriate machinery for ease of conservation agriculture application.	Provision of innovative financing mechanism for appropriate machinery leading to reduced tillage with implementation of basin and rip row tillage resulting in precise placement of fertilizer and lime and facilitated timely planting
Social, culture and behavioral	Awareness and information program to highlight the benefits and technologies for sustainable agriculture	Awareness and information program to highlight the benefits(high productivity, lower consumption of inorganic fertilizers, carbon financing, improved soil fertility and water retention), and new technologies to include: (i) integration and annual and perennial legumes in crop production for medium and long term soil productivity improvements, (ii) stover management to maintain ground cover of 30 – 50 percent, (iii) weed management(early stage weeding to past harvest time using less costly management technologies)

The measures identified for sustainable agriculture; (i) provision of development resources (ii introduction of appropriate machinery for ease of conservation agriculture application. (iii) awareness and information program to highlight the benefits and technologies for sustainable agriculture.

7.4 Cost Benefit Analysis

Cost benefit analysis was undertaken for introduction of sustainable agriculture practice as elaborated under market analysis. Three scenarios were considered assessing the benefits and costs of baseline situation with and without subsidy, and sustainable agriculture to small scale farmers in Zambia . In the case of sustainable agriculture increased productivity averaging 5 tonnes per hectare against a baseline of 1.2 tonnes per hectare without subsidy and 2.5 with subsidy, and reduced inputs (inorganic fertilizers) and associated costs. The costs for sustainable agriculture include resources for R&D and extension services which are estimated at US$ 1,000,000 per annum.

Given in annex VI are the input parameters to the analysis to include; production figures, price of maize per tonne at which the small scale farmer is selling the product, cost of fertilizer and development costs for sustainable agriculture for the three scenarios. Table 2.18(II) summarizes the costs and benefits in form on Net Present Value (NPV) at 4% and 7% discount rate for the three scenarios

Table 2.18(II): costs and benefits expressed in NPV at 4% and 7% discount rate for the three scenarios

Category	NPV as at 4%	NPV as at 7%
Baseline without subsidy	(897,826)	(808,070)
Baseline with subsidy	8,236,535	6,908,673
Sustainable Agriculture	30,338,641	25,426,824

Results of the analysis clearly indicate that sustainable agriculture has positive benefits with NPV of US$25.4 million against a negative NPV US$ 808,070 baseline without subsidy at 7% discount rate. If adopted sustainable agriculture will contribute to reduction of resources currently been used for supporting subsidy from maize production. Besides small scale farmers will benefit from carbon financing under various mechanisms to include CDM and NAMAs.

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SREEN 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

ILUA, 2005: Integrated Land Use Assessment Report

RESAP, 2011: Renewable Energy Strategy and Action Plan

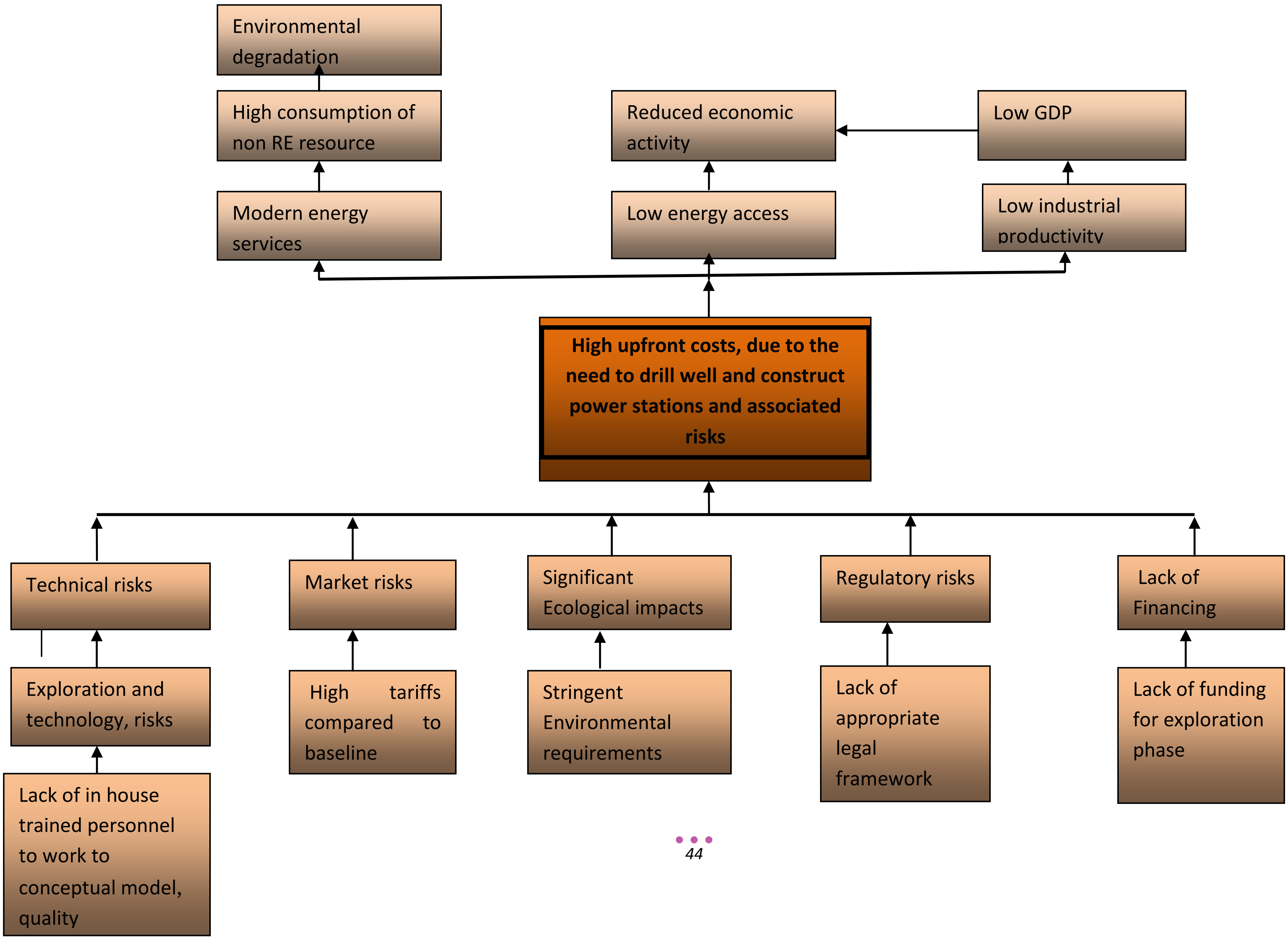
SAPP, 2010: SAPP annual report

List of stakeholders involved and their contacts

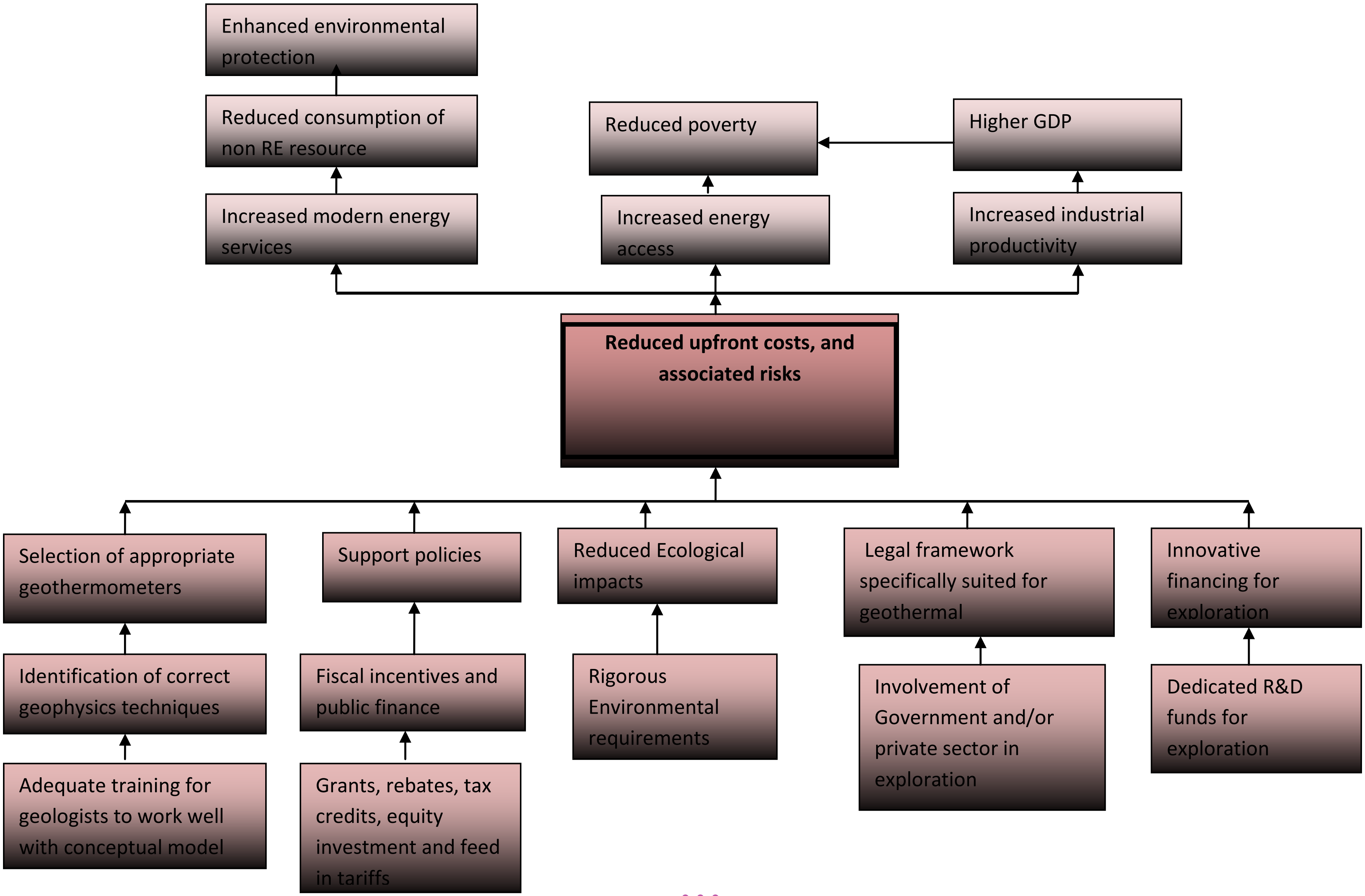
Group	Technology	Personnel	Institution	E-mail
1	Geothermal Electricity	Ms B Muyunda	Zesco	bmuyunda@zesco.co.zm
	Off- grid	DoE	DoE	
	Energy Management	Dr Kwenda kwema	Lloyds	
		Mr G Kayawe	Ash Field	georgekayawe@yahoo.co.uk +260976317107
2	Improved cook stoves	Mr Luwaya	UNZA	
	Brick klins	Mr Siakachoma	UNZA	csiakachoma@yahoo.com
		Mr A Makano	MPMC-Metro	abraham.makano@gmail.com
		DoE	DoE	
3	Sustainable Agriculture	Dr K Muyinda	UNZA	kmunyinda@unza.zm Cell:+260 978270898
	Bio-diesel	Ms Mwangala	Ministry of Agriculture	
		Dr D Chibamba	UNZA	doutypaula@yahoo.co.uk
		DoE	DoE	

Annex I: Geothermal

Geothermal – Barriers

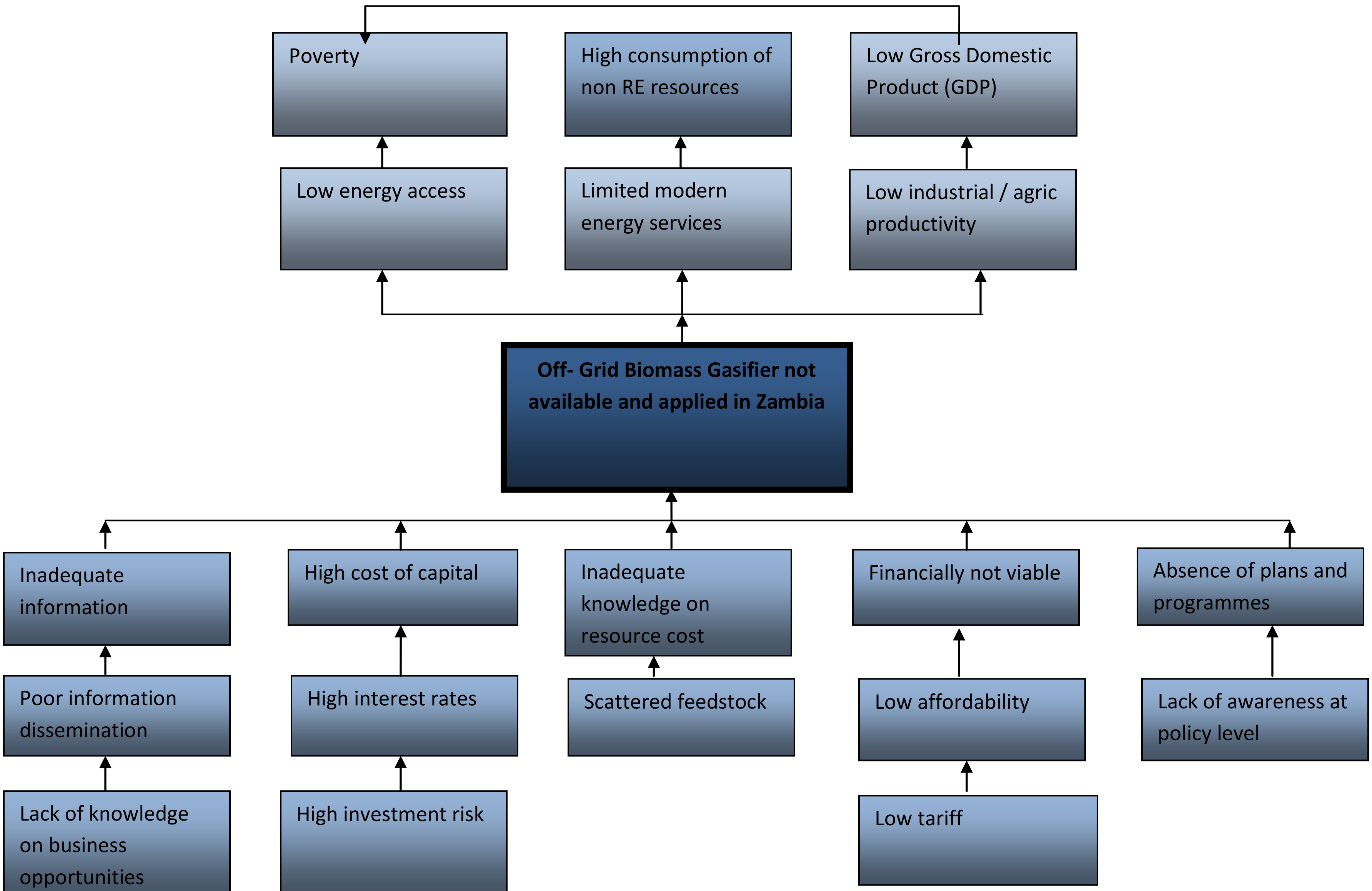


Geothermal - Measures

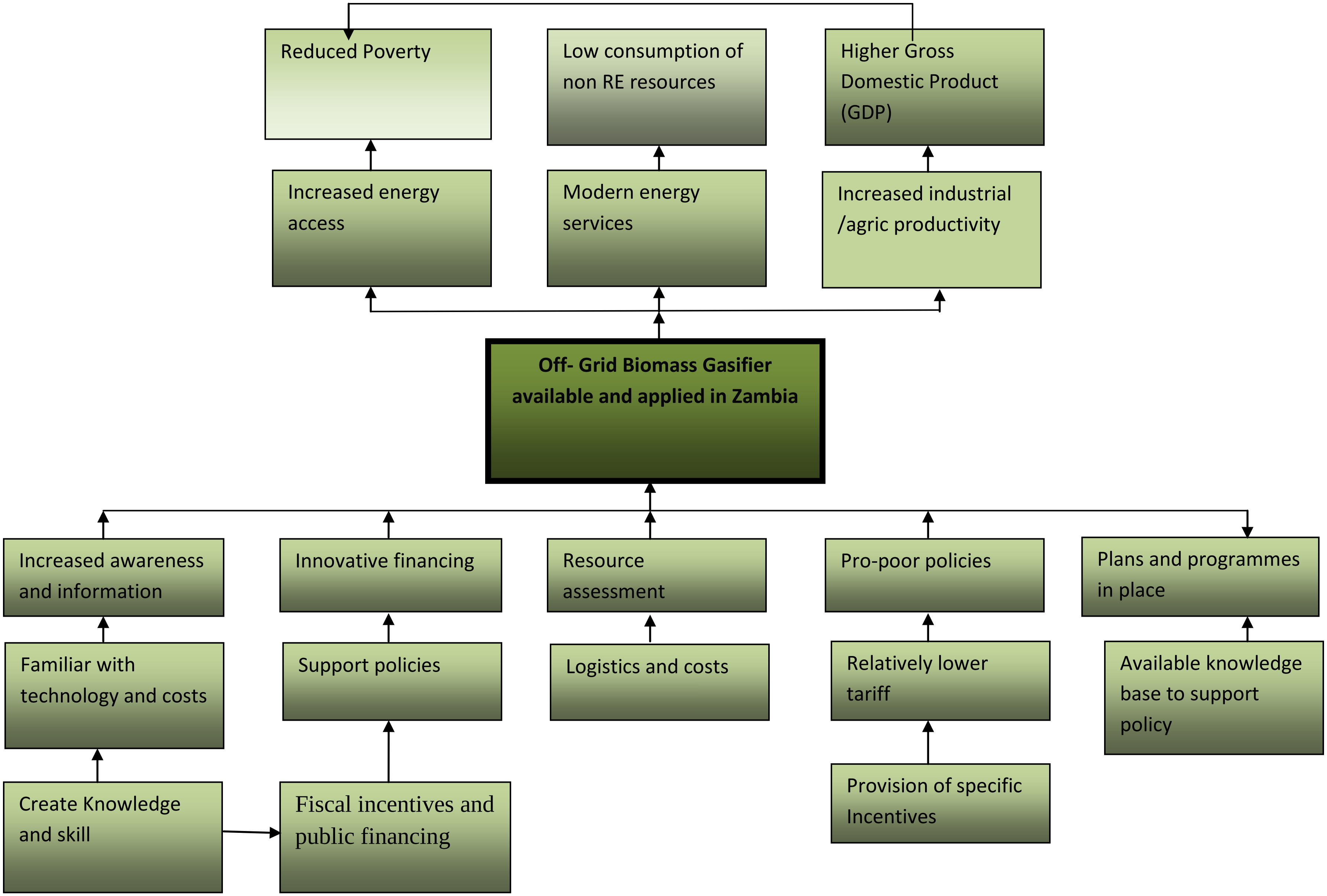


Annex II: Biomass Gasifer for off grid

Biomass Gasifer Barriers

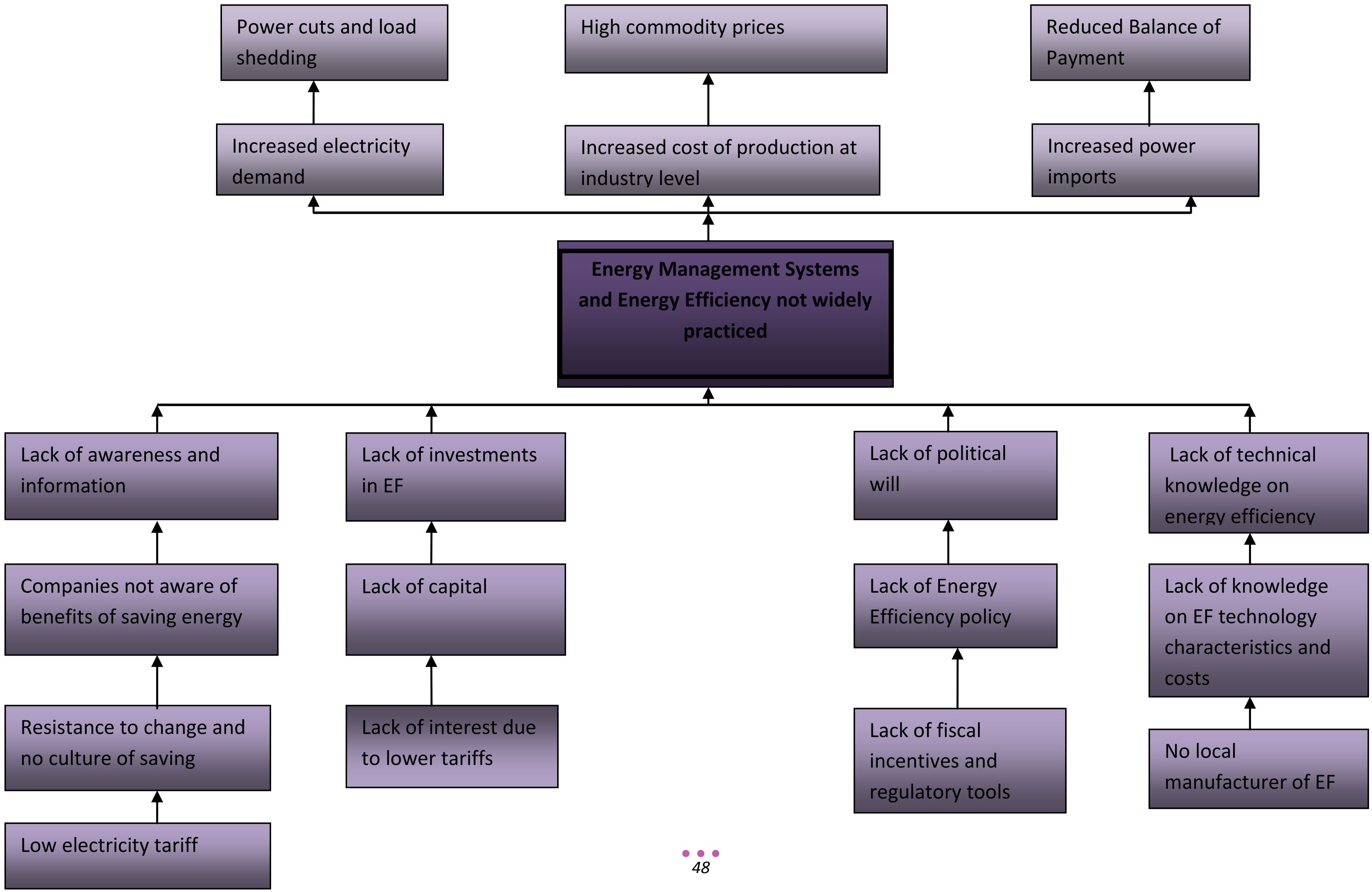


Biomass Gasifier : Measures

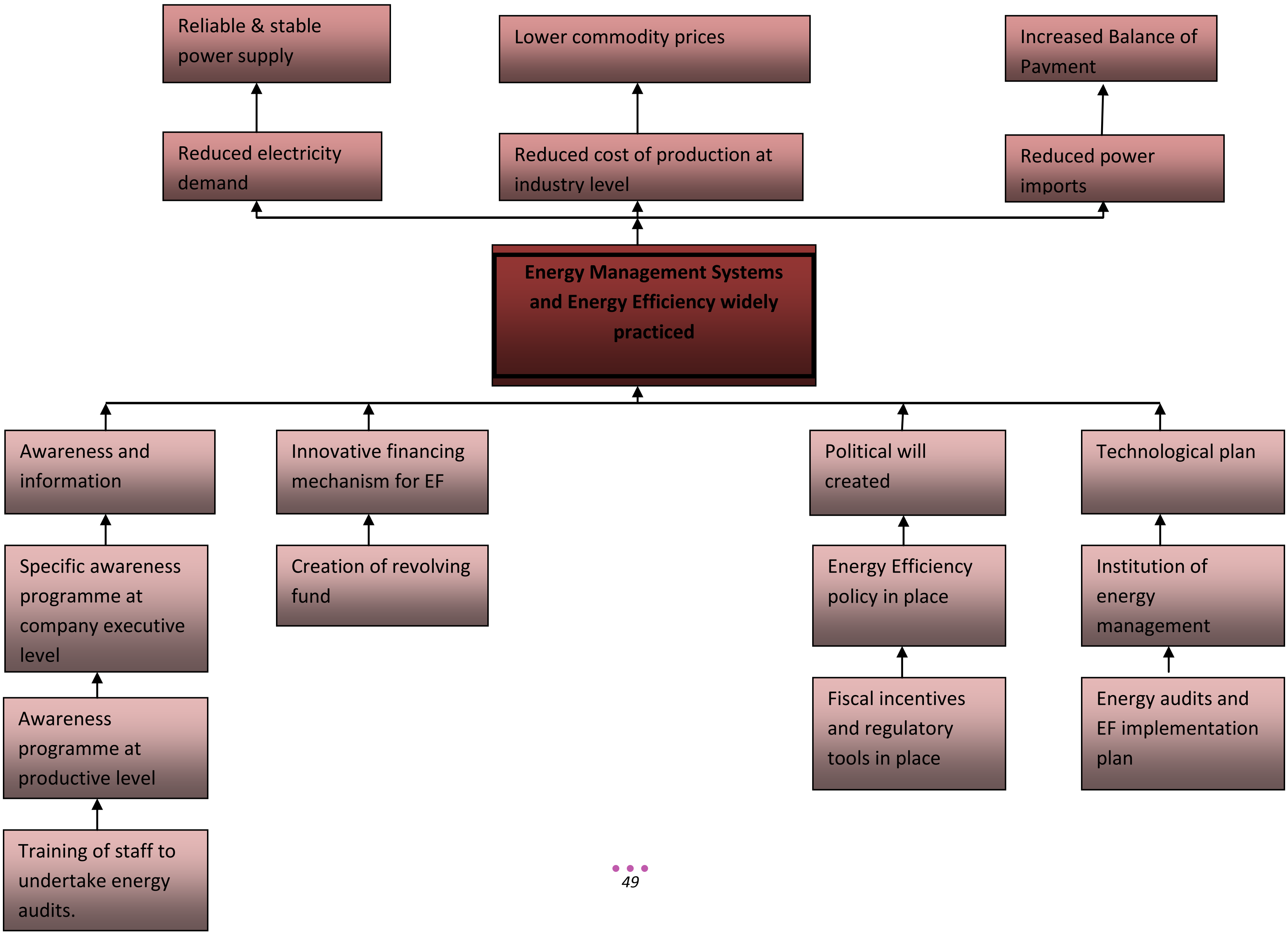


Annex III: Energy Efficiency and Management systems

Energy Management Systems and Energy Efficiency: Barriers

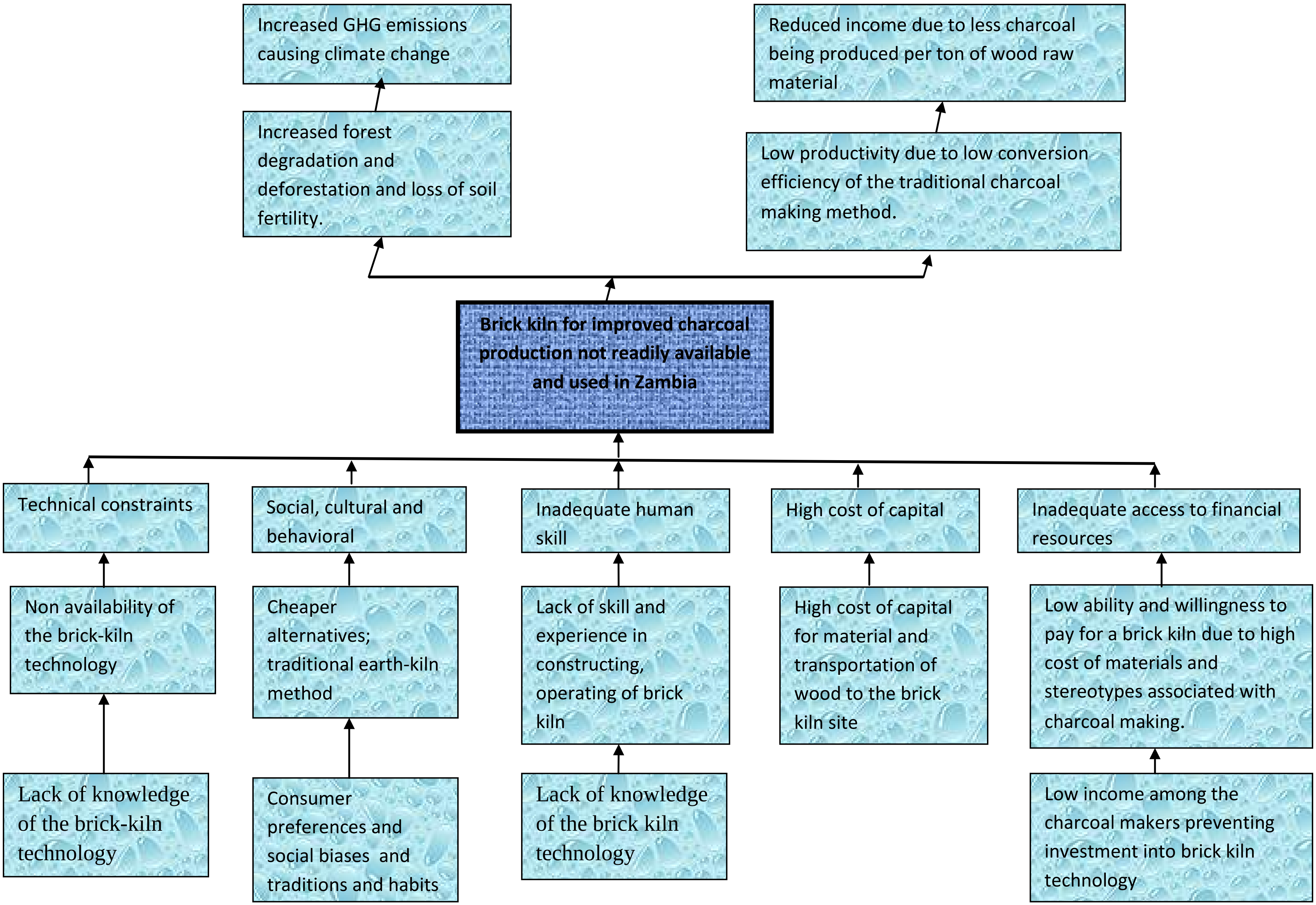


Energy Management Systems and Energy Efficiency: Measures

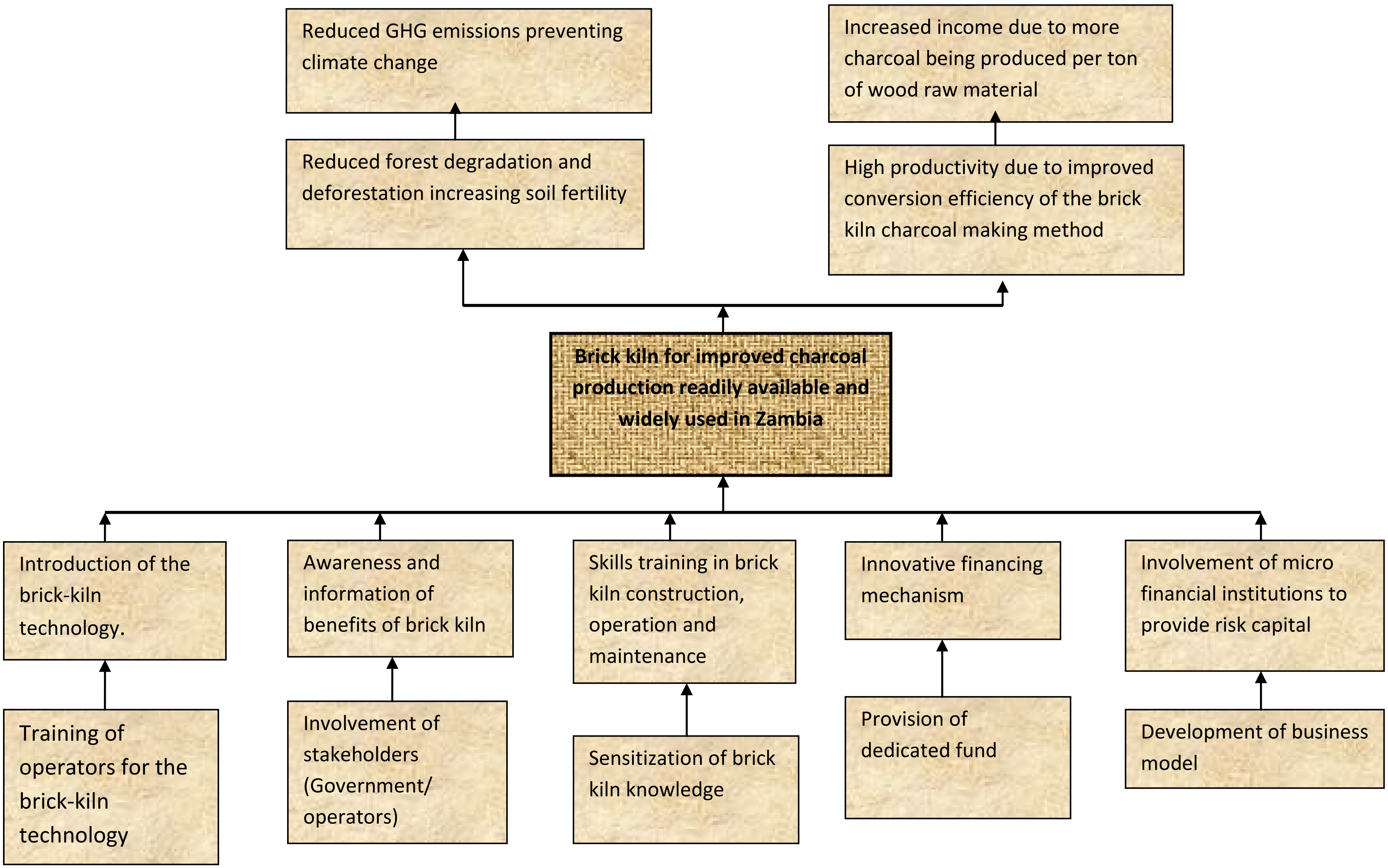


Annex IV: Charcoal production

Brick Kiln for Improved Charcoal Production: Barriers

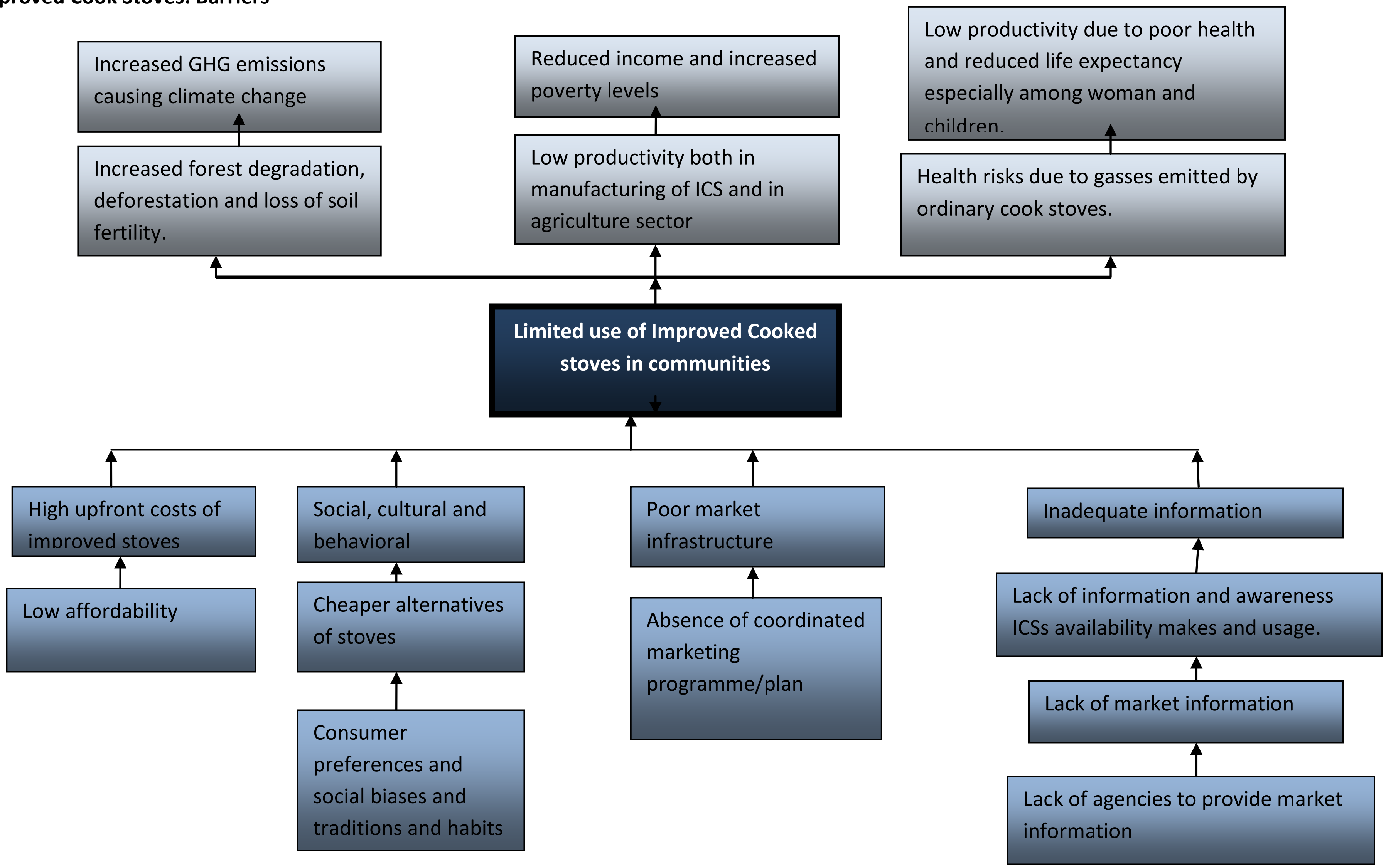


Brick Kiln for Improved Charcoal Production: Measures

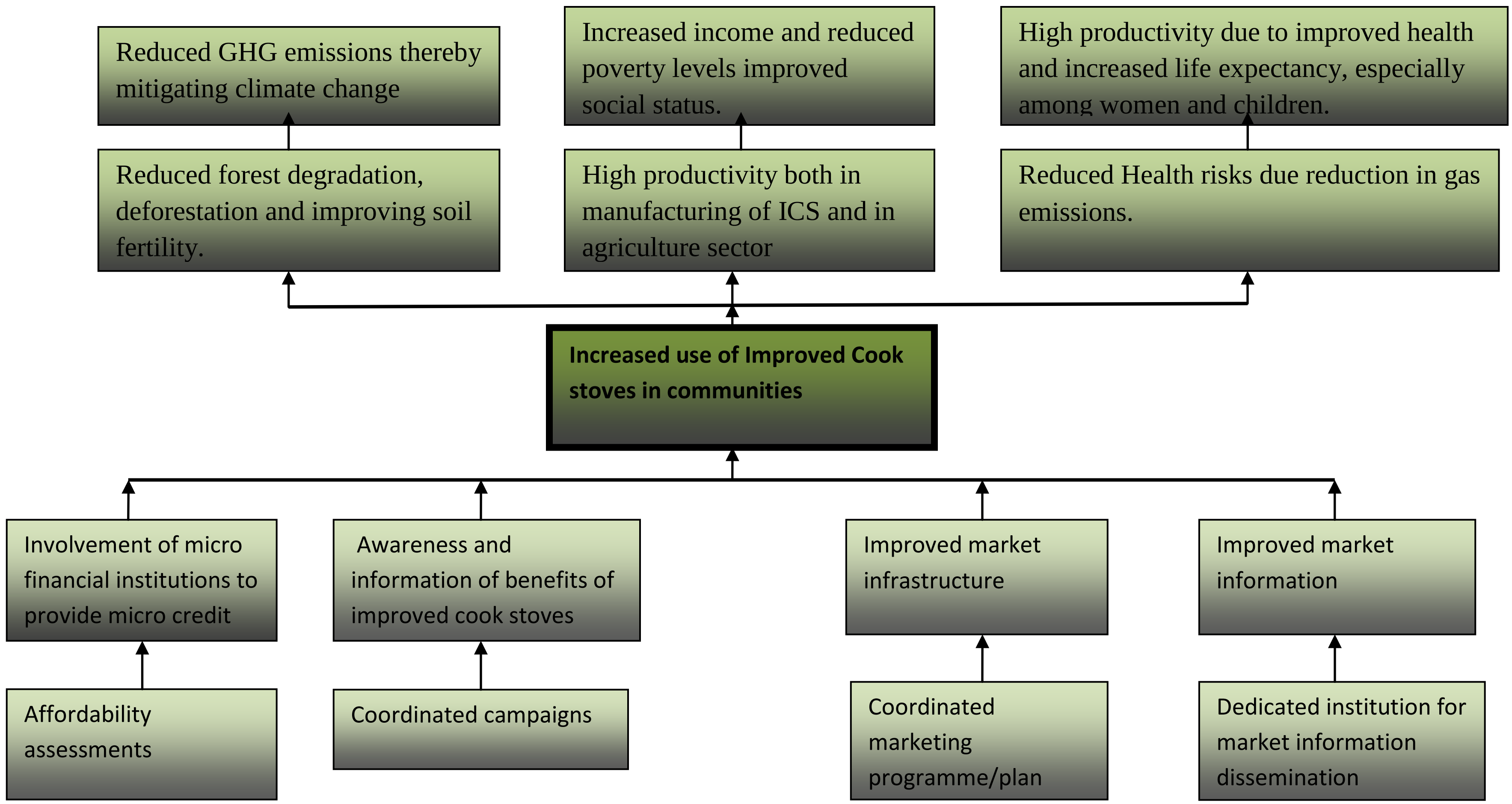


Annex V: Improved cookstoves

Improved Cook Stoves: Barriers

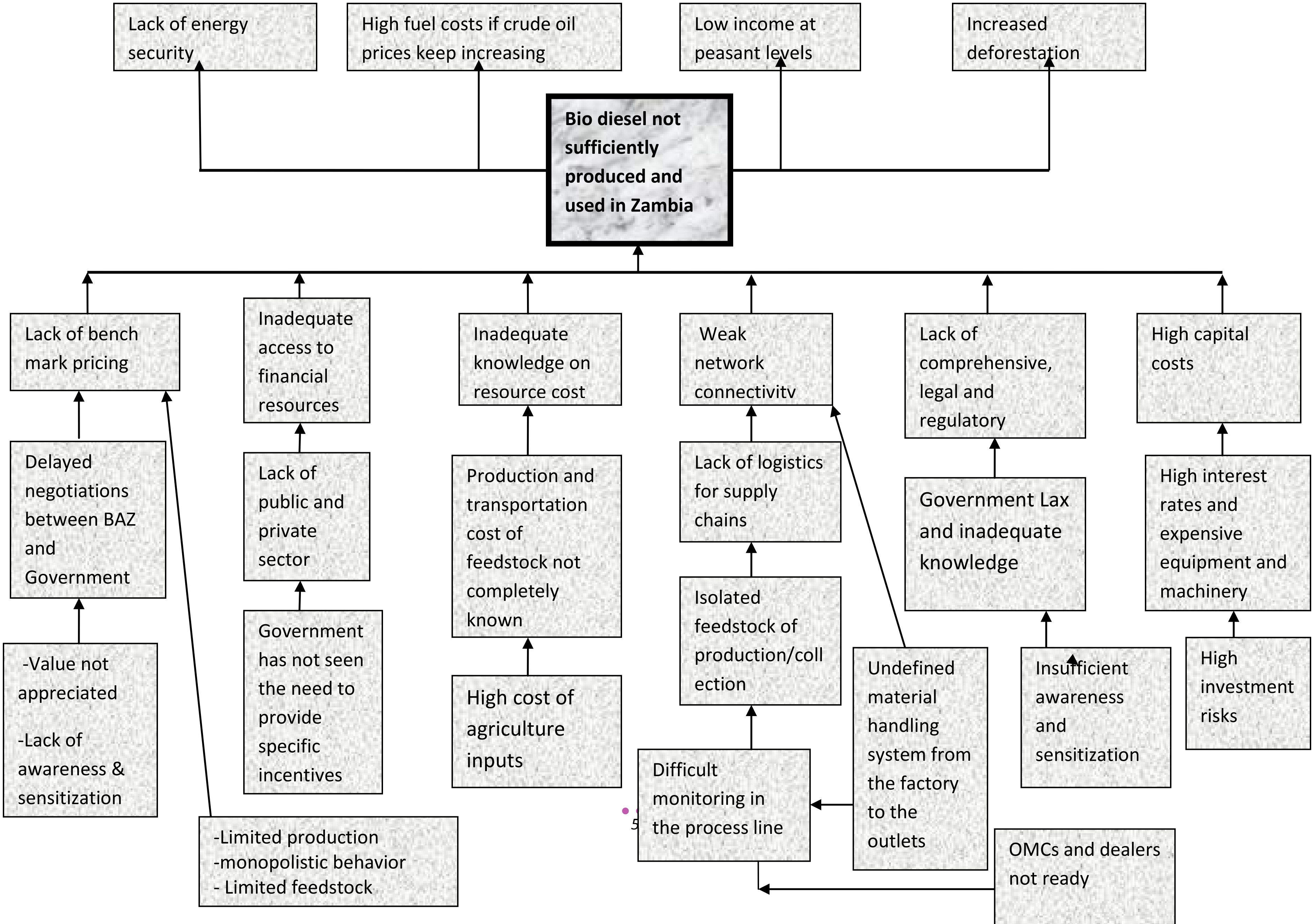


Improved Cook Stoves: Measures

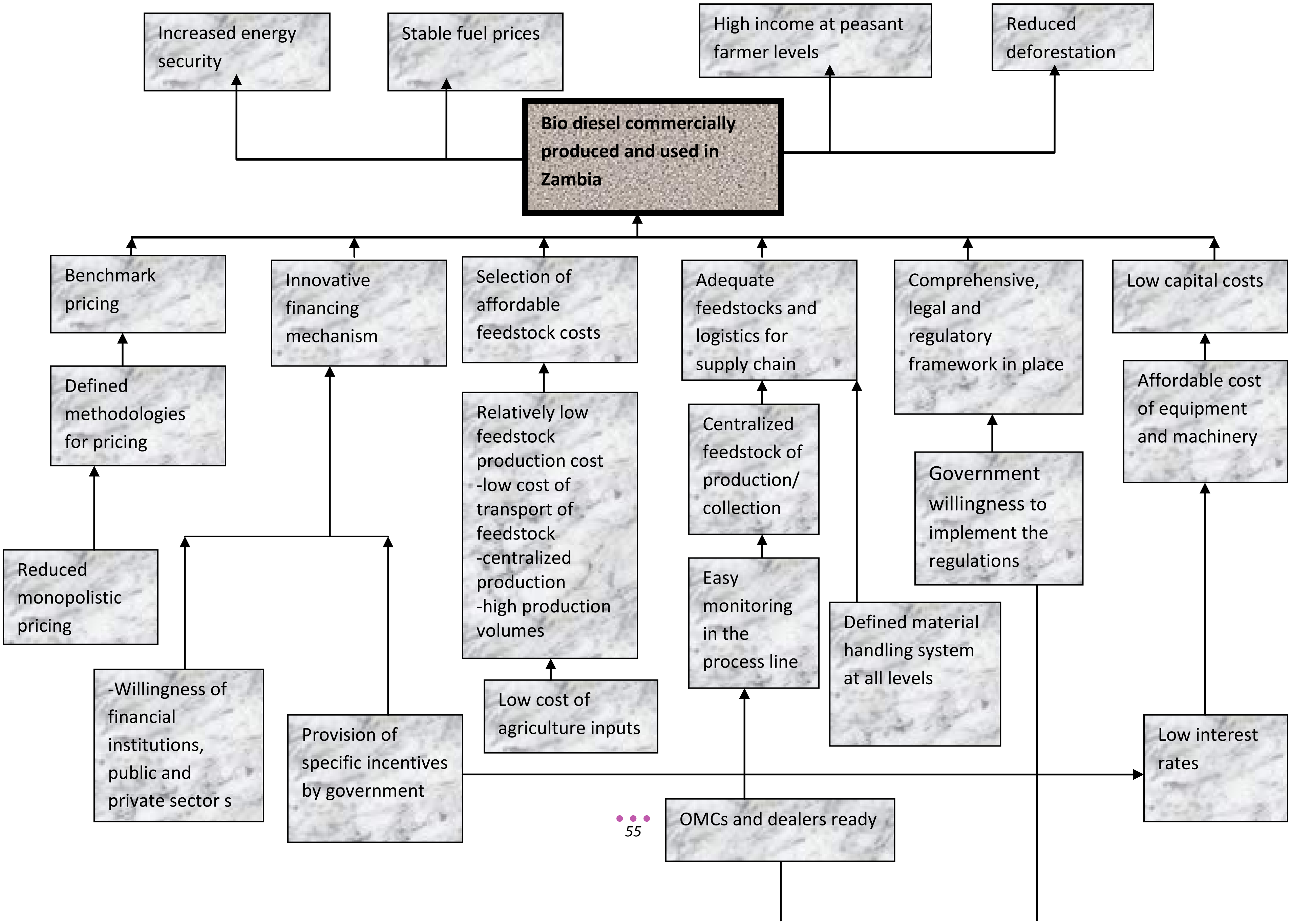


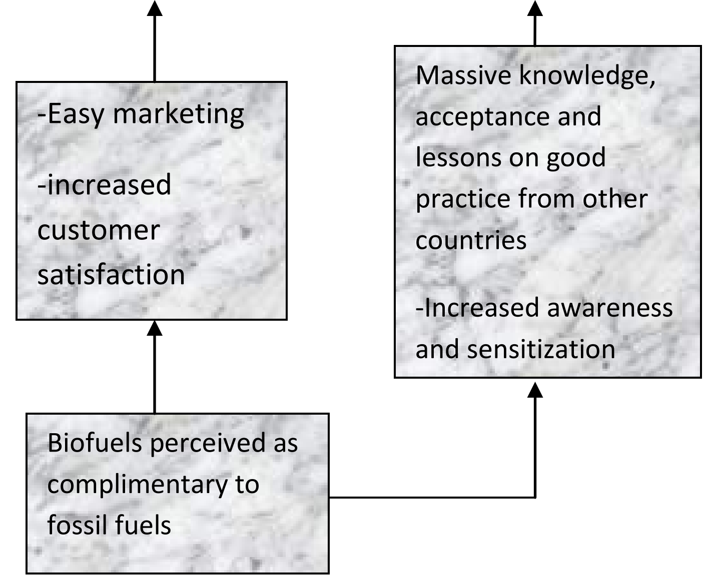
Annex VI: Biofuels from Jatropha

Biodiesel from Jatropha/Bioethanol from sugar cane and sweet sorghum: Barriers



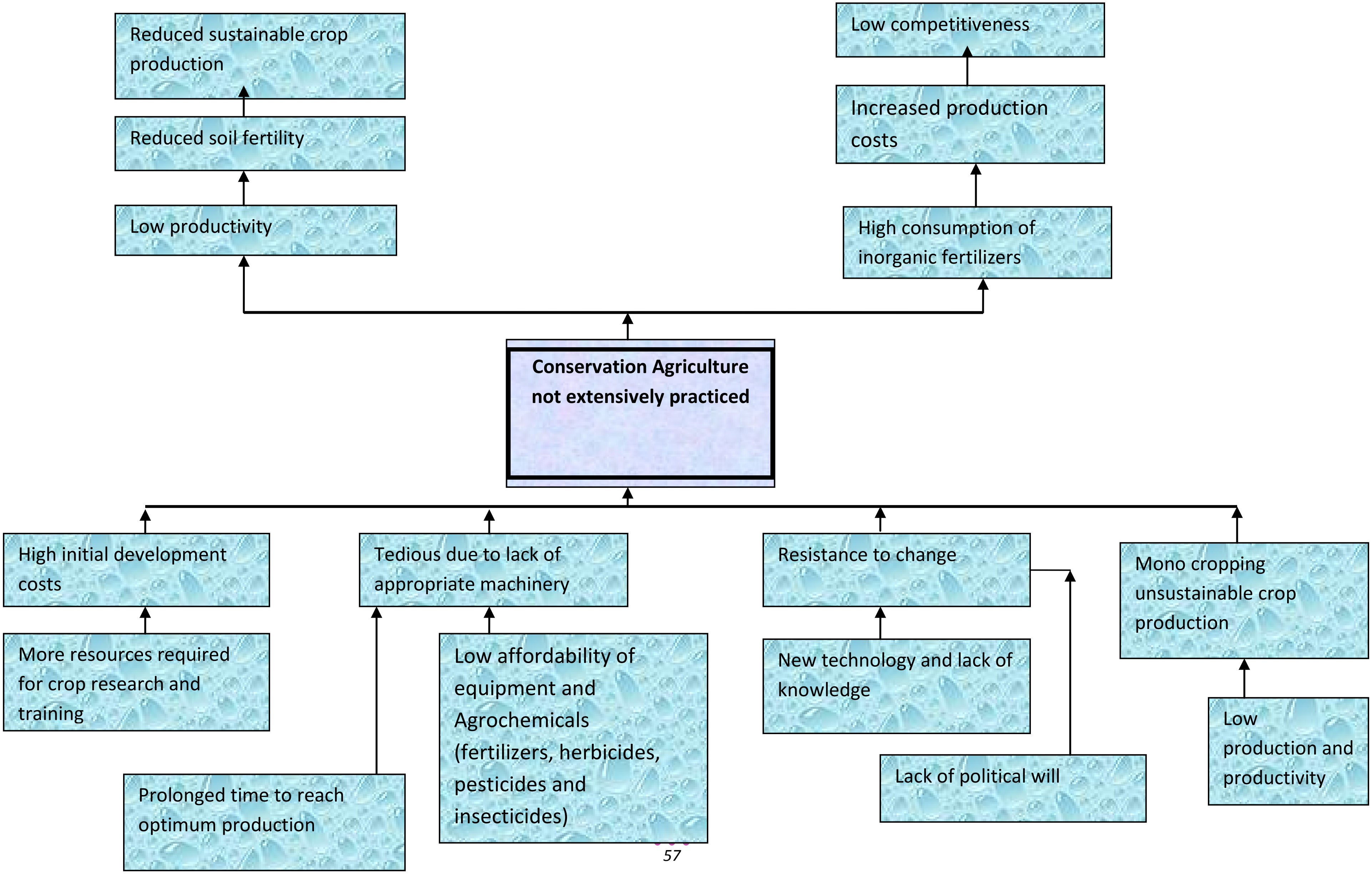
Biodiesel from Jatropha: Measures



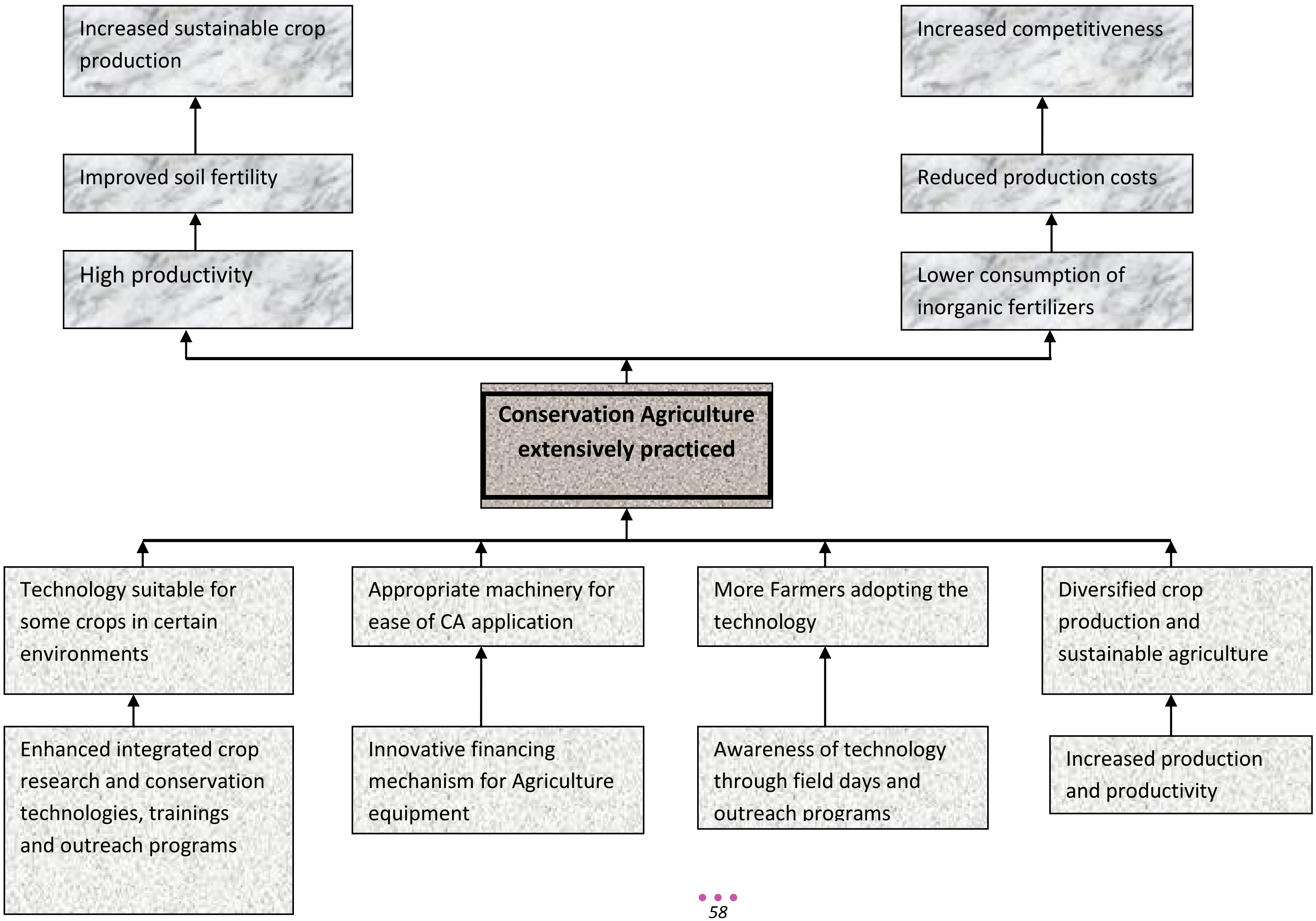

-Easy marketing
-increased customer satisfaction
Massive knowledge, acceptance and lessons on good practice from other countries
-Increased awareness and sensitization
Biofuels perceived as complimentary to fossil fuels

Annex VII: Sustainable Agriculture

Sustainable Agriculture: Barriers



Sustainable Agriculture: Measures



Annex VIII: Results of Cost Benefit Analysis

Baseline without subsidy

Year	Benefits total	Costs total	Net benefits	Discounted 4%	Net benefits 7%
1	300,000	313,000	(13,000)	(12,381)	(12,150)
2	390,000	937,000	(547,000)	(505,732)	(477,771)
3	1,500,000	1,561,000	(61,000)	(54,229)	(49,794)
4	1,500,000	1,561,000	(61,000)	(52,143)	(46,537)
5	1,500,000	1,561,000	(61,000)	(50,138)	(43,492)
6	1,500,000	1,561,000	(61,000)	(48,209)	(40,647)
7	1,500,000	1,561,000	(61,000)	(46,355)	(37,988)
8	1,500,000	1,561,000	(61,000)	(44,572)	(35,503)
9	1,500,000	1,561,000	(61,000)	(42,858)	(33,180)
10	1,500,000	1,561,000	(61,000)	(41,209)	(31,009)
NPV				**(897,826)**	**(808,070)**

Total yield, tonnes (additional and arising from the adaptation)	Total yield, (additional and arising from the adaptation)	cost of subsidies (USD/ha 9000*4500 tonne improved maze seeds)	Awareness cost	Labor and fertilizer costs
1.2	1,200	0	1,000	312,000
1.2	1,560	0	1,000	936,000
1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000

1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000
1.2	6,000	0	1,000	1,560,000

Where;

(a) Benefits total = Price(US$) * total yield(addition and rising from the adaptation)
(b) Costs total= Awareness cost + labor and fertilizer costs
(c) Net benefits = Benefits total – Costs total
(d) Discounted at 4% = Net benefits/$(1.04)^n$
(e) Discounted at 7% = Net benefits/$(1.07)^n$

Baseline with subsidy

Year	Benefits total	Costs total	Net benefits	Discounted 4%	Net benefits 7%
1	625,000	393,000	232,000	220,952	216,882
2	812,500	1,057,000	244,500	(226,054)	(213,556)
3	3,125,000	1,801,000	1,324,000	1,177,031	1,080,778
4	3,125,000	1,801,000	1,324,000	1,131,761	1,010,073
5	3,125,000	1,801,000	1,324,000	1,088,231	943,994
6	3,125,000	1,801,000	1,324,000	1,046,376	882,237
7	3,125,000	1,801,000	1,324,000	1,006,131	824,521
8	3,125,000	1,801,000	1,324,000	967,434	770,580
9	3,125,000	1,801,000	1,324,000	930,225	720,168
10	3,125,000	1,801,000	1,324,000	894,447	673,054
NPV				**8,236,535**	**6,908,673**

Total yield, tonnes (additional and arising from the adaptation)	Total yield, (additional and arising from the adaptation)	cost of subsidies (USD/ha 9000*4500 tonne improved maize seeds)	Awareness cost	Labor and fertilizer costs
2.5	2,500	80,000	1,000	312,000
2.5	3,250	120,000	1,000	936,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000
2.5	12,500	240,000	1,000	1,560,000

Where;

(a) Benefits total = Price(US$) * total yield(addition and rising from the adaptation)

(b) Costs total= Awareness cost + labor and fertilizer costs + costs of subsides(USD/ha 9000/4500 tonne improved maize seeds)

(c) Net benefits = Benefits total – Costs total

(d) Discounted at 4% = Net benefits/$(1.04)^n$

(e) Discounted at 7% = Net benefits/$(1.07)^n$

Sustainable Agriculture

Year	Benefits total	Costs total	Net benefits	Discounted 4%	Net benefits 7%
1	1,250,000	1,312,000	(62,000)	(59,048)	(57,944)
2	1,650,000	1,468,000	157,000	145,155	137,130
3	6,250,000	1,390,000	4,860,000	4,320,522	3,967,208
4	6,250,000	1,390,000	4,860,000	4,154,348	3,707,671
5	6,250,000	1,390,000	4,860,000	3,994,566	3,465,113
6	6,250,000	1,390,000	4,860,000	3,840,929	3,238,423
7	6,250,000	1,390,000	4,860,000	3,693,201	3,026,564
8	6,250,000	1,390,000	4,860,000	3,561,154	2,828,564
9	6,250,000	1,390,000	4,860,000	3,414,572	2,643,518
10	6,250,000	1,390,000	4,860,000	3,283,242	2,470,578
NPV				**30,338,641**	**25,426,824**

Total yield, tonnes (additional and arising from the adaptation)	Total yield, (additional and arising from the adaptation)	cost of subsidies (USD/ha 9000*4500 tonne improved maize seeds)	Awareness cost	Labor and fertilizer costs
5	5,000	0	1,000,000	312,000
5	6,500	0	1,000,000	468,000
5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000

5	25,000	0	1,000,000	390,000
5	25,000	0	1,000,000	390,000

Where;

(a) Benefits total = Price(US$) * total yield(addition and rising from the adaptation)

(b) Costs total= Awareness cost + labor and fertilizer costs + costs of subsides(USD/ha 9000/4500 tonne improved maize seeds)

(c) Net benefits = Benefits total – Costs total

(d) Discounted at 4% = Net benefits/$(1.04)^n$

(e) Discounted at 7% = Net benefits/$(1.07)^n$