Republic of The Gambia

Technology Needs Assessment – Phase II

Report II

BARRIER ANALYSIS REPORT

By

1: Ms. Lallah Badji	Ministry of Environment, Climate Change and Natural Resources	Conservation Agriculture, Tidal Irrigation and Groyne Systems
2: Mr. Lamin Komma	National Environment Agency	Breakwater Systems
3: Mr. Ebou Mbye	Department of Fisheries	Aquaculture and Fish Farming
4: Mr. Benedic Leese Mendy	Department of Water Resources	Water Conservation
5: Mr. Momodou Dumbuya	Ministry of Works and Transport	Waste Management
6: Mr. Amulaye Jarjusey	Ministry of Works and Transport	Direct fuel injection technology and Wind Turbine
7: Mr. Bubu Pateh Jallow	National Consultant	Sustainable Sand Management

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ABBREVATIONS

BCR	Benefit cost ratio
CBA	cost-benefit analysis
CBR	cost benefit ratio
CO_2	Carbon Dioxide
CRR	Central River Region
CRS	Catholic Relief Services
ECU	Engine Control Unit
ENDA	Acronym for Energy Centre in Dakar, Senegal
EST	Environmentally Sound Technology
FAO	United Nations Food and Agriculture Organization
GBA	Greater Banjul Area
GBOS	Gambia Bureau of Statistics
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOTG	Government of The Gambia
IWRM	Integrated Water Resources Management
km/h	kilometer per hour
kWh	kilowatt-hour
LDCF	Least Developed Countries Fund
LPA	Logical Problem Analysis
LRR	Lower River Region
NAPA	National Adaptation Programme of Action
NAWEC	National Water and Electricity Corporation
NBR	North Bank Region
NDP	National Development Plan
NGOs	Non-Governmental Organizations
NTP	National Transport Policy
PURA	Public Utilities Regulatory Agency
SE4A	Sustainable Energy for All
SPCR	Special Programme for Climate Resilience
SWM	Sustainable Water Management
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URR	Upper River Region
WAA	West African Aquaculture
WCR	West Coast Region

1. CLIMATE VARIABILITY AND CHANGE IN THE GAMBIA:

It is certain that rainfall over the country has decreased in recent decades. Graphics provided in the First National Communication to the UNFCCC suggest decreased rainfall in most, if not all, months between the two periods 1951-1980 and 1961-1990, most substantially in July and September. Decreased rainfall is noted also by McSweeney *et al*. (2012) between 1960 and 2006 at a rate of about 8.8 mm per month per decade.

Rainfall in The Gambia is part of the Sahelian rainfall system, which has undergone a substantial change from the observed wetter years of the 1950s and 1960s to the well-known Sahelian drought that peaked in the 1980s; there has been some recovery since over the region as a whole.

Long-term weather records from the capital Banjul indicate a shift in the rainfall pattern. From 1950 to 2000 annual rainfall amounts have decreased by about 30% at an average rate of 8.8mm per month per decade between 1960 and 2006. This decrease has been evident in the reduction in the length of the rainy season and also the quantity of rainfall amounts recorded in the month of August, particularly during the period 1968 to 1985, and in 2002. This rainfall pattern has led to devastating droughts during the last three decades of the 20th century alternating however, with periods of intense rainfall that have also created increasingly numerous flooding events following closely to the average pattern of rainfall variation across the Sahel region. This erratic rainfall pattern is impacting in the farming system by reducing the Length of Growing Period (LGP) and the additional mid-season dry spell can create drought conditions for farming purposes even during normal rainfall conditions.

There have been at least five significant intense drought episodes (1968, 1972, 1977, 1983 and 2002) between 1951 and 2007 and the year 1983 witnessed the worst climate change induced drought (worldwide drought). There was significant and extreme rainfall reduction in two of these events (1983: 479.50mm and 2002: 577.95mm respectively) when compared to the highest recorded rainfall of 1,425.67 mm/year (occurred in 1958) (GoTG/UNDP, 2015). This climate change induced dryness and other contributing factors such as the human impacts of overgrazing and deforestation, has also led to an increase in the frequency and intensity of dust and sand storms across the farm land and woodlands lands of the Gambia with negative impact on agriculture by eroding fertile soils and uprooting young plants, disrupting the flowering cycle in fruit trees and enhancing potential evaporation.

Based on downscaling by RCM of projections from 5 GCMs to end of century, temperatures are projected to increase in the range 3.0°C to 4.5°C, greatest inland. Rainfall projections are in range of decreases of 40% to 60%. Even at the regional scale, the most recent climate scenarios are only coherent where it concerns temperature evolution - with an expected increase for West Africa of between 1.5 and 4 °C by 2050. The projected changes in rainfall trends show significant trends ranging from -40% to +20% (Future Climate for Africa, 2016).

2. BARRIER ANALYSIS OF ADAPTATION TECHNOLOGIES

2.1 Agriculture Sector

2.1.1 CONSERVATION AGRICULTURE TECHNOLOGY

Barrier analysis and possible enabling measures for Conservation Agriculture Technology

2.1.1.1.1 General description of Conservation Agriculture

Conservation agriculture (CA) is an agricultural system that aims at soil and water conservation, nutrient improvement and enhanced production. Conservative agriculture technologies are based on the principles of (a) minimal soil disturbance (zero-tillage), (b) maintenance of good soil cover (cover crops, residues and mulches), and (c) appropriate crop rotation or crop association depending on the availability of land. Zero tillage is a method of tilling a field in which the soil is disturbed as little as possible and it aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. Zero Tillage improves the soil, increases production and decreases the cost of production. It consists of improved agricultural packages including (a) crop residue from previous crop and crop rotation; (b) application of herbicide for control of emerging and non emerging weeds (pre- post emergence herbicides); (c) planting in rows and application of fertilizer in one operation by a special planter; and (d) starting agricultural operations after the soil has received 110 mm of rainfall.

Zero tillage, as a component of Conservative Agriculture, was applied in The Gambia on a relatively small scale in the 1980s and 1990s. This simple and cost-effective approach to increasing the climate resilience of agriculture is particularly well suited to low input rain-fed agricultural systems such as those in The Gambia. Zero tillage improves the productivity in rainfed and irrigated farming systems. A fundamental criterion related to coverage is that annual rainfall must exceed 600mm.

Due to increased human and animal population, and the reduction in productivity due to negative impacts of climate variability (which is now compounded by climate change), there is now the need to grow and produce more food in a shorter period. Agricultural mechanization was introduced which has negative impacts on the shallow and poor soils of The Gambia. Productivity continues to decline and there is need to go back to conservative agriculture which is recommended as a climate resilient agricultural technique because conservation of soil organic matter increases the fertility and water holding capacity of soils. The CA approach is compatible with the use of green manures to increase soil fertility. Intercropping, as a component of CA, involves planting two or more crops in close association, often focusing on nitrogen-fixing

species. This approach can increase the climate resilience of agriculture by diversifying the risk of monoculture farming, as well as by increasing soil fertility through planting of nitrogen fixing crops.

2.1.1.1.2 Preliminary targets for technology transfer and diffusion of Conservation Agriculture Technology

The Gambia has a total population of about 1,900,000 persons of which 1,520,000 (80%) dependent on agriculture. With a population of 8 persons per House Hold (HH), there are 190,000HH engaged in agriculture. The preliminary target for the adoption of Conservation Agriculture is 100,000HH or 53% of the households engage in Agriculture. The targeted area for transfer and application of the zero tillage system is geographically large for The Gambia as rainfall is everywhere equal to or greater than 600mm.

Cost associated with establishment of one production unit using zero tillage equipment (tractor, 90HP+planter+ sprayer) is 31,600 USD. In field crops, the cost of implementing the technology is reduced to the cost of the seeder or planter (2,000 US$/yr) (MoE/URC/GEF, 2012). Application of conservative agriculture technologies shows that the cost of production is maintained as the inputs do not augment because soil fertility and water content are preserved. The major saving will be in terms of costs for tillage and land preparation for plantation.

Zero tillage improves the productivity in rain-fed and irrigated farming systems. There will be increase in farmers' incomes, increased food production and encouragement of private sector investments and thus new job opportunities in the production of agricultural crops. An overall yield stability, a reduction in cost of production, and increases in farmer's income are realized. Revenue increases of about 760$/ha/yr for cereal/legumes have been registered (MoE/URC/GEF, 2012). Under baseline conditions with the application of Conservation Agriculture, farmers need Tractor or Ox-drawn ploughs, seeders, seeds, inorganic fertilizers, herbicides and much more labour. With zero- or no-till diggers and hoes, seeds, organic fertilizers from crop residues, herbicides.

2.1.1.1.3 Identified barriers for Conservation Agriculture

conservation agriculture is not recommended in soils with high clay content, in humid areas with shallow water table, in saline soils and for crops with no residues left and that small holders are unable to apply economically viable crop rotations, and unable to access machinery.

Economic and financial barriers include

- High initial and application cost of zero tillage compared to conventional agriculture
- Limited financial availability and capacity to adopt, promote and conservation agriculture techniques and demonstration of field trials

- Limited financial support for research, extension and crop insurance that encourages the application of conservation agriculture;
- Little valuation (price assignment) to the positive impacts of conservation agriculture techniques in relation to environmental damage and the services of ecosystem;
- Lack of access to financing because of not being able to provide collateral to support loan applications
- Loan conditions are not favourable as repayment is within one season and risk of crop failure may result to defaulting and then followed by asset seizure
- High interest rates by Commercial banks (23-27%);

Non-financial barriers

Non-financial barriers have been categorized into the following:

- **Policy and regulatory barriers** include
  - Weak implementation of existing legal and institutional frameworks that promote research and transfer of conservation agriculture
  - Limited incentives that encourage the adoption and implementation of conservation agriculture;
- **Institutional and organizational capacity**
  - Farmer to extension worker ratio is too high because of the high attrition rate of staff;
  - Farmers are unfamiliar with all aspects of conservation agriculture technology;
  - Government promotes other approaches over conservation agriculture;
- **Social, cultural and behavioural barriers**
  - farmers are more familiar with conventional agriculture to the extent that they view conservation agriculture as a downgrade to basic technology
  - Promotional activities on conservation agriculture are inadequate and thus farmers have limited awareness of the benefits of increased yields accrued from conservation agriculture;
  - Farmers have resistance to change from conventional to conservation agriculture;
- **Technical barriers**
  - Many site-specific barriers that include types and characteristics of soils, rainfall amounts and ground landscapes
  - Extension workers will greater specialization are required;
  - Crops with limited crop residues do not do well for conservation agriculture;
- **Information and awareness**
  - Availability and dissemination of information on conservation agriculture are limited;
  - Farmers awareness is limited to allow adoption of conservation technology

2.1.1.1.4 Identified measures to remove barrfiers

Economic and financial measures

Economic and financial barriers include

- Government subsidy provided to farmers to reduce initial and application costs of adoption of conservation agriculture;
- Sustainable financial flows establish to promote research, extension and crop insurance that encourages the application of conservation agriculture;
- Techniques and skills for valuation of the benefits of conservation agriculture are adopted and applied in relation to environmental damage and the services of ecosystem;
- Farmers receive higher income from conservation agriculture practices to enable provision of collateral to support loan applications
- Loan conditions are not favourable as repayment is within one season and risk of crop failure may result to defaulting and then followed by asset seizure
- Farmers deal with village level financial services that provide low interest rates of about 5%

Non financial measures

Non-financial measures to remove barriers include:

- Policies and legal instruments under the agriculture sector are fully implemented to encourage adoption and implementation of conservation agriculture;
- Government provides adequate incentives that encourage the adoption and implementation of conservation agriculture;
- Government has provided capacities, skills and incentives to build a larger number of extension agents to improve the Farmer to extension worker ratio;
- Conservation agriculture is popularized and has become and acceptable technology to the farmers;
- Extension workers with greater and varied specialization are available;
- Crops with high crop residues are adopted to promote conservation agriculture;
- Information on conservation agriculture is generally available and widely disseminated to farmers;

2.1.1 TIDAL IRRIGATION TECHNOLOGY

2.1.2.1 Barrier Analysis and Possible Enabling Measures for Tidal Irrigation

2.1.2.1.1 General description of Tidal Irrigation in The Gambia

Tidal irrigation is one of the recent irrigation methods used to supplement rain fed agriculture. It has been introduced in The Gambia in early 80s by the government of Taiwan. With Tidal irrigation system double cropping have been achieved early.

The River Gambia is tidal thus making tidal irrigation schemes feasible with tidal heights varying from 3.5m at the mouth of the river to 0.9m at Bansang, 310km upstream. This technology uses canals and gates to supply tidal water to rice fields. It is designed in a way water flows from the river due to gravitation force to the primary canals (see Figures 1a and 1b below). When gates are opened at high tides, tidal water enters the secondary canals and then to tertiary canals to irrigate the farm lands. The opening of the gates is from 3hrs to 24hrs depending on the size of farm to be irrigated.

Figure 1a: Primary canal with a gate

Figure 1b: Rice fields irrigated with tidal water

2.1.2.1.2 Preliminary targets for technology transfer and diffusion of Tidal Irrigation

The preliminary targets for the transfer and diffusion for Tidal irrigation is aimed at introducing the technology to all farmers within CRR North and South inorder to switch from the diesel pump irrigation system to tidal irrigation in those areas. Tidal irrigation is only applicable in these areas where fresh water is available throughout.

2.1.2.1.3 Barrier to Tidal Irrigation Technology

Barrier identification of for Tidal Irrigation was a process of tracing the causes that affects the development, transfer and diffusion of this technology. This process was based on the

stakeholder consultations and consultant's own knowledge and international experience as follows:

- A desk study of policy papers and other pertinent documents to identify the primary reasons why the technology is not currently use country wide, and why both public and private sector have not invested significantly.
- A proper economic, environment, and institutional capacity should be included in the desk study.
- Technical working group during workshop was use to collect such information.
- Telephone interviews with the Irrigation and Agricultural Engineering Services of the Department of Agriculture responsible for Tidal Irrigation in The Gambia.

The identified barriers were then group into various categories and described to be able to facilitate analysis and screening (Table 1 below)

Table 1: Barrier Categorization and Description of Tidal Irrigation as Technology

BARRIER CATEGORY	BARRIER	BARRIER DESCRIPTION
Economic and Financial	• High cost of system initial installation • Inadequate credit/loans for the famers • Fear of loans by small scale farmers • High cost of maintenance • Inadequate incentives	• The constrained for the implementation of the tidal irrigation in the Gambia is due to high cost of capital initial investment. This is because both the tidal system equipment, materials and components are very expensive and are imported • Small scale farmers are always reluctant to take loans because of the pay back due to low income generated from the crops at the end of the season. • Frequent de-silting of tidal canals (primary and secondary) is expensive since heavy machineries are need. • Experts are needed for the construction of tidal canals which involve cost. • Continuous and regular maintenance of gates (primary and secondary canals) is costly. • Land development requires high amount of finances and is the most expensive part of tidal irrigation. Heavy machineries and engineers are needed to do cutting of the soil and leveling the ground to set the land for tidal irrigation. • Generally, the maintenance of the perimeter dyke is costly. • Water user committees are not motivated either by cash or goods produced by the farmers at the end of the crop production
	• Water quality • Inadequate expertise • Damage by animals (eg. Hippopotamus, bush	• Salty water does not support tidal irrigation • Limited know how to construct new gates and to repair the broken gates. The gates provided by the Taiwanese during the initial installation are finish and there are no spares at

Technical	pigs, monkeys) • Lack of spare parts • Inadequate pest and disease control. • Sewer water • Uneven water distribution	the moment. • Inadequate training of Water users committees to control the gates and advise farmers to clean secondary and tertiary canals. • The continuous movement of animals destroyed the constructed perimeter dikes. • In crop productions pests always intrude bonds separating the plots • The gates brought by The Taiwanese during the designing and initial installation are finished and water. • The bond separating different plots in the area of the tidal irrigation system attract pests. • Leakages cause by broken gates and the compacting of the bonds separating the plots. • At high areas during high tides, the gates have to be close until high areas get the water which needs human resources.
Socio-cultural	• Gender biases • Poverty	• Farmlands control and allocation predominantly dominated by men. • Women are considered as rice producers not men which is a burden to women • Some farmers living below poverty line cannot afford to service their own gates when broken.
Information and awareness/ Networking	• Inadequate networking • Inadequate market • Lack of awareness	• Networking is inadequate since cost is involve the farmers have to travel outside the country in order to meet other farmers who already experts in tidal irrigation to share. • There is no ready market available for farmers to sell their produces.
Human Skills	• Low literacy • Inadequate training	• Most of the farmers in the country are illiterates, literates do not venture into farming • Technical know- how on the regular maintenance of the system becomes a barrier. • No regular training particularly for water users committees
Environmental Issues	• Tidal not applicable country wide • Water control • High areas	• Tidal irrigation cannot be applied in salty areas. • High tides and low tides in rivers are un controllable • During the rainy season water level in the river rises, both run off and river water will cause the fields to submerge
Policy	• Land tenure system policy	• Farm lands are not accessible to all. • Land belongs to government

A thorough screening was conducted in order to be able to identify, and address the most significant categorized barriers in the adoption and diffusion of the Tidal Irrigation System in The Gambia. This was accomplished through various interviews conducted and discussion sessions with the Ministry of Agriculture officers directly under the Tidal Irrigation. The firsthand information on Tidal Irrigation was obtained directly from the officers working daily

and directly with farmers at Central River and Lower River Regions where Tidal Irrigation is taken place.

Many barriers were identified during the discussions but few are selected and analysis.

1. High cost of initial system installation
2. High cost of maintenance
3. Water scarcity
4. Land tenure system

Economic and Financial Barriers

Throughout our discussions, economic and financial barriers emerged as the key in The Gambia Tidal Irrigation. Using Problem Tree (see AN1 in the Annex) exercise for the decomposition of economic and financial barriers, it proved beyond thought that high cost of system initial installation is in relation to high cost unit kits and as well as the land development which even requires higher cost. The equipment and components are not manufactured locally but imported and bringing the engineers for land and soil preparations further increased the cost.

The investment cost for the initial installation of Tidal Irrigation of the Gambia was funded by the Gambia Government in collaboration with Taiwanese Government. The most challenged faced by farmers as we speak is the operational and maintenance cost. Operations in most areas with Tidal Irrigation have been halted and this is due to siltation of primary canals.

Table 2: Decomposition of Economic and Financial Barriers

Broad Category	Barrier within category	Elements of a barrier	Dimension of barrier
Economic and Financial	High cost of system initial installation	• High cost of unit kits • High cost of land development	• The unit kits are not manufacture in the Gambia • Importing the components and equipment is costly • The duty tax on the business institution and individuals is high • Heavy machinery and engineers for land preparation.
	• Inadequate credit/loans for the famers	• High interest rate	• Farmers are reluctant to take the loan • Some farmers never pay back the loan
	• Inadequate incentives	• Lack of motivation	• Farmers are not willing to pay Water Users Association either in kind or cash
	• High cost of maintenance	• High cost of di-silting the canals • High cost of replacement of broken gates	• Siltation occurs • Water escape from the secondary canals

Non-financial Barriers

Using the Problem Tree (see AN2 in the Annex), the main non-financial barrier of Tidal Irrigation in the Gambia is water scarcity on some tidal areas. The Tidal Irrigation is designed at three different levels:

- Areas designed purposely for rainy season production because of the high areas;
- Areas designed purposely for dry season production because only river water is needed.
- Areas designed purposely for both rainy and dry season production. With both river water flow and rainfall, rice fields may be submerged.

Rice fields on areas designed purposely for dry season production at Jahally and Pacharr reportedly encountered water shortage. According to the officers in charge of the Tidal Irrigation in those areas, insufficient water for the rice fields might be due to three different factors, namely siltation of the primary canals, climate change that might cause river water levels to drop and bad gates causing water to flow back to the primary canals. As a result of the mentioned factors most of the rice fields dry off. This will have a major effect on food security and income earned by farmers at the end of the season.

Secondly, water scarcity may be due to siltation of primary canals. Silts accumulate in most of the primary canals and thus block the flow of water to secondary canals. This has affected all the three designed areas for Tidal Irrigation.

Table 3: Decomposition of Economic Non-Financial Barriers

Broad Category	Barrier within category	Elements of a barrier	Dimension of barrier
Human skills	• High human skills are required	• Limited skills for the repairing, and preparing the gates • Few skilled engineers for land development	• Few Water Users Association are trained • Inadequate knowledge of farmers as to when to open and close the gates • Limited skills on making new gates to replace the old owns brought by the Taiwanese
Land tenure system	• Land tenure system policy	• Landownership	• Private sector and individuals not having access to lands for farming
Water scarcity	• Climatic variation • Siltation • Bad gates	• Climate change difficult to control • Improper designing of tidal areas	• Water level from the river drops due to climate change • During low tides water does not flow to the primary canals which supply the secondary connected to them and then to farmers via the tertiary canal. • heavy machinery like excavators for de silting the canals are costly • Bad gates cause water to flow back to the primary canals.

Tidal irrigation not applicable country wide	• Salt intrusion • Low river water	• Not all type of river water support farming • Insufficient water for irrigation	• Low production, some areas are not suitable for tidal irrigation • Irrigation not possible with low tides

2.1.2.1.4 Identified enabling measures of Tidal Irrigation

Measures to be taken to overcome the identified barriers of tidal irrigation have been presented in the form of Solution trees (See AN3 and AN4 in the Annex) and categorized as economic and financial and non-financial.

Economic and financial measures

The causes and effects base on the economic and financial barriers of Tidal irrigation in the Gambia are illustrated in AN1 in the Annex. The limited uptake of Tidal irrigation is the starter problem in the center of the problem tree, the causes below and the effects above. The measures for the starter problem and the results are shown in AN2 in the Annex.

Non-financial Measures

The starter problem in economic and financial is same as the one in for non- financial measures. The Limited uptake is the starter problem, the causes and effects as well as measures to be taken and the results are below and above the problem tree respectively. The Solution Trees are represented by AN3 and AN4 in the Annex on page 65.

Cost Benefit Analysis

Cost benefit analysis is a method used to assess the economic benefit associated with the adoption of and diffusion of a new technology. Table 4 shows the comparison of an existing Pump irrigation (representing the baseline of no Tidal Irrigation) and the adoption and diffusion of Tidal irrigation based on the general information. The approach taken was based on monetary term identifying the most suitable and economic option method. Both these different irrigation systems do not depend on rain fed agriculture but on pumped water and tidal water respectively. The result on the economic and food security of these irrigation systems varies immensely.

To compare them, the cost benefit analysis was done on the cost of installing both the existing Pump irrigation and the Tidal irrigation technology. Cost and benefit values were assigned to the different irrigation system taking into account the raw materials, capacity building, and environmental benefits applicable for a period of one year.

Table 4: Elements of Costs and Benefits of an Existing Pump Irrigation and adopting Tidal Irrigation Technology

Costs of Pump Irrigation (in lieu of Tidal Irrigation)			**Cost of Tidal Irrigation**	
Item	**Amount US$**		**Item**	**Amount US$**

Pump irrigation kit	80,000		Tidal irrigation kit	90,000
Cost of seeds	5,000		Cost of seeds	10,000
Fertilizer	10,000		Fertilizer	15,000
Labour (land preparation, weeding, planting, harvesting)	60,000		Labour (land preparation, weeding, planting, harvesting, canal preparation)	100,000
Food security	10,000		Food security	20,000
Environmental degradation (soil salinisation	25,000		Environmental degradation (soil salinisation	20,000
Capacity building	25,000		Capacity building	25,000
Fencing (for security and hyppotamus)	20,000		Fencing (for hyppotamus)	10,000
Fuel lines, tanks	40,000		Gates	10,000
Total Cost	**265,000**		**Total Cost**	**300,000**
Benefits of Pump Irrigation			**Benefits of Tidal Irrigation**	
Crop production	100,000		Crop production increase per hectare	210,000
Food security improved health	15,000		Food security and improved health	25,000
Environmental conservation	5,000		Environmental conservation	20,000
Employment creation	35,000		Employment creation	80,000
Total Benefits: (this is because farmers can't afford to buy sufficient fuel for the tanks, fence the farms, cost of fertilizers and others)	**155,000**		**Total Benefits**	**335,000**

The cost benefit ratio (CBR) of the Tidal irrigation Technology was evaluated as follows.

- Cost Benefit Ratio = $Benefits/Costs$
- CBR = $335{,}000/300{,}000$
- CBR = 1.1167

The CBR for Tidal irrigation is greater than 1($1.1167 > 1.0$), meaning the benefit exceeds the cost. Therefore the adaption and diffusion of this technology should proceed and as well as encourage its application on all areas of tidal water within the country.

The payback period was also evaluated in order to find out the duration it take to reach the point in time in which the benefit just repaid the cost. For Tidal Irrigation the:

- Length of time (payback period) = Total Costs/Total Benefits
- Length of time (payback period) = $300{,}000/335{,}000$
- Length of time (payback period) = 0.8955
- Net Benefits for Tidal irrigation = US$ $(\text{Benefits} - \text{Cost})$

- Net Benefits for Tidal irrigation =US$ $(335{,}000 - 300{,}000) = \text{US\$ } 35{,}0000\ (2)$
- Net Benefits for the Tidal irrigation Technology =US$ $(2) - (1)$
- Net Benefits for the Tidal irrigation Technology =US$ $(35{,}000) - (-110{,}000)$
- =US$ 145,000

The Net Present values for the Tidal irrigation

- The Net Present values for the Tidal irrigation for total of 10 years was calculated and presented in Table 5.
- Net Present values for the Tidal irrigation Technology (NVP) = $\sum \frac{NetBenfit_t}{(1+d)^t}$
- Where *t* is the year and *d*is the discount rate
- To find d:
- CBR = $\frac{[\sum B_t/(1+d)^t]}{[\sum C_t/(1+d)^t]}$ summed over 1 = 0 to n years
- CBR = $\frac{[\sum 335{,}000_1/(1+d)^1]}{[\sum 300{,}000_1/(1+d)^1]}$
- $1.1167(300{,}000) + 1.1167(300{,}000d) = 335{,}000 + 335{,}000d$
- $1.1167(300{,}000d) - 335{,}000d = 335{,}000 - 1.1167(300{,}000)$
- $d(335{,}010 - 335{,}000) = -10$
- $d = \frac{-10}{-10}$
- $d = 1$
- d = discount rate = 1%

- Calculate NPV:

- NPV= $\sum \frac{NetBenfit_t}{(1+d)^t}$
- NPVfor year 1 $= \frac{145{,}000}{(1+0.01)^1} = \frac{145{,}000}{1.01} =$ US$ 143,564
- NPV for year 2 $= \frac{145{,}000}{(1+0.01)^2} = \frac{145{,}000}{1.0201} =$ US$ 142,143

Table 5: NPV values for Tidal Irrigation Technology		
Year	**Calculation**	**Net Benefits, 1% Discounted (US$)**
1	$145{,}000/(1+0.01)^1 = 145{,}000/1.01\,00$	143,564
2	$145{,}000/(1+0.01)^2 = 145{,}000/1.0201$	142,143
3	$145{,}000/(1+0.01)^3 = 145{,}000/1.0303$	140,736
4	$145{,}000/(1+0.01)^4 = 145{,}000/1.0406$	139,343
5	$145{,}000/(1+0.01)^5 = 145{,}000/1.0510$	137,964
6	$145{,}000/(1+0.01)^6 = 145{,}000/1.0615$	136,599
7	$145{,}000/(1+0.01)^7 = 145{,}000/1.0721$	135.249
8	*$145{,}000/(1+0.01)^8 = 145{,}000/1.0829$*	133,900

9	$145{,}000/(1 + 0.01)^9 = 145{,}000/1.0937$	132.577
10	$145{,}000/(1 + 0.01)^{10} = 145{,}000/1.1046$	131.269
US$ NPV		**840,881**

From Table 5, it is shown clearly that the Tidal Irrigation technology has positive cost benefits which are considered viable for the project.

2.1.3 AQUACULTURE AND FISH FARMING.

2.1.3.1 Barrier Analysis and Possible Enabling Measures for Aquaculture and Fish Farming

2.1.3.1.1 General description of Aquaculture and Fish Farming in The Gambia

The term Aquaculture means the form of culture of aquatic (fish and fishery) animals on land, in fresh, brackish and marine environments (Pilly and Kutty, 2005). Aquaculture is the latest fisheries sub-sector in The Gambia after Artisanal and Industrial fisheries sub-sectors. During the TNA identification of sector areas meeting held at the Department of Water Resources, The Gambia on 15th May, 2018, Aquaculture was selected as priority sector—due to its vulnerability to climate change tendencies. The focus was mainly centered on barriers affecting the sub-sector. Existing barriers have been creating obstacles and affect the transfer and diffusion of prioritized adaptation technologies. This report is based on the existing Aquaculture projects in The Gambian. It is prepared through observations, literature review, interviews and discussions. The Fisheries Act, 2007 and the Fisheries and Aquaculture Policy (2018 – 2022) aim to outline the analysis of existing barriers and enabling framework for prioritized technologies in the aquaculture sector.

Aquaculture development was introduced in the world mainly to minimize over-fishing of the fish stocks from the wild in order to preserve abundant fish resources for the future generations and to play a leading role in food security, generate revenue and employment particularly at the rural communities. Due to the protein contents, the demand for fish and fishery products continues increasing.

In The Gambia, per capita consumption of fish at the urban communities outstrips that of the rural communities. People in the latter also find it difficult for fish to be readily available and affordable. Unemployment rate has ever been high. Government of The Gambia found it prudent to introduce aquaculture as an alternative to capture fisheries and by way of alleviating poverty and facilitating the improvement of the nutritional standards of the population. The first aquaculture project was introduced at Bansang, CRR, through the cooperation of The Gambia Government, the CRS and the American Peace Corps. Tree types of aquaculture are practice in The Gambia: borehole aquaculture, irrigation aquaculture and tidal aquaculture. The only state

owned hatchery is at the Aquaculture site in Sapu. There is another private shrimp hatchery in Pirang owned by the West African Aquaculture (WAA) which is engaged in aquaculture for shrimps on a commercial scale. About 100 hectares from their 550 hectare land have been used for construction of ten (10) ponds and less than 100 tonnes of shrimps was produced. The hatchery is producing 2.5 million post larvae (PL). The production cycle is 6 months from April – November (Fisheries and Aquaculture Strategy Action Plan 2017 – 2021). This report concentrates only on tidal aquaculture practice in The Gambia. This technology is selected because it is more reasonable in terms of cost compared to the other two types.

Figure 2: Government officials conducting Need Assessment at the Aquaculture ponds and hatchery at Sapu.

Aquaculture is steadily increasing from few trial ponds in 1979 to about 98 small-scale fish ponds in 2016. In The Gambia, Aquaculture ponds are owned by the Government, communities, private individuals and schools (Dibba B, May 2016).

Table 6: Location of existing Aquaculture and Fish Farming Facilities owned by communities and schools.

No	Operators	Funded by	Site	No. of ponds	Beneficiaries
1	Brikamaba Fish Farmers Association	FAO	Madina Ufanly	56	Brikamaba & surrounding communities
2	Bureng	FASDEP	Bureng	4	Bureng
3	Pakaliba	FASDEP	Bureng	3	Pakaliba
4	Barrow Kunda	"	Barrow Kd	2	
5	Sutukung	"		2	
6	Janjangbureh	"		4	Amitage Sen. Sec. School
7	Japineh	"		1	Community
8	Baringoto - NBR	WABSA		2	"

Numerous institutional challenges continue to threaten developments of the sector that included among others are the absence of an institution dedicated to the development of inland fisheries and aquaculture, inadequate implementation of policies, inadequate human resources for research

and financing, management, aquaculture and inland fisheries development, inadequate laboratory, inadequate capacity for monitoring and evaluation and lack of funds to enhance capacity of Fisheries Department personnel (EIF 2016 – 2020).

Aquaculture under tidal irrigation is the act of pumping water from the river through pipes to the ponds (Figures 3a and 3b below). The further the ponds from the river the more cost ineffective the project is. Free water is readily available with this technology.

Figure 3a: Constructed Tidal Irrigation Aquaculture owned by one community

Figure 3a: Tidal Irrigation Aquaculture pond constructed for educational and feeding programme at Armitage Senior Secondary School

Most ponds in The Gambia are measured as in Table 7 below. The size generally depends on the target culture fish species, space of land and the environment. Table 7 below, shows some of the cost estimates applicable in The Gambia and are used in the assessment.

Table 7: Size of ponds in relation to target fish to be cultured.

No	**Fish type**	**Size**
	Cat fish	25.0 m x 20.0 m
	Tilapia	25.0 m x 20.0 m

Table 3.2: Cost estimate of Tidal Irrigation Aquaculture

Items	**Cost**
- Construction of a canal from the river / sea to the fish ponds. - Sluice gate (primary canal) from the river / sea (closed and open for water to enter and out) - Smaller canals (secondary canals) - Tertiary canals to the ponds. - Construction of grow-out ponds (20 x 25 m)	**D1,000.00 / m.** **D10,000.00** **D500.00 / m.** **D250.00 / m**. **D50,000.00** / pond
Fencing	D1,000,000.00 (**D250,000.00** / set of 25 ponds)
Fertilizer	D250.00 / 12.5 kg (**D25,000.00** for 100 ponds)
Finger-lings	1,500 finger-lings for each pond

	D3.00 / species) x 1,500 finger-lings = D4,500.00 / pond x 100 ponds = **D450,000.00**
Feed	150.0 kg. / day for the first month (50.0 kg bag = 3 bag) Therefore, 3bags x 30 days = 90 bags x (D40/KG x 150 kg x30 days = D180,000.00 for the first month x 6 months = **D1,080,000.00**
Total	

2.1.3.1.2 Preliminary targets for technology transfer and diffusion of Aquaculture and Fish Farming

As a first step to this work, two main reasons were highlighted as starting points:

- Why Aquaculture as a productive sector is not recognized by Gambians compared to other productive sectors like Agriculture, Livestock and fisheries.
- Why are Gambian investors not extending business in Aquaculture projects
- Why is The Gambia Government not investing significantly in Aquaculture apart from relying on external donor interventions?

This assessment targets 100 ponds each measuring 25.0 x 20.0 m and for 8 communities. A 25.0 kg fertilizer is needed in each pond to enhance productivity of the fish species. Stocking of finger-lings in the ponds is calculated as follows:

1. 1.0 m² of the ponds to be stocked with 3 finger-lings x 100 ponds = 150,000 finger-lings needed.
2. 150,000 finger-lings x 20.0 grams (wgt of each finger-ling) = 3,000,000 grams / 1000 = 3,000 kgs of finger-ling is required for 100 ponds.
3. Feeding of the finger-lings is calculated as 5.0 % of body weight.
4. Therefore, 3,000 kg (total weight of finger-lings) x 5/100 = 150.0 kg of feed required in each day for the 100 ponds.

This will involve induced breeding of the selected fresh water cat fish and tilapia species, rearing of post larvae to fry stage and raising over 250,000 fingerlings annually. The interventions will involve research on physical, chemical and biological properties of aquaculture for maximum production through adoption of better land management practices. The LHDP under the Ministry of Agriculture has transferred technology to Rural Fish Farmers to improve and diversify production, nutrition and increase revenue through integration of poultry into fish farming technology. Five communities with fish ponds in *Ndemban, Japichum, Medina Kanuma, Njawara* ARI and Barra are integrated with poultry. Chicken are place in an In-house built with strips slightly separated on the floor and the poultry excreta drops into the fish ponds and recycled to fertilizer. According to the Fish Farmers, the technology transfer minimizes the land space that should have been prepared at different grounds for poultry and fish ponds. The

technology also reduces costs of transportation to bring manure to the ponds, fertilizers and feed (**Dibba B**. **2016**, Aquaculture Sector Review, The Gambia).

Under normal circumstances, 50.0 % of the operational cost goes to feed. However, the stocking density depends on the number of fish that the fish farmers wanted to have in each pond. The more density of fish in the ponds the less number of ponds and the less stocks of fish the more ponds is needed. It must be put into consideration that if the ponds are stocked with too many finger-lings the mortality rate will be high.

2.1.3.1.3 Identified Barriers for Aquaculture and Fish Farming Technology

It was necessary to organize relevant stakeholders under one ceiling in order to apply a participatory approach for barrier analysis and identification of enabling measures in Aquaculture. Barriers related to technology implementation have been identified in five categories (a) Economic/financial barriers, (b) Information/capacity barriers, (c) Social barriers, (d) Technical barriers and (e) Legal and policy barriers

Economic and Financial barriers

Economic and financial barriers for adoption of Aquaculture and Fish Farming technology are indicated in Table 8 below.

Table 8: List of barriers, their categories and causes

No	Categories of barriers	Barriers	Causes of the barriers
1.	Economic / Financial barriers	• High cost of Aquaculture operations (pond construction). • Lack of loans to communities to invest • Inadequate potentials investments in aquaculture. • Aquaculture is highly risk investment • Poor marketing of fish. • Weak access to markets • Inaccessible energy • Inadequate process feeds • Expensive costs of imported seeds • Low levelinvestments resulting to less economic and financial benefits • Inadequate funds to prevent intruders consuming the fish species in the ponds	• Banks and Micro finance Institutions may not have knowledge about potentials of Aquaculture • The stiff Bank conditions could not be met plus high interest rate of 22 %. • Family members not willing to deposit collaterals for loan • Fish are sold on bargains and not fixed price • Local feed (coos, maize etc.) kept for food for the family may not be used as feed for fish. • The Government Executive may not be well informed about Aquaculture potentials. • The nationalization of Scan-Gambia Aquaculture Shrimp Ltd by the 2nd Republic may have had negative bearing for foreign Investors to risk the challenge.

		• Lack of foreign investments • Under cultivation of significant land for Aquaculture purposes.	

Non-Financial Barriers

Table 9 provides a list of non-financial barriers and their causes. The identified barriers are provided by the Author but with guidance from the National Consultant and support from some Aquaculture Extension personnel and fish farmers. The Problem Tree (see AN5 in Annex) indicates the main starter problem, the causes and relevant effects of the inadequate penetration of Aquaculture and Fish Farming technology.

Table 9: List of barriers, their categories and causes

No	Categories of barriers	Barriers	Causes of the barriers
1.	Information & Capacity	• The public is not well sensitized about benefits of the aquaculture industry. • Inadequate training for the Aquaculture farmers • Weak capacity on Aquaculture at research institutions • Lack of awareness at the school level. • Aquaculture is not treated like Agriculture especially at the school level. • Lack of sensitization about cutting of mangroves and sand mining	• Inadequate sensitization after the successful late 70's and early 80's first trials by CRS and the Peace Corps. • The first highly trained Aquaculture Specialist was based at the Fisheries Department in Banjul and engaged in administration of the fisheries sector instead of staying closer to the Aquaculture sites. • Climate Change impact was never foreseen and resulted to lack of research before 1995.
2.	Social	• Societal set-ups • Time consuming before maturity stage. • People are not willing to establish partnership • The few Aquaculture farmers used the products for food for the family and not commercial. • The youth have migrated to the city and main towns for greener pasture. • Men have upper voices in Executive Committees than women • Heads of committees are always	• Certain works are considered as men domain work (pond construction). • The fish marketing is women dominated area. • A 24 hr. time needed at the ponds cannot be met by women. • The good thing in Aquaculture is that social or traditional stigma based on the caste / ethnic system. • Anyone can do Aquaculture • Inadequate development and job opportunities for the youth to keep them at the rural communities. • Criteria for selecting committees depend on tradition and citizenry of

		men • Committees are weak and mostly a one man decision. • Expansion of settlement reduce Aquaculture farm area.	a community and not by elections.
3.	Technology barriers	• Use of traditional methods • • Inadequate high level trained and experience personnel's • Efficient seed production methods not used. • Efficient feed production technologies are not currently been practised. • Inadequate knowledge on when and where to collect seedlings from the river / sea • Lack of proper technologist for the production of good quality fingerlings. • Less knowledge on the different sex, stages and the sock size in a pond • Less knowledge of mortality rate in a stock. • Lack of good roads to and from the Aquaculture sites. • Inadequate capacity on biological sampling methods. • Disease outbreak • Weak laboratory and qualified technicians to test feed, water samples among others • Inability to co-opt space from rice farmers • Inadequate logistics and incentives for high level trained personnel to stay at the communities. • Inadequate Fisheries Department Extension Field staff • There is no Aquaculture Expert for site selection and designing of ponds.	• Modern technologies are not currently being used by farmers. • Farmers go to the river to collect seeds (fingerlings) • Farmers used poor quality feed to feed their fish. • None of the few Aquaculture ○ Experts are based at the Aquaculture community sites. • Fishermen and Extension Technicians have less knowledge about the biology, environment and migration of the fries and the spawning periods of the target fish species. • There has been no exclusive research on the biology. • Weak production and employment rate resulting to lack of priority by the Government. • Inadequate competent people at the Fisheries Department and communities. • Lack of Marine Biologist • Inadequate testing materials and tools. • Lack of knowledge and funds to diversify into Aquaculture.

		• Inadequate knowledge on good site selections. • No funding for research and inadequate development from Government	
5.	Legal barriers	• Aquaculture not exclusively highlighted in the Fisheries Act resulting to weak enforcement • Stringent provisions in the Fisheries Act & Regulations	• Lack of Amendment of the Fisheries Act and no specific Act for Aquaculture. • Provisions in the Fisheries Act & Regulations are very difficult to be implemented. • Many sectors are involve before a license to operate is issued (NEA, Food Safety).
4.	Institutional barriers	• Aquaculture embedded under Fisheries Department • Only few staff working in the Aquaculture Unit • Expensive feasibility study • Expensive cost to write project proposals, feasibility study, site selection and construction of ponds.	• Aquaculture is not a full-fledge Institution operating its activities. • The Aquaculture Unit at Fisheries Department is under staff and there is only one highly trained staff.

As indicated in the Problem Tree (Figure AN5 in Annex), the under development and low penetration of Aquaculture and fish farming in The Gambia is attributed to the use of poor quality seed (fingerlings) and feed and inadequate technical know-how from the technicians and fish farmers. Other problems included inadequate research, space, seen as time consuming, hard work and low production. Communities are not well sensitized about the potentials of diversifying to Aquaculture from the tradition Agriculture practices. The Government is also weak for inadequate promotion of the Aquaculture sector for foreign Investors to venture into the sub-sector. More than averages of the youths who form 65 % of the population have migrated within the city and elsewhere for greener pasture leaving the communities with unskilled aged people.

Climate Change has also cause significant effect to the sub-sector. The river and sea are taking the load. High level of sea/river water and unexpected rainfall changes have significant impacts on the water retention in the Aquaculture ponds are sweeping fish from the ponds to the river and most cases stagnant at rice fields or on land. The changes in rainfall pattern have been creating uncertainty of maintaining required amount of water in the aquaculture ponds. The following are highlighted as concerns that are affecting progress of Aquaculture.

- Most aquaculture ponds depend on irrigation even though the sites are far from the river.
- Engineers are not accessible to aquaculture farmers.

- Plastic pipes and accessories are not affordable to farmers.
- Communities are poor and reluctant to contribute and establish aquaculture projects.
- Aquaculture Experts are not directly involved in the designed projects.
- There are few Aquaculture Experts in The Gambia.
- Foreign Technical Experts concentrated only on their areas of assignments.
- Inadequate data on the number of operators, sites and aquaculture ponds.
- There are no fixed prices to the sales of fish products from Aquaculture farms and this is really affecting the producers and even discouraging others to take the sub-sector as a profession.
- Most ponds are not cemented / concrete. They are constructed in muddy or soil grounds without protection.
- There are no proper roads to and from the Aquaculture farms neither on sight.
- Apart from the Sapu hatchery there is no other in operation.
- The farmers do not have protection gears.
- The low quality of products are a direct result of lack of upgrading of women's fish processing facilities and techniques,
- Lack of information (forecast) about the fresh, brackish and marine water level to take necessary actions b/4 inundation.
- There are no forms of protections against water level rise and also no shelter against effects of too many rains.

2.1.3.1.4 Identified Measures to improve penetration of Aquaculture and Fish Farming in The Gambia

Control measures are also most required in all the three sub-sectors of fisheries. Sand mining has also caused havoc at the coastal communities resulting to highly vulnerable to the climate change impacts. As climate change is likely to apply direct influence on pond culture, alternative techniques and/or improvement of existing technologies become imminent. Research on similar or different techniques can also be conducted on few other fish species suitable for aquaculture under the current climate change issues.

Identified measures include the following:

Finance and Economic Measures

- To reduce cost, it will be necessary to construct ponds closer to the River Bank or any other source of water;
- Provided subsidies to farmers to enable them procure pipes and accessories for aquaculture;
- Improve value chain of aquaculture and fish farming products for higher prices and income for aquaculture and fish farmers;

Non-Financial Measures

Technical Measures

- Improve aquaculture and fish farming infrastructure to add value to products and provide protection from pests and other invasive flora;
- Provide adequate transport and communication infrastructure to and from the Aquaculture farms to reduce time spent on transport and thus spoilage;
- Increase the number of hatcheries to cover the whole country;
- Improve the engineering of canals and ponds so that the structures are not flooded beyond requirements during height of the rainy season;
- Upgrade and expand women's fish processing facilities and techniques.

Human Capacity and Awareness

- Improve the quality and quantity of engineers and aquaculture experts and network them with aquaculture farmers, thus improving access to services;
- Proved adequate protective gears to engineers, experts and aquaculture and fish farmers;
- Improved the timeliness and availability of information (forecasts/predictions) related to the fresh, brackish and marine water levels so as to take necessary actions before inundation.

2.2 Coastal Resources Sector

2.2.1 SUSTAINABLE SAND MANAGEMENT

2.2.1.1 Barrier Analysis and Possible Enabling Measures for Sustainable Sand Management

2.2.1.1.1 Description of Sustainable Sand Management Technology

Sustainable sand management is a comprehensive approach to advance sustainable soft and hard coastal engineering measures at strategic locations of the coastal zone of The Gambia that is vulnerable to rising sea levels and coastal erosion. Sustainable sand management, including beach nourishment (Figure 4 overleaf) is well recognized in The Gambia and deemed to have made positive impacts in the beach restoration system. Beach nourishment or replenishment is one of the most popular soft engineering techniques of coastal defense management schemes. This involves importing alien sand off the beach and piling it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so it can integrate with the natural processes occurring there, without causing any adverse effects. Beach nourishment can be used alongside groyne and breakwater schemes to stabilize the movement of the sand. The scheme requires constant maintenance.

Figure 4: Pictures of Beach nourishment activities and beach produced in 2004 along a section of the coastal zone of The Gambia

Beach nourishment activities (ref.: https://en.wikipedia.org/wiki/Beach_nourishment+

A 100-metre wide beach created after the beach nourishment of 2003 and 2004. No shoreline sand stabilization structures were added to keep the sand and more than 80% of the volume of the sand was lost within seven years

2.2.1.1.2 Preliminary targets for technology transfer and diffusion

The Gambia's coastal zone consists of 80 km of open ocean coast and approximately 200 km of sheltered coast within the tidal reaches of the River Gambia. This coastal area is vulnerable to climate change impacts from rising sea levels, potential changes to precipitation patterns and potential increases to wet season rain storm intensity. Generally accepted impacts include (a) tidal flooding of low-lying areas along the open coast and up the river, with loss of important urban areas, port infrastructure, roads, fish landing sites, farmland, forestry and significant natural habitats; (b) saline intrusion into fresh water aquifers; and (c) shoreline erosion of the open coast with loss or damage to urban areas, roads, fish landing sites, historic and cultural sites and tourism assets.

The target for the direct application of sustainable sand management technology is 69 kilometers of the open coast and the indirect application to 200 kilometers of sheltered coast. All the settlements and communities within 20Kms of the shoreline must benefit from the application of the technology. Applications of sustainable sand management in the open coast will protect the expensive tourism and private structures (hotels, resorts and residential villas) on the coastline.

Fish landing sites, high value residential / diplomatic properties, cultural sites and tourism assets are at risk. Applications of the technology in the sheltered coast will support wetland agriculture and aquifer recharge, maintain a minimum flow above the natural dry season rates; and regulate the influence of the natural habitat of the fresh and brackish water sections of the river, which traverses a very extensive low lying agricultural basin, with impacts on artisanal fisheries and river margin vegetation.

2.2.1.1.3 Identified Barriers to adoption of Sustainable Sand Management

Economic and Financial Barriers

- Much of the residential area of the city is extremely low lying and already at risk from tidal flooding;
- Lack of comprehensive policy and regulations to manage the coastal zone and the inadequate implementation of existing policies and regulations related to environment and natural resources management including the coastal zone.
- Almost all the supply of drinking water for the country, and much of the agricultural water supply is taken from the underlying aquifers.
- Absence of the regulatory measures on the minimum requirements of the abstraction of groundwater near the coast which has resulted in saline intrusion, reducing water quality and making some bore holes unviable.
- Absence of in-depth baseline study on the nearshore and offshore sediment status and long shore movement of the sand along the coast;
- Sustainable sand management requires periodic beach replenishment leading to increased costs depending on the source of the sand;

Non-financial Barriers

Institutional and Organization capacities

- There are collaborative, cooperative and coordination shortcomings between and amongst the institutions and organization in charge of the operations to effectively manage the coastal resources;
- The institutions also need enhanced institutional and human capacity which is currently inadequate;
- It is technically unacceptable to pump sand on the dynamic beach of the Gambia without construction of accompanying shoreline stabilizations structures.
- It is technically hard to find a perfect match between avoidance of damage and destruction of marine life, disturbance of the original beach and production of an alternative that serves to adapt to climate change

2.2.1.1.4 Identified Measures to improve adoption of Sustainable Sand Management

The identified measures are divided in financial and non-financial measures need to lift the barriers identified in the preceding section.

Economic and Financial Measures

- Provide Government subsidies and tax waivers to imported equipment and materials to be used in sustainable management of the sand;
- Impress on the business and private owners of hotels, resorts and residential assets on the coastline to contribute financially to the management of the sandy beaches adjacent to the structures;
- Review the tax system related to waterfront property on the coastal zone of The Gambia with a view to generate greater income necessary for the sustainable management of the coastal zone;

Non-Financial Measures

These category of measures include the following

Policy and Regulatory Measures

- Develop and operationalize policies and regulations on sustainable sand management
- Develop and operationalize policies and regulations against inappropriate construction of immovable hard structures on the beach, particularly in the tourism development zones;
- Apply the recommended precautionary policy principle against development of significant structures within 150 m of the shoreline to allow a buffer zone for erosion.
- Regulate abstraction of sand on the coastal zone;
- Disallow projects that use coarser grain sand instead the natural fine sand originally found on the beaches of The Gambia.

Technical Measures

- Construct well designed shoreline stabilization schemes that help stabilize the movement of sand on the coastal zone;
- All elements of sustainable sand recharge and management must involve the much needed recreational, aesthetic and touristic benefits:
- Conduct regular monitoring and maintenance of identified defects and damages, and re-nourish the beach as and when found necessary;
- Facilitate the return and recruitment of faunal and floral species that were lost due to reduced beach area and loss of ecosystems;

Institutional and Organization capacities

- Facilitate the institutions and organizations to effective exercise their mandates collaboratively and efficiently for effective management of the coastal resources.

2.2.2 BREAKWATER SYSTEMS TECHNOLOGY

2.2.2.1 Barrier analysis and possible enabling measures for Breakwater Systems

2.1.1.1.5 General description of Breakwater Systems

Breakwaters are segmented, shore parallel structures built along the upper beach at approximately high water mark. They are normally built of rock, but can be formed of concrete armor units. Breakwaters reduce the energy of waves reaching the shoreline, but do not completely isolate dunes from the natural beach processes. The structures act as a direct barrier to waves, but at very high water levels they allow some overtopping. The gaps between segmented structures allow some wave energy to reach the upper beach and dune face, but this is dissipated by refraction and diffraction. Erosion may continue in the lee of the gaps leading to formation of an embayed shoreline as sand moves into the shelter of the structures. The width of the upper beach along the embayed shoreline may increase, providing improved recreation. New fore-dunes may develop in the lee of the breakwaters. The structures allow natural beach-dune processes to continue, albeit along a modified shoreline. Existing dune habitats and land forms may be retained and/or enhanced in the areas behind the structures (SNH, 2011).

Costs for breakwater systems depend on structure dimensions and spacing. They can be heavily influenced by the availability of suitable rock (or other material), transport and the costs of any recycling or nourishment. Rock structures can be assumed to have an unlimited life with respect to economic assessments.

Breakwater systems (e.g., Figure 5 overleaf) have high impacts on shoreline processes, intertidal habitats and landscape systems, and may be unacceptable in environmentally sensitive areas. Erosion in the lee of the gaps may well continue for several years after construction while a new beach plan shape develops. On frontages affected by long-shore transport the breakwaters may reduce drift rates, resulting in the erosion of downdrift stretches of coast, but helping to stabilise the updrift shore.

Where the nearshore waters tend to be silty, the breakwaters may encourage lee-side deposition of mud leading to both unwanted odours and unsafe beach areas. Other lee side deposits may include sea weed and jetsam from ships (plastic containers, nets, rope, etc). Wave induced currents around the ends of breakwaters can be locally strong and a danger to beach users (SNH, 2011).

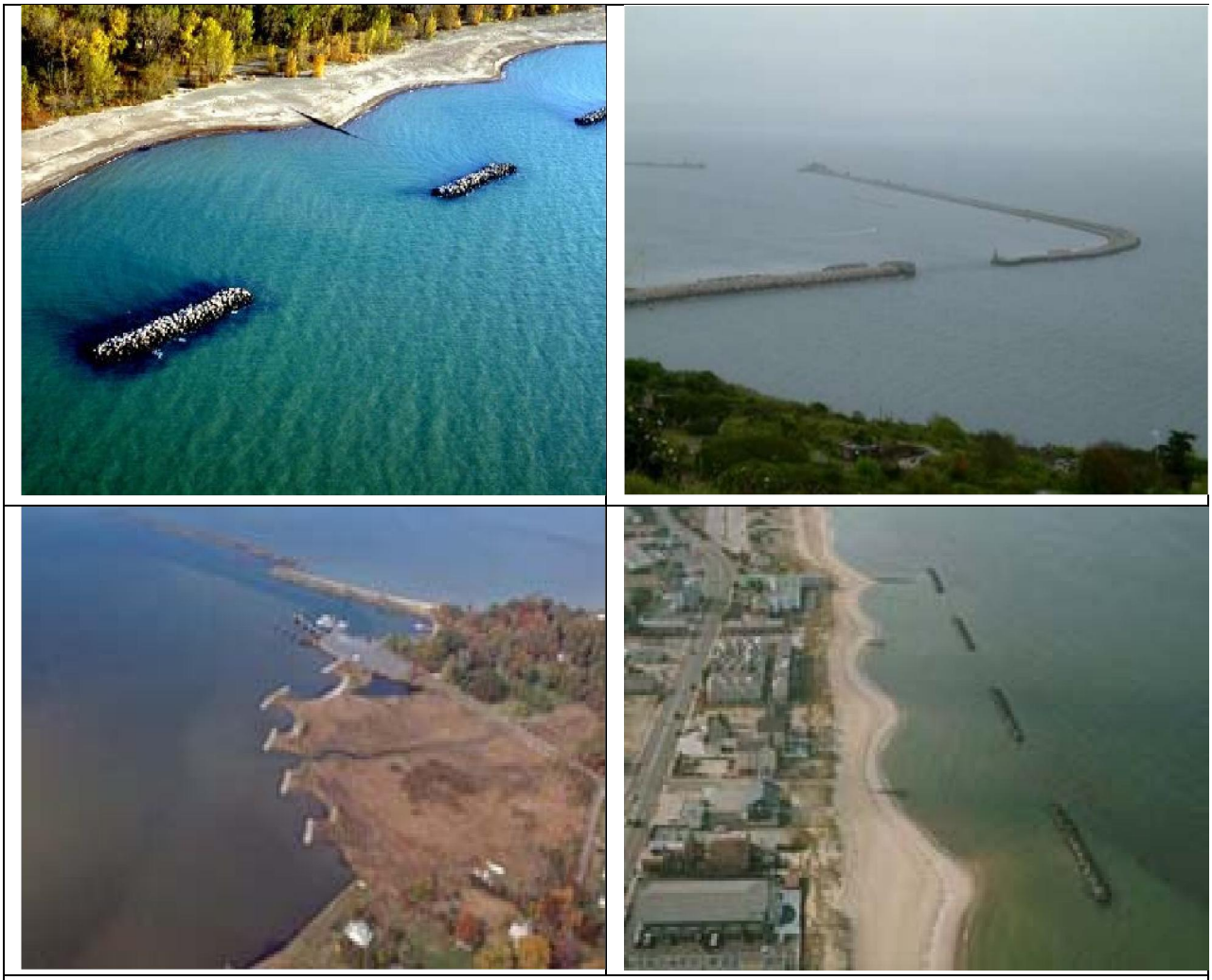

Figure 5: Various Types of Breakwater Systems

2.2.2.1.1 Preliminary targets for adoption of Breakwater Systems

Offshore breakwaters facilitate the breaking of the waves further offshore and therefore reduce the erosive power of the waves. These breakwater systems do not exist in The Gambia. Nevertheless, with the failure of the beach nourishment along the coast especially at the Kairaba and Senegambia beach areas, it is now planned to build offshore breakwaters to protect the coastline and beach around those areas. This decision also arose from a feasibility study under the GOTG/GEF/UNDP LDCF NAPA project (Enhancing Resilience of Vulnerable Coastal Areas and Communities to Climate Change) on the coastal zone which concluded on the viability of the technology in reduction of erosion on the shoreline. (Government of The Gambia, Coastal Protection Project, 2013).

The coastline of The Gambia is sandy and dynamic and the need to stabilize the sand is eminent. Shoreline stabilization techniques have been tested in various segments of the open coast but

Breakwater systems seem to satisfy the dynamic conditions of the coastline. It is proposed to construct breakwater systems along the 69km land stretch of open coast.

2.2.2.1.3 Identified Barriers and enabling measures for Breakwater Systems

One of the main activities in the Technology Needs Assessment process is identifying barriers in order to get the chosen technologies transferred, diffused and uptaken in a successful, replicable manner.

Economic and financial barriers associated with Breakwater Systems

The general barriers that are challenging the implementation of offshore breakwater systems remain almost directly linked to the cost involved in the use of the technology. Majorly, the technology requires a high initial investment and eventually some periodic inputs to cater for their maintenance in view of ensuring their sustainability on the long run.

High cost for implementation of offshore breakwater system

According to Problem Tree (see AN6 in the Annex), one of the main barriers to the implementation of a well-designed offshore breakwater system is cost. The design of an effective breakwater requires good quality, long-term environmental data such as wave heights and extreme sea levels and requires a combination of engineering and oceanographic expertise and experience. The construction of an offshore breakwater system would usually require several thousand tons of massive boulders, large excavators and other specialized equipment to put these boulders in place and the cost of these together with the time required for such construction thus becomes very.

Non financial barriers associated with Breakwater Systems

Other barriers that have been identified include the lack of information on the technology itself at various levels ranging from officials to the general public through private bodies. It is thus proposed that information and awareness campaigns be undertaken in the use of the technology and this would contribute to the better acceptance and appreciation of the benefits of the breakwater systems. The legal framework, including the enforcement of existing laws and regulations, to deal with the implementation of the breakwater systems is also a barrier especially for the coastal zone sector of the Gambia.

Limited capacity and experience

The design of the offshore breakwater system does not usually include consideration of coastal dynamics, sediment transport and the hydrodynamics. This has for effect that erosion, to various degrees, occurring at the end of the structure is exacerbated because of the mere presence and design of the structure. The use of this technology might entail additional environmental cost especially in the case of wrong design and implementation of works.

Lack of awareness and information to coastal communities and tourism facilities

The use of offshore breakwater system may provide an erroneous sense of protection against erosion. It will usually control the erosive forces at specific location whereas adjacent areas remain or can become more vulnerable. Also the use of this technology largely affects the aesthetics of our beaches and may be regarded as an eyesore especially for a country which is betting a large portion of its economy on the tourism industry. Moreover the use of offshore breakwater system may limit the accessibility to the sea and thus find public opposition to its implementation.

Policy intermittency and uncertainty

Offshore breakwater systems have not been implemented in The Gambia. However, the use of rock revetments as erosion control have been mainly implemented at certain areas along the southern coastline of the country especially in Bakau and the recently coastal protection work along the Senegambia-Kololi strip following severe erosion of the shoreline and where buildings or infrastructure are being left exposed to damages. The use of this technology is being implemented on an ad-hoc basis in the absence of the specific national plan for the control of erosion. Rock revetments do not address the source or cause of the erosion and this implies that erosion will persist unabated in those areas and at times the significant impacts on the region could be more damaging following the placement of these structures.

Policy/planning

- Lack of a comprehensive policy for coastal zone management
- Overlapping legislation for different aspects of coastal zone management
- Need high level of potential buy-in for sustainability

Institutional capacity

- Unclear institutional roles
- Slow bureaucratical process
- Weak inter-agency coordination

2.2.2.1.4 Identified Measures for an offshore breakwater system

In view of implementing offshore breakwaters, it would be important to take note of the following actions:

Economic and Financial Measures

Offshore breakwater systems are usually associated with high cost. Up till now, there are no major works done by the Government of The Gambia in the implementation of offshore breakwater systems. In view of decreasing the load on the government, it can be contemplated that hotels or other private bodies contribute to the cost of the breakwater systems. This contribution should not be in the form of tax but rather as a social contribution for the benefit of

the area. This participatory and cost sharing approach would assist in the implementation of the technology (AN7 in Annex) and thus providing for some protection to the coastline from the impacts of coastal erosion.

Non-Financial Measures

a) Support to research and development

Offshore breakwaters can be made from different materials and the use of other materials in lieu of rocks to form breakwaters should be studied as it can have major impacts on the cost of the structure. Research can be further developed and included in the National development Plan to control coastal erosion in as much as it would give the various methods which can be most appropriately used upon consideration of the individual characteristics of the eroded site. This national plan would identify the measures or technologies to be used for the various locations and it would have the added advantage that works would be done following a schedule plan and thereafter the monitoring of the works shall be undertaken.

b) Information and awareness raising:

An information and awareness campaign on the problem of erosion along the coastline of the country and the various methods that exist to control the erosion would be most appropriate for The Gambia. The benefits and disadvantages of each method should be highlighted. This campaign should be targeted towards the public at large and the authorities and this would ensure early detection of erosion. Whilst several degree of erosion exists if dealt with at its very early stage, the effort and cost incurred in controlling it could be consequential. The most pertinent information to be disseminated with regards to climate change and coastal erosion in The Gambia to the stakeholders and the public at large, would be to explain how such measures can help in controlling erosion, any alternatives that can be used and also the benefits of the use of such technology especially in terms of being environment friendly with little negative impacts on the surroundings.

4.2.5. Other possible measures

- Implement policy for Integrated Coastal Zone Management
- Strengthen inter-agency coordination for coastal zone management
- Raise awareness of coastal zone management and technology among policy makers and key stakeholders
- Provide support for research and capacity building within local institutions in coastal engineering

2.2.3 GROYNE SYSTEMS TECHNOLOGY

2.2.3.1 Barrier Analysis of Groyne System Technology

2.2.3.1.1 General description of Groyne Systems

Groynes are wooden, concrete and/or rock structures built perpendicular to the sea. Beach material builds up on the updrift side, where littoral drift is predominantly in one direction, creating a wider beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring that another groyne to be built there.

Groynes are extremely cost-effective coastal defense measures, requiring little maintenance, and are one of the most common coastal defense structures. They are common in The Gambia and lack of wood for their construction has limited their use but this has recently been overcome with the use of concrete and rock structures. The groyne systems in The Gambia have been constructed out of matured rhun palm trees which are suitable for saline conditions.

2.2.3.1.2 Preliminary targets for technology transfer and diffusion of Groynes

The preliminary target for the transfer and diffusion of Groynes is aimed at protecting the 80km Open Coast from erosion and also for the stabilization of sand. Groynes as indicated, is one of the identified and adapted technologies to protect our beaches and businesses around the sea.

2.2.3.1.3 Identified Barriers to Groynes Systems

Barrier identification of Groynes was a process of tracing the causes that affects the development, transfer and diffusion of this technology. This process was based on the stakeholder consultations and consultant's own knowledge and international experience as follows:

- A desk study of policy papers and other pertinent documents to identify the primary reasons why the technology is not currently use country wide, and why both public and private sector have not invested significantly.
- The inclusion of a proper economic, environment, and institutional capacity assessment was included in the desk study.
- Stakeholder consultation in the form of Focus Group Discussion and a technical working group were used to collect such information.
- Telephone interviews with some staff of the the National Environmental Agency of The Gambia was also employed.

The identified barriers were then group into various categories and described to be able to facilitate analysis and screen them (see Table 1 below).

Table 10: Barrier Categorization and Description of Groyne as Technology

Category	Barrier	Barrier description
Financial and economic	• High cost of investment capital • High inflation rate and high price fluctuations • High import duties • Lack of funds for costal management plan if any • High maintenance cost	• Design and implementation of the technology is expensive • The unstable market price increase the cost further • The cost of the materials and equipment used are expensive • High duty tax levies on imported materials and equipment • Maintaining the technology infrastructure is costly • Implementation of coastal management plan is costly • Boulders are bought and transported from Senegal which increases further cost. • Transportation difficulties. Ferrying the boulders from Barra Ferry Terminal
Technical	• Inadequate technical standards and institutions • Inadequate expertise • Inadequate technology know-how • Uncertainties about the scale of sea-level rise	• Limited institutional capabilities at NEA and Ministry of Works since they are the only institutions to give relevant technical advice and support • Limited capacity to install, implement , operate and maintain the technology • Limited engineers to do geotechnical survey; to know the strength and structure of the soil, bathymetric survey; to know how the sea flow looks like and topographic survey on the shoreline and upland • As at now there is no Gambian costal engineer • Newly qualified engineers lack support to develop and implement new techniques and working practices • Most of the newly qualified engineers are unwilling to serve apprenticeships before given the position of expert • limited supervision of local young qualified engineers • possible changes in waves and wind climate makes government reluctant to commit expenditures
Information and awareness	• Inadequate technical information • Low literacy on coastal engineering • Limited public awareness	• Inadequate training on coaster engineering literature about what works and does not work • As at now no local coater engineer literate • Insufficient sensitization of the community on the need to adapt the transfer and diffusion of the technology. • Few or no track records of the already existing groynes in the Gambia
Socio-cultural	• Property right • Spiritual beliefs	• Private businesses, hotels owners, and other infrastructure are sometimes unwilling to give up for the development and transfer of the technology • Tradition and religious practices on areas near coast discourages the adaption of the technology
Political	• Instability • Corruption by government officials	• Planning and consultation necessary for coastal project can be hampered by political unrest • Mismanagement of funds by government officials since

		government is the implanting body. • Regime change can cause the delay on the installation and implantation of the coastal project.
Human skills	• Limited skills coastal engineering • Limited skills in research and new tools development	• There is no local qualified coastal engineering expert • Funds are need to bring foreign coastal consultant and construction engineers
Environmental	• Inadequate understanding of sea-level rise • Inadequate knowledge of other climate change impact • The land condition	• Improper prediction of sea-level rise • Limited tools to use in order to understand possible changes in climate change. • Adaption of the technology depends on site-specific conditions.
Policy	Government laws and regulations	• Lack of proper adaption policy to guide land use and planning by the government

Barrier screening was conducted in order to be able to identify and addressed the most significant categorized barriers in the adoption and diffusion of Groynes in The Gambia. This was accomplished through various interviews conducted and discussion sessions with National Environmental Agency.

Many barriers were identified during the discussions but few are selected and analysis.

5. High cost of initial system installation
6. High cost of maintenance
7. Environmental
8. Technical

Economic and Financial Barriers

With the decomposition of economic and financial barrier (see AN8 in Annex) it proves beyond thought that high cost of system initial installation is in relation to high cost unit kits and as well as cost maintenance. The equipment and components are imported and since there is no local coastal engineer, importing can be costly.

Table 11: Decomposition of Economic and Financial Barriers

Broad Category	Barrier within category	Elements of a barrier	Dimension of barrier
	High cost of system initial installation	• High cost of boulders • High cost ferrying the boulders	• Boulders use are not available in the Gambia • Importing the boulders and heavy machinery is costly • The duty tax on the business institution and individuals is high • Heavy machinery and engineers for assessment
	• High cost of	• High cost on the adjusting	• Adjusting groynes to match

Economic and Financial	maintenance	the groynes	beach changing profile is expensive

Non-financial Barrier

From AN9 in the Annex, apart from lack of local production of materials used in the construction of Groynes, technical and environment issues are also among the main barriers for the transfer and adaption of the technology. Table 3 shows the decomposition of non-financial barriers.

Table 12: Decomposition of Economic Non-Financial Barriers

Broad Category	Barrier within category	Elements of a barrier	Dimension of barrier
Environmental	• Inadequate understanding of sea-level rise • Inadequate knowledge of other climate change impact The land condition	• Limited proper tools to understand climate change impact • Uncertainty of sea level rise	• Improper prediction of sea-level rise • Limited tools to use in order to understand possible changes in climate change. Adaption of the technology
	• Inadequate technical standards and institutions • Inadequate expertise • Inadequate technology know-how Uncertainties about the scale of sea-level	• Only one technical institution (Ministry of works) • lack of local coastal engineers	• Limited institutional capabilities at NEA and Ministry of Works since they are the only institutions to give relevant technical advice and support • Limited capacity to install, implement , operate and maintain the technology • Limited engineers to do geotechnical survey; to know the strength and structure of the soil, bathymetric survey; to know how the sea flow looks like and topographic survey on the shoreline and upland • As at now there is no Gambian costal engineer • Newly qualified engineers lack support to develop and implement new techniques and working practices • Most of the newly qualified engineers are unwilling to serve apprenticeships before given the position of expert

2.2.3.1.4 Identified measures for Groyne System Technology

Measures taken to overcome the identified barriers of Groynes have been represented in the form of problem and solution trees categorized as economic and financial and non-financial.

Economic and financial measures

The causes and effects base on the economic and financial barriers of Groynes in the Gambia are illustrated in Problem Tree (AN8 in Annex). The Limited uptake of Groynes is the starter problem in the center of the problem tree, the causes below and the effects above. The measures for the starter problem and the results are shown in the Solution Tree (AN10 in Annex).

Non-financial Measures

The Limited uptake is the starter problem, the causes and effects as well as measures to be taken and the results are below and above the problem tree respectively. AN9 in the Annex represents the Problem Tree and AN11 in Annex, the Solution Tree.

Conclusion

The barrier analysis and enabling frame work for Coastal Zone sector prioritized in TNA report is discussed in this chapter. The identified barriers and measures to overcome the barriers on both financial and non-financial are presented.

Groynes if applied can protect our eroded beach and business around the coastal areas.

2.3 WATER RESOURCES SECTOR

2.3.1 Water Conservation Technology

2.3.1.1 Barrier Analysis and Enabling Measures for Water Conservation Technology

2.3.1.1.1 General description of Water Conservation

Availability of usable water is becoming a major cause of concern throughout the whole world. Freshwater sources are fast becoming depleted. This is attributed to growing demands on water, inefficient distribution systems and poor or in most cases unavailable water management and development strategies. The National Water and Electricity Company, a state owned company responsible for the supply and conservation of portable water, is already faced with the challenge of adequately meeting the water demands of the population. Reports have emerged of failing infrastructure in the distribution network coupled with institutional incapacity. The impending climate change impacts are poised to further aggravate water shortages.

Thus in a bid to meet these challenges, there has to be an overhaul in the overall water management and development in the country. This calls for the implementation of water conservation technologies to save enough water for future demands. However, these interventions are confronted with challenges hereafter referred to as barriers to water conservation technologies. This report discusses the barriers hindering the acquisition and diffusion of water conservation technologies. The report also discusses the measures identified to overcome the barriers and facilitate the transfer, adoption and diffusion of these technologies. Further to these, a detailed cost-benefit analysis (CBA) has been conducted and reported.

Water conservation in very simple terms can be referred to as a simple technical efficiency in consumption of water. This technical definition expresses the desire to secure the most physical output per unit of water used. Water conservation in itself is a combination of specific technologies that are designed to overcome specific barriers. Water conservation related barriers include chiefly poor distribution efficiency, inefficient management structure and too much dependency on groundwater source. And so, water conservation technologies able to counter the root causes of these problems are considered in this report. Such conservation measures considered will target developing an efficient distribution system, designing legal and institutional policies to govern water use and suggesting alternative sources of water.

2.3.1.1.2 Identified Targets for Water Conservation Technology

The National Water and Electricity Corporation (NAWEC) losses a lot water from burst pipes and leakages throughout the country but more sure in the Greater Banjul Area. It is targeted to overhaul all the obsolete plumbing systems that are older than 10 years with pipes that are more durable. This is huge but in the long term it is worth the investment due to savings as a result of the water conserved. Procure and use a leak detection software and equipment, and design and implement leak detection and repair strategy.

Water must be valued and it is targeted to institutionalize an effective costing, pricing (per unit used) and billing of water for all communities in the country; revise the currently low cost of service charges and introduce a new rate structure per user category. It is also the target to introduce and promote the use of water efficient appliances and devises in all homes. The Public Utility and Regulatory Agency (PURA) in collaboration with NAWEC must promote water conservation measures at all user-category levels and also conduct nation-wide education and sensitization of communities on the water conservation measures especially at domestic level. The two agencies must build and strengthen the technical and managerial capacities and skills of all service providers to execute their duties effectively and also build legal and institutional framework.

2.3.1.1.3 Identified barriers for Water Conservation

Based on literature review and consultation with water providers and users, the following barriers were identified as hindrances to water conservation based on the construction of a Problem Tree (AN12 in the Annex). The starter problem is that there is inadequate water supply to meet the demands of users.

Economic and Financial barriers

The following categories of barriers have been identified.

- **Low income:** Despite high investment in trying to meet customer demands, NAWEC and other water service agencies have not been able to synchronize demand and supply. Demand still outstrips supply. This is attributed to low income from service provision. Water has always been undervalued. Water bills only occur in the urban areas and in most cases are not commensurate with the volume consumed. In smaller communities where boreholes are drilled to supply water, it is a free commodity.
- **Operating and Maintenance Inefficiency:** As well as supply and conservation of water, NAWEC is also responsible for provision of Electricity to The Gambian population. This bares a heavy load on NAWEC in terms of operating and maintenance cost. The company spends 50 per cent of its operating cost on the purchase of heavy fuel and lubricant (Point Newspaper, Oct. 5th 2017).Thus there is a great lack of sufficient moneys for maintenance of the distribution network. Further to this is the fact that there is limited attention to the important aspect of Operation and Maintenance of water distribution systems. Besides lack of sufficient funding for maintenance, there are also other issues that include inappropriate system design and poor workmanship, no emphasis on maintenance, inadequate training of personnel to track what happens at the network and to repair and lack of real time information about the network. There is also an unsuitable policy regarding leakages. NAWEC's policy is that it is the customer's responsibility to protect themselves against losses through leakage after the water meter.
- **High Rate of Non Revenue Water:** This refers to water that does not generate revenue for better water conservation. Such water is lost in the system and is expressed as a percentage of the total volume of water pumped. It sums the unaccounted for water and the authorized unbilled water. NAWEC and other community water supply agencies have had a lot of issues concerning non-revenue water. These include metering inaccuracies, illegal connections and distribution system leakages which can be grouped under unauthorized unmetered water; and there are also cases of hydrant flushing, fire fighting and government office maintenance which can be grouped under authorized unbilled water. With an average of 17% non revenue water, it can be deduced that a lot of revenue is lost giving rise to financial burden of the company to conserve water.

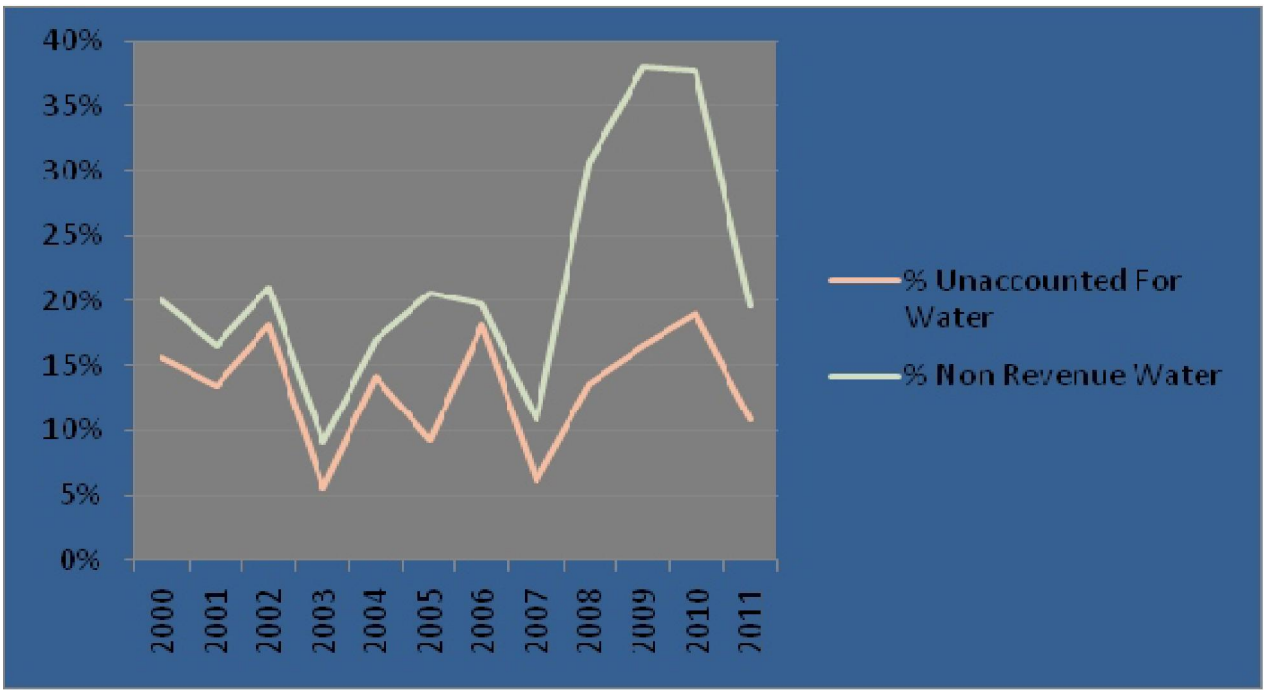

Figure 6: Graph showing percentage of non revenue and unaccounted for water (Source: PURA annual report 2011)

Non-financial barriers

Non-financial barriers include:

- **Poor and outdated infrastructure:** There have been many cases of burst pipes and leakages reported. The pipe network was laid many years ago. With age there is bound to be a considerable reduction in carrying capacity of the pipes due to corrosion. In most places within Kanifing Municipality and Banjul City and major towns in The Gambia, the pipes have suffered from degradation over time due to operational measures, environmental conditions that include exposure to pressure from heavy road use and general wear and tear resulting in increased leakages and water losses. Equally, in the smaller communities where hand pumps and boreholes are most popular, several of these facilities are damaged due to lack of proper maintenance. In many cases the following issues are observed. Where a community uses a solar powered borehole, issues are observed at the source. Water tanks too small to contain produced water often overflow for long hours resulting in great water loss and wastage. Again at supply points tap heads very frequently get loose and water flow is uncontrolled. Thus poor and old infrastructure effectively contributes to poor distribution and consequently inadequate water for end users. This is a major barrier to water conservation.
- **Lack of legal and institutional policies:** Currently in The Gambia, there is no active or operational national water policy to promote the efficient, equitable and sustainable use of water. There have been in existent several Acts with no clear agenda to conserve water. No particular Act promotes water conservation technologies such as use of rain

water harvesting technology to supplement supply, water metering and water audit policies, water use bills and abstraction controls. Water rights are not clearly defined in any legislation related to water. With virtually all sectors depending on the groundwater source for fresh water, there will be more stress with climate change. Further, there is no institutional arrangement for supporting Integrated Water Resources Management (IWRM).

- **Lack of human capacity:** There is also a general lack of human capacity in water conservation technologies implementation. Service providers are short of trained personnel to handle the optimal production, management and development of water in the most effective integrated manner. And so water integrity is not prioritised in any way. This incapacity extends to Village Water Committees where management is compromised. In most cases, these committees lack the technical know how to manage water and decisions taken are politicised. These committees have proven to be not viable to solve water related issues in their communities and in a relatively short period of time a lot of damage is registered.
- **Community behaviour:** Water losses can not only be attributed to engineering faults. But losses also reflect community behaviour towards water. The socio cultural concepts about water are great impediments to water conservation. Water is regarded as a free commodity amongst most Gambians and treated so. Worse of all people have wrong perceptions about the infinite state of water and lack knowledge of issues related to climate change and water. This has for long played an influential role in their behaviour towards the equitable and efficient use of water.
- There are cases of water overuse, illegal connections, uncontrolled borehole drilling and reluctance to pay water use bills even at very minimal rates. In most cases such behaviour also contribute to the rampant loss of water to leakages because even the closest neighbour to a burst pipe does not seem to care and water is left wasted for days.
- **Heavy dependence on groundwater source:** The only absolute and reliable source of potable water in The Gambia is the underground aquifers. Basically all water use sectors (including Domestic/Residential, Hotels, Clubs and Industries, Area Councils, Commercial, Agriculture and Central Government) solely rely on groundwater abstraction for their daily use.

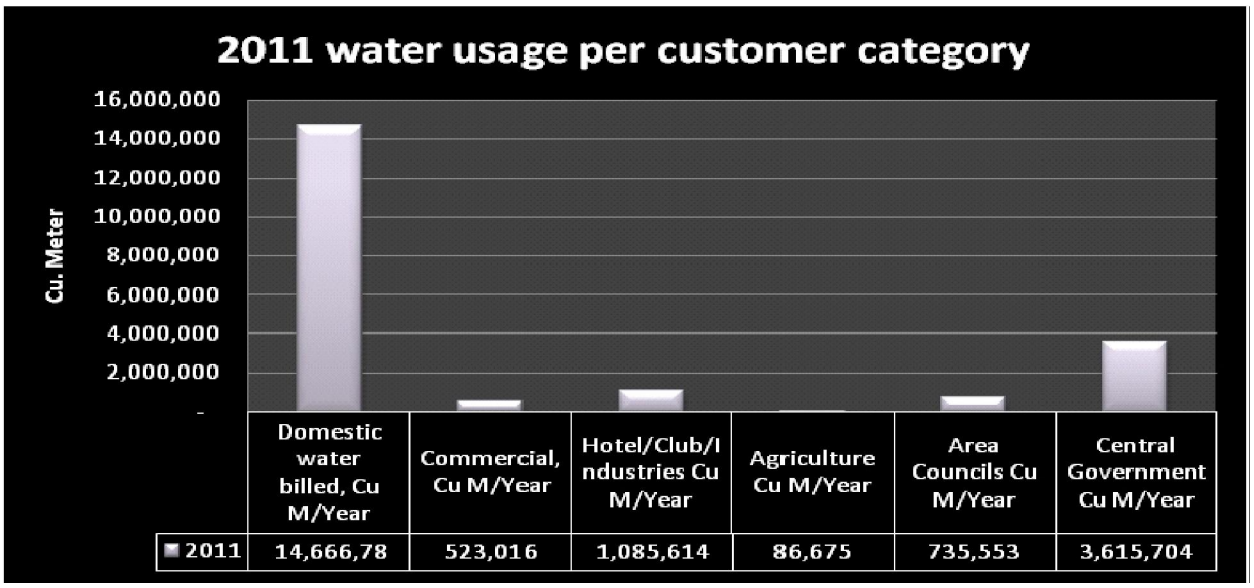

Figure 7: Volumetric water consumption by sector in 2011 (Source: PURA annual report 2011)

From the statistics in figure 7, it can be seen that domestic water consumption is the most critical to water conservation. The situation begs the question "How much more water will be consumed in future with the rapidly growing population especially in the urban Gambia and with socio-economic development?" There is certainly going to be a rise in water demand for all sectors. From figure 2, agricultural water use from groundwater supply seems insignificant. This can be attributed to lack of proper records. For instance, boreholes in gardens are not metered and livestock water consumption is also not accounted for. Yet irrigated agriculture is expected to expand. Bearing in mind the fact that there are the impending climate change impacts of saline intrusion from sea level rise and low aquifer recharge due to low rainfall, water conservation will definitely be challenged.

2.3.1.1.4 Identified measures to lift the Barriers (See Figure 4.4 Solution Tree)

Measures have been identified to target specific barriers based on the Solution Tree (see AN13 in Annex) approach. Such measures were chosen based on their feasibility and benefits they will incur in conserving water for the country. A few already being practiced in some countries have also been considered.

Economic and Financial Measures

Identified barriers under this category include:

- **Costing and pricing:** an effective way of understanding the true value of water and transmitting information about that value to customers is by tagging it with price per unit used. This is a necessary measure to help control water usage. Customers will be forced to use water optimally and try as much as possible to save. This measure can be ensured through the following:

a. **Metering:** Metering is a fundamental tool in system management and water conservation. This will ensure that the water use bill corresponds to the actual water usage so that both supplier and user benefit. This measure should be done at source and at the service connection point. All public-use water (currently provided free of charge especially in the villages) should also be metered. This is beneficial in that it allows the service providers to more accurately account for water. A lack of metering will undermine loss control, costing and pricing. It should be noted that meters can deteriorate with age thus producing inaccuracies. This probably has been the cause of conflicts between NAWEC and users. Therefore service providers should assess all current meters and replace them with standard metering systems.

b. Cost of service charges: NAWEC and other service providers should consider introducing a new rate structure that puts into effect the overall costs incurred in providing service. Once these costs are established, the user charge fees will be judiciously established. This way, costs incurred will be recovered to support service operation and maintenance.

c. Introduction of water user chares at the pump facility: At small community level where water is currently used freely, Village Water Committees should commit to collect water use charges from customers. A mechanism should be put in place to ensure all water users pay according to usage. Prepaid cards may be instituted in which case taps will be replaced with machines that will open up flow upon insertion of the card. This is already working in India.

- **Water Accounting and Water Loss Control Measures:** A lot of water has been lost to unauthorized unmetered uses. The first step to control these losses is to develop a system of accounting. This system will be used to track water throughout the whole system. The strategies applicable here include the following:

a. Leak detection and repair strategy: A well trained unit in the service companies should be established to be responsible for leak detection and repairs. Whereas automated sensors / telemetry leak detection may be too expensive just yet for The Gambian companies, there is an option of regular on-site testing using computer-assisted leak detection equipment.

b. Use of advanced plumbing materials: The poor and outdated equipment currently in use should be changed to the most recent advanced plumbing materials.

Non-financial measures include:

- **Use of water efficient appliances at homes:** According to PURA Annual Report of 2011, the biggest water user group is the Domestic sector in The Gambia. Thus a residential water conservation measure is urgently needed to save water in the homes. The government should design a policy to encourage households to have water efficient devices. With socio-economic advancement, there is bound to be wide use of flush

toilets, overhead showers / water beds and car washers. The government should embark on importing low-flow devices for such water uses.

- **Urine collection technology:** It has been proven that urine is highly rich in nitrogen and phosphorus, a great nutrient for crop cultivation. Collection of urine will serve two purposes. First the urine will be used for watering vegetation. This will reduce pressure on water. And second, water used for flushing will be conserved as the urine will be collected in containers. This is quite very simple and cost effective. It is a practice already done in China to fertilize apple trees. (Documentary, Urine Superpower)
- **Water-use Audits:** Water-use auditing is not practiced in The Gambia. Yet it is very vital in providing invaluable information to users on how much water is used and how usage might be reduced. Most customers are uneducated about water requirements and therefore demand water uncontrollably. A water audit policy should be created to ensure that all water use sectors perform water use audits regularly. This will help service providers with information to know just how much water to supply.
- **Education and Information:** These are critical to the success of water conservation programs. These will play a role in how customers respond to new measures. This can be done through schools, public education programs (videos, radios, and community outreach), workshops or even Technical Advisory Committees. The content of the education and information should include understanding water bills, need to manage water, technologies to conserve water, legal and institutional policies on water related issues.
- **Capacity building for service providers:** Service providers need technical kwon how and skills to execute their duties effectively. They should be trained on water related disciplines and how to handle conservative measures appropriately. By extension, the Government through the Ministry of Education should mainstream water education in the school curriculum.
- **Building legal and Institutional Framework:** A complete analysis of the laws and acts related to the water sector in The Gambia was undertaken by NIRAS, a consulting firm. Significantly, omissions, conflicts and duplications were readily identified. Recommendations were made for a new water bill to be designed and enacted. The new water bill would incorporate IWRM principles. This gave birth to The Gambia Water Bill, 2014 which s meant to make provision for the water sector and its management and regulation, incorporating the vision of the National Water Policy, to provide the enabling environment for Ministers and Government Agencies to collaborate comprehensively in safeguarding the water of The Gambia within a common legal framework with guiding principles. The bill provides for the establishment of a National Water Management Authority tasked with management and development of water resources.
- It is worthwhile to note that if conservation of water resources must take effect and pay dividend, this legal and institutional framework be enacted. This is the only sure means of supporting all water development technologies in the country.

2.4 LINKAGES OF THE BARRIERS IDENTIFIED

The Adaptation Technologies (Conservation Agriculture, Tidal Irrigation, Aquaculture and Fish Farming, Sustainable Sand Management, Breakwater Systems, Groyne Systems, and Water Conservation) have common barriers applicable to all and include:

- Inadequate representation in the sectors (agriculture, coastal and water) concerned;
- Low technical capacities and awareness of the extension services and the major users (farmers, fishers, herders, coastal engineers, tourism, water practitioners, etc.) of the technologies;
- High farmer to extension staff ratio which makes it difficult to provide adequate technical advice to the user communities
- Weak research and demonstration of the technologies nationwide;

2.5 ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS

Based on the common barriers to the penetration of the adaptation technologies assessed in this report, the following enabling environments are required for the promotion, diffusion and adoption of the technologies.

- Continuation of the integration of climate change adaptation into relevant sectoral plans and medium-term national and sub-national development plans. This is particularly true if The Gambia has to improve its food and water security in the face of climate change. Climate change being a development issue and of cross-cutting nature, it has wide implications for the sustainable economic growth for the agriculture and water sectors. Provision of the relevant and necessary enabling environments will promote adoption of all the technologies, increase food production and security, and contribute to the climate change resilience of the livelihoods of the communities that adopt the technologies.
- Adoption of the technologies in the agriculture and water sectors will contribute to policy adjustments in the sectors and enhance the capacities of extension agents, civil society organizations and communities;
- The creation of a suitable enabling environment will improve the financial allocation and flows to the sectors, improve the entrepreneurship of communities and business entities and the provision of support and more logistics at the local levels for the assumption of ownership of the technologies.
- The overall economy may become stable based on the suggested financial measures (low interest rates, favourable import duties and tax relief incentives) for the importation and supply of equipment and materials for the diffusion of the technologies will reduce costs considerably and encourage private participation in delivery, diffusion and uptake of these technologies.

3. BARRIER ANALYSIS OF MITIGATION TECHNOLOGIES

3.1 Energy Sector

3.1.1 DIRECT FUEL INJECTION TECHNOLOGY

Barrier analysis and possible enabling measures for Direct Fuel Injection

3.1.1.1.1 General description of Direct Fuel Injection Technology

The role of Gambia transport sector in its development is critical; this important role has been identified in the framework of successive National Development Plans (NDP), including the 1998-2006 National Transport Policy (NTP), and now of the NDP 2018-2021 (Improving and Modernizing Infrastructure). This can be illustrated more clearly by the fact that certain sectors (the agricultural, industrial, and tourism sectors) demand the transport system to enhance their productive capacity and competitiveness, e.g. transport provides connectivity and access in the urban and rural areas to transport freight, passengers, agricultural produce to markets, etc. Hence an efficient transport system facilitates economic development and reduces poverty.

With the rapid rate of urbanization due mainly to the continuous rural-urban migration, the Greater Banjul Area (GBA) presently hosts more than 50 per cent of the national population, putting more strain on the transport system and ultimately affects the productivity of the economy of the area. There is currently growing traffic congestion road trauma and air pollution, and Government therefore needs to improve urban transport and land use planning.

Modern light- and heavy-duty road vehicles are predominantly powered by internal combustion engines (ICEs) running on energy-dense fuels such as gasoline or diesel. Essentially, ICEs rely on the synchronous operation of air-supply and fuel-supply sub-systems. With environmental concerns gaining traction on the global policy agenda, and environmental standards driving technological innovations on several fronts, fuel injector systems were first introduced as substitutes for carburetors by the automobile industry in the 1980s. One type of fuel injection system; port fuel injection or indirect fuel injection system, works by spraying a mist of fuel through a small nozzle at a pressure of 2.5 to 4.5 bars over the intake valve head where the fuel mist mixes with air in specific proportions, ideally 14.7 parts of air to 1 part of fuel by mass, in readiness for combustion inside engine cylinders. A second type of injection system, conceptually associated with diesel engines, sprays with precise timing an ultra-fine mist of fuel directly into individual engine cylinders. The main benefits to an electrically operated and electronically controlled direct injection system is that at all times a vehicle is on the road, a finely calibrated amount of fuel can be injected into its engine cylinders in response to the

engine's operating conditions, resulting in higher power output, improved fuel efficiency and lower GHG emissions.

An electrically operated and electronically controlled direct injection system comprises three basic components: 1) high pressure fuel pump; 2) fuel pressure sensor; and 3) injectors; operationally controlled by a vehicle's engine control unit (ECU); an onboard micro-computer that directs various sub-systems of the vehicle by actuating certain key components and monitoring engine performance through feedback from multiple sensors.

In new vehicles, the cost of direct injection systems is inseparable from the vehicle cost which itself is strongly correlated to performance-related specifications such as volumetric displacement, top speed, range, acceleration, tailpipe emissions, and brand name as well. Thus, indicative costs of a 1,300 and 1,600cc vehicles fitted with direct injection technology lies between 19,000 and 22,000 Euros, with corresponding power train specific costs of 50.9 and 67.3 Euro/kW (Thiel et al, 2010). Assuming, a retrofit strategy is adopted by policy-makers/owners, the cost of direct injection unit approximates the market price of key component parts, cost of engine modifications and professional fees of engineer carrying out retrofit. At this point, a conservative estimate of direct injection retrofit cost falls within the range 1,300 to 1,550 Euros.

3.1.1.1.2 Preliminary Targets for Direct Fuel Injection

The Gambia National Transport Policy (NTP) 2018- 2027, sets the target to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities, and older persons. A number of initiatives are being taken in the transport sector, which include streamlining passenger transportation through improvement in public transport system and pollution prevention in vehicles.

Most of the vehicles registered annually in The Gambia (Table 13 below) are imported second hand, with the average age of vehicles over ten years. Vehicle licensing is under the purview of the Police, and practically all vehicles are licensed irrespective of age of vehicle. The preponderance of over-aged vehicles in the fleet has resulted in low availability and high spare parts requirements as well as environmental pollution. This, compounded by the poor road conditions, would result in high vehicle operating costs. It also raises safety concerns due to poor mechanical inspections facilities for establishing vehicle road worthiness, and environmental issues of pollution.

Clearly, this requires appropriate response from Government in terms of policy support. In this situation where transport operators do not invest enough for fleet renewal, Government can consider incentives (such as tax relief on vehicles, spare parts, technology etc.) to encourage fleet renewal and improved vehicle standard for public service vehicles operators.

Table 13: Registered Motor Vehicles and Motor Cycles – 2005-2015							
Period	**Mini bus**	**Buses**	**Trucks**	**Tractors**	**Cars**	**Motor cycles**	**Total**
2005	615	29	320	26	2,337	2,593	5,920
2006	729	41	187	44	3,100	1,000	5,101
2007	1,650	10	140	26	1,899	1,673	5,398
2008	243	55	213	10	4,832	2,726	8,079
2009	231	11	238	29	2,090	1,130	3,729
2010	436	34	210	15	3,256	2,941	6,892
2011	979	29	93	36	2,948	1,862	5,947
2012	1,065	18	219	15	2,257	2,235	5,809
2013	618	3	71	14	3,630	3,260	7,596
2014	1,194	24	348	59	5,438	11,767	18,830
2015	1,623	35	504	49	6,724	1,820	10,755
Total	**9,383**	**289**	**2,543**	**323**	**38,511**	**33,007**	**84,056**

Source: GBOS, 2017

Given that the road transport system is liberalized, the private sector will be invited to play a role. Government should create incentives to facilitate its entrance into public transportation activities.

As a result of the virtual absence of formal public transport services, the population has come to rely on locally modified vehicles called “gelegele” and mini-vans for public transport in order to reach their places of business, employment, recreation, education and health facilities, etc. Most of the operators of this mode of transport ply routes they deem profitable to them since there is no fixed route allocated to the operators; they can choose to stop their operation any time they feel it is not profitable for them to operate.

Under the transport sector, the Technology Needs Assessment report identified three technologies, namely Direct Fuel Injection, Turbocharger, and Fuel cell electric car. As part of the multi-criteria analysis undertaken in Part I, Direct fuel injection system received the highest priority and was thus prioritized for barrier analysis and possible enabling measures for technology.

With regards to barriers for the technologies mentioned above, possible barriers to implementing include economic and financial barriers, legal and regulatory barriers, technical barriers, network barriers, institutional and organizational barriers, information and awareness barriers, as well as social, cultural and behavioral barriers.

3.1.1.1.3 Identified Barriers for direct fuel injection technology

Identifying barriers is the process of determining the reasons that hinder the transfer and diffusion of technologies. These include the identification of any missing measures that could have sustained the diffusion. For the organization of the barrier analysis process, a sectoral/technology working group representing relevant stakeholders was formed. National consultants have applied a participatory approach for barrier analysis and identification of enabling measures in transport sector.

As an initial step in the process of barrier analysis, a desk study of policy papers and other pertinent documents was conducted in order to identify the primary reasons why the technology is not currently applied widely, and why neither the private nor public sectors have invested significantly in it. Next, a consultation process was conducted with stakeholders through direct interviews and questionnaires.

After compiling a long list of barriers, a stakeholder workshop was organized in order to screen barriers and group them under different categories (economic/financial, policy/regulatory, information, social, technological, capacity building). Potential barriers related to the acceptance and penetration of Direct Fuel Injection technology implementation has been identified in categories as indicated in Table 14 below.

Table 14: Potential Barriers and their Categories

Potential Barriers	**Category of Barriers**
Economic and financial	a. Investment in technology considered risky b. Exchange rate fluctuations c. Poverty- Low affordability amongst rural and peri-urban dwellers d. There is need for financial support
Market conditions	a. Few local suppliers of auxiliary goods and services b. Market control by industry incumbent
Human skills	a. Unskilled technical personnel b. Inadequate training
Social, cultural and behavioral	a. Consumer preferences and social biases, traditions
Technical	a. Few local reference examples and unfocused training
Institutional	a. Inadequate Public private partnerships b. Few professional institutions c. Limited institutional capacity
Policy, legal and regulatory	a. Conflicts of interest b. Inadequate policy for Direct Fuel Injection c. Few/No manufacturers in the country d. Bureaucracy

Network failure	a. Few distribution networks
Information and awareness	a. Inadequate information and awareness of the potential benefits of Direct Fuel Injection

In order to enable stakeholders to approach and delimit a problem area, the Logical Problem Analysis (LPA) tree was applied as an analysis technique. LPA tree helps to create systematic and logical analysis of problems and to bring together all elements of the problem.

Economic and financial barriers

The Problem Tree (AN14 in Annex) provides the causes and effects of the main problem of the None Financial Viability of the Direct Fuel Injection technology in The Gambia. In spite of the fact that the country's economy is in the early development stage, the government has established strategy and programmes for the development of transport sector taking into account its environmental, economic and social advantages. However, at the present time the market for direct fuel injection technology is not economically viable for technology producers/importers, as transportation means whether formal or informal users are accustomed to the use of cheap and affordable.

The current tariff policy and market condition of The Gambia does not create a favorable economic environment, which leads to a decrease in the interest level of private sector in investing in the technology and considering it risky. There are many reasons for low tariff rates: the economy is still in transition phase, GDP per capita and average salary levels are not high, there about 1 million persons living under difficult conditions who are in need of social and economic support from the government, due to the high unemployment rate and dependency. Macroeconomic indicators of the country are improving year-by-year, however at the present time increase in tariff rates is not an expedient step.

High cost of investment and infrastructure is another barrier to the development of the sector. This leads to low interest and lack of initiatives from the private sector. Not having access to low-interest and long-term financial means (loans, credits), the private sector is unable to provide sufficient investment for the development of the technology. Current interest rates in the financial market are high and the private sector does not have access to suitable financial means at local and international market.

Presently, all technology related to direct fuel injection is imported into the country, as there is no local production of the technology. This leads to high prices and high investment costs, which impede large private sector investments in the sector.

Capacity of local institutions dealing with tertiary education as well as research and development activities is low and does not meet up-to-date requirements. This is mainly due to the lack of

public financing and insufficient fiscal support to institutions. As a result, technical capacities of institutions are underdeveloped. Consequently, private sectors are obliged to apply to international institutions providing relevant services, which are relatively expensive.

Based on the results of market mapping analysis it could be assumed that the number of market players in the current direct fuel injection technology market is low, as existing market opportunities do not provide suitable conditions for involvement of other key players (input suppliers, business service and technical service providers) to the market chain. Along with this, business extension services (research development, financial services, market information, input suppliers and so on) are very weak and almost non-functional in the market chain. Enabling environment also does not provide suitable opportunities for development of local market for technology diffusion.

Non-financial barriers

Non-financial barriers to deployment of direct fuel injection are analyzed into the following categories. All these categories are linked to the Problem Tree on Enabling Environments shown in AN15 in the Annex at page 65 to this report.

Policy/regulatory barriers: The country has recently validated the National Transport Policy 2018 - 2027 and clear strategy regarding the development of transport sector, including road user and vehicles. Notwithstanding that, regulatory actions from the government are necessary in order to support the development of the sector including regulations on consumption of new technologies such as direct fuel injection. Currently, there is no mechanism for the application of direct fuel injection. Policy/regulatory barriers also include regulations on tax discounts or exemptions for local producers, in order to promote investments in this sector. Tax exemptions will make the sector more attractive for private sector and lead to increase of investments in sector development. Lack of coordination and information between relevant institutions and agencies is another barrier.

Technical barriers: In The Gambia there is no initiative for production of direct fuel injection in the country and no investments provided for construction of facilities. Current conditions are unsuitable for research institutions to provide necessary research in this field. Non-compliance to standards and certification is another important barrier to the deployment of this technology in The Gambia. Standards for direct fuel injection have not yet been identified and the certification mechanism is not in place. Lack of qualified specialists in this field is also an important barrier. Presently the technology is little known or use, but the assessment shows high potentials due to the age and nature of the fleet of commercial vehicles plying the road networks of the country.

Capacity building/information barriers: One of the important barriers to the implementation of the technology is weak capacity and inadequate information for consumers on use and

advantages of the technology. The same could be said for local authorities, state and private organizations. Weak access to information on current opportunities in the direct fuel injection, as well as on advantages of technology application could be mentioned as another barrier.

Social barriers: Unfamiliarity with the new technology could be mentioned as a social barrier to application of the technology. Local populations are accustomed to traditional vehicles and, for the most part, are not interested in replacements, as current costs of buying are fairly high.

3.1.1.1.4 Identified measures for Direct Fuel Injection

Identifying relevant measures is the process of analyzing necessary actions to be taken in order to overcome current barriers to the implementation of prioritized technologies. These measures should be such that they remove the barriers identified and discussed under section 3.1.1.1.3 above and should be able to sustain the diffusion of the direct fuel injection technology.

For the identification of relevant measures, detailed analysis of current practices at national and international level was provided. National consultants have applied a participatory approach during the analysis by involving a wide range of stakeholders in the process. The same procedure was applied for identification of measures. Measures have been indentified based on grouped barriers. The Solution Tree (ANA16 in Annex) was applied in the identification process of measures that will lead to the financial viability of Direct Fuel Injection technology. Current measures for development of direct fuel injection were also taken into account during the process.

Economic and financial measures

In order to overcome existing economic and financial barriers to the implementation of direct fuel injection technology, the following measures should be provided:

- Current market in direct fuel injection systems should be supported and production/import of technology and other necessary equipment should be promoted by the government through different subsidy mechanisms (such as tax discounts/exemptions). Promoting local production of technology will lead to decrease in technology prices and investment costs;
- Technology is not cost-effective at current tariff rates. Relevant economic regulations, such as regulations of tariff system, should be provided in order to promote investments in the sector. Market oriented tariff systems will make the sector attractive for private sector investors;
- Government should support the investors in this field by providing long-term and low-interest loans through different state funds (for instance, State Fund for Support to Entrepreneurship functioning within the Ministry of Trade, Investment and Employment), private sources (different Banks) and international funds (GEF, UNEP,

and ENDA). Having access to affordable financial means, the private sector will be able to provide large and long-term investments to the sector.

Non financial measures

In order to overcome existing non-financial barriers to the implementation of direct fuel injection technology, and based on representation in AN17 in the Annex, the following measures should be adopted.

- ✓ Necessary regulatory actions must be provided by the government in order to create a mechanism for consumer use of direct fuel injection, including tariff regulations;
- ✓ Capacity building for research institutions by involvement in different trainings or study tours with the support of government and other international funds in order to improve their skills and capacities;
- ✓ Strengthen international research network programmes in order to learn from best international practices;
- ✓ Information campaigns on the advantages of applied technology must be organized and funded in order to increase capacity of consumers (local residents, local authorities and private sector), by involving NGO sector in the process;
- ✓ Organize specific capacity building activities for private sector representatives and local communities in order to increase capacities and awareness level on advantages of transport system technologies;
- ✓ Organize study tours to other countries by involving representatives of local authorities, local communities, private sector and NGOs, in order to increase awareness level and demonstrate practical application of the technology.

These measures will result in increase in private sector initiatives in the direct fuel injection system. Moreover, consumers, local communities, municipalities, and private sector will start wide application and promotion of penetration of the technology.

3.1.2 WIND TURBINE TECHNOLOGY

3.1.2.1 Barrier Analysis of Wind Turbine Technology

3.1.2.1.1 General description of Wind Turbine Technology

A wind turbine is a device that converts the wind's kinetic energy into electrical power. The term appears to have been adopted from hydroelectric technology (rotary propeller). The technical description of a wind turbine is aerofoil-powered generator. As a result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply

while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels. Wind was shown to have the "lowest relative greenhouse gas emissions and highly eco friendly, the least water consumption demands and the most favorable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas.

A wind turbine installation consists of the necessary systems needed to capture the wind's energy, point the turbine into the wind, convert mechanical rotation into electrical power, and other systems to start, stop, and control the turbine. In addition to aerodynamic design of the blades, design of a complete wind power system must also address design of the hub, controls, generator, supporting structure and foundation.

The speed at which a wind turbine rotates must be controlled for efficient power generation and to keep the turbine components within designed speed and torque limits. The centrifugal force on the spinning blades increases as the square of the rotation speed, which makes this structure sensitive to over speed. Because the power of the wind increases as the cube of the wind speed, turbines have to be built to survive much higher wind loads (such as gusts of wind) than those from which they can practically generate power. Wind turbines have ways of reducing torque in high winds.

A wind turbine is designed to produce power over a range of wind speeds. The cut-in speed is around 3–4 m/s for most turbines, and cut-out at 25 m/s. If the rated wind speed is exceeded the power has to be limited. There are various ways to achieve this.

All wind turbines are designed for a maximum wind speed, called the survival speed, above which they will be damaged. The survival speed of commercial wind turbines is in the range of 40 m/s (144 km/h, 89 MPH) to 72 m/s (259 km/h, 161 MPH). The most common survival speed is 60 m/s (216 km/h, 134 MPH). Some have been designed to survive 80 meters per second (290 km/h; 180 mph).

The modern wind turbine is a complex and integrated system. Structural elements comprise the majority of the weight and cost. All parts of the structure must be inexpensive, lightweight, durable, and reproducible, under variable loading and environmental conditions. Turbine systems that have fewer failures, require less maintenance, are lighter and last longer will lead to reducing the cost of wind energy.

Wind turbines need regular maintenance to stay reliable and available; in the best case turbines are available to generate energy 98% of the time. And as technology needed for wind turbines continues to improve, the prices will decrease as well. In addition, there is no competitive market

for wind energy, as it does not cost money to get a hold of wind. The main cost of wind turbines is the installation process. The average cost is between $48,000 and $65,000 to install. However, the energy harvested from the turbine will offset the installation cost, as well as provide virtually free energy for years after.

Wind turbines provide a clean energy source, emitting no greenhouse gases and no waste product. Over 1,500 tons of carbon dioxide per year can be eliminated by using a one megawatt turbine instead of one megawatt of energy from a fossil fuel. Being environmentally friendly and green is a large advantage of wind turbines.

3.1.2.1.2 Preliminary Targets for Wind Turbine Technology

The National Energy Policy was launched in June 2005. It defines broad policy objectives and strategies, including those for rural electrification and renewable energy. It contains objectives for electricity which encompass improving and expanding the generation, transmission and distribution of electricity, reducing the cost of electricity, encouraging investment in the supply of rural electricity, and encouraging the use of alternative technologies (Ministry of Energy, 2005). In the renewable energy subsector, the policy promotes the use of renewable sources of energy and encourages the use of renewable energy technologies and the development of a domestic production capacity. The policy also seeks to ensure a sustainable supply of technologies at competitive prices in the private sector.

Furthermore, the new energy policy highlights the importance of energy in meeting SD goals. The Policy prioritizes rural electrification and promotes the use of renewable energy resources such as wind and solar for electricity generation, particularly in the rural areas. The Policy includes a target of achieving at least 30 per cent renewable energy generation capacity by 2018. From information from the population census of 2003, the population is estimated at 1.36 million and was growing at the rate of 2.74% per annum. With this growth rate, the population by the year 2011 is estimated to reach 1.79 million.

The Gambia is confronted with both infrastructural and financial constraints in providing grid connectivity to rural and remote areas. Electricity in the country is quite expensive: regional benchmarks suggest that electricity tariffs in The Gambia are quite high for both residential and commercial users. In the regional context (West Africa), the country has the highest electricity tariffs for domestic (credit metering) customers, at US$0.24 per kWh (PURA, 2012). During times of high international oil prices and unfavorable foreign exchange rates, which are beyond the control of government institutions, the regional power stations operate for limited hours and on a day to-day basis. The regional grids experience constant challenges in operating and carrying out necessary equipment maintenance (SE4All, 2012).

Wind turbines are not very prevalent in The Gambia. The Ministry of Water Resources indicated that the European Union funded some wind pumps along the coastal villages in the early 1990s. The pilot systems were installed in Brufut, Tanji and Batakunku by the Atlantic Coast. However, none of these systems are currently working, with most of the systems abandoned and rusting. Many more wind pumps are currently in use in the country but they have been private projects mostly on private farms (see Figure 8).

Figure 8: Typical wind pump system

The Gambia has some potential to tap renewable energy sources that are in widespread use in countries around the world such as wind, solar, hydro, biogas, biomass, and geothermal. While most of these technologies show reasonable potential based on the limited information available, further detailed studies would be required to definitively determine the most economical solutions.

Energy access is a priority area in national development policies because it is a crucial component of sustainable development. The current baseline scenario affects sustainable development in two ways: first, because of the technologies that it currently uses; and second, because of a lack of reliable energy access.

3.1.2.1.3 Identified Barriers to Wind Turbine Technology

Economic and financial barriers

A Problem Tree analysis (AN18 in Annex) of the economic and financial barriers that are responsible for the low penetration of wind energy in The Gambia. The barriers are as follows:

- High initial capital cost of wind turbine equipment and their operations and maintenance, high and variable fluctuations in the costs of equipment causing investors and local developers to lose interest in the technology. This high initial cost is compounded by the following sub-barriers.
  - Limited access to loans, high interest rates
  - Low market competitiveness and returns

- Insufficient incentives and subsidies
- Non-operational Carbon credit
- High transaction cost due to high import duties on wind power products. Investors have limited involvement in research and studies on wind energy
- Local industry and manufacturing of wind technologies and related equipment are inexistent and this contributes to barriers such as:
- Limited information on grid connected wind power
- Unfamiliarity with private mini grid
- Inadequate awareness of wind power
- Limited human skills in wind power opportunities

These barriers responsible for the low penetration of wind as a source of energy, particularly electricity in The Gambia are resulting to increased use of fossil fuel for power generation and thus increased emissions of greenhouse gases into the atmosphere. Electricity bills remain high as all the fossil fuel used for electricity generation is imported. Also, current incentives for new investments are low. Consequences also include continuous use of woods fuels and large-scale deforestation. The deployment of large wind turbine system is also limited by the inexistence of pilot projects for further demonstration beyond the phase of research and development. One of the adverse impacts is the limited diversification of electric energy sources in Gambia and low exploitation of such a clean resource.

Non-financial barriers

The critical non-financial barriers identified for large scale wind power to support the national grid are:

(i) the lack of updated information on wind power potential;
(ii) limited capacity (institutional and technical);
(iii) monopoly of transmission and distribution of electricity;
(iv) a limited policy framework driving the renewable energy sub-sector;
(v) lengthy negotiation process for inter-connection to the national grid due to the lack of experience, procedures to guide the negotiation process; and grid readiness to accept investment and other sources of energy;
(vi) inadequate policy incentives to encourage private sector investments to establish large scale wind turbines across the country; and
(vii) absence of a strong legal framework to support interconnection to the national grid.

The schematic Solution Problem Tree (AN19 in Annex) shows the process to support the analysis of the non-financial barriers.

3.1.2.1.4 Identified measures to improve acceptance of Wind Turbine Technology

The measures for overcoming barriers to the adoption and diffusion of wind turbine technology were identified through stakeholder consultation, desk review, and review of relevant policy documents, expert knowledge and analysis using objective trees for each barrier according to Boldt et al. (2012). The identification of measures for both economic and financial and non-financial barriers is discussed below.

Economic and financial measures

In order to overcome existing economic and financial barriers to the application of wind turbines technology (see AN20 in Annex), the following measures are proposed:

1. Specific National Action Plans should be developed to enhance application of wind power generation technology;
2. Develop specific subsidy mechanism for private sector to enhance application of wind power technology;
3. Provision of long-term and low-interest loans through different state funds, private sources (different Banks) and international funds (World Bank, GEF, UNEP) to support the application of wind turbines.
4. For Real-time durability component - allocating maintenance budget for the devices and supporting locally-developed devices/research works.

Non financial measures

In order to overcome existing non-financial barriers to the implementation of wind turbines technology, the following measures (also see AN21 in the Annex) could be proposed:

1. Support research institutions in providing assessment on identification of potentialities and sustainability of wind power generation system;
2. Information campaigns to raise public awareness on the advantages of applied technology;
3. Support capacity building activities for technology development and transfer;
4. Improve legislative and regulatory reforms to stimulate the application of the technology;
5. Develop support policies (specific subsidy mechanism) to encourage local deployment of the technology;
6. Implementation of pilot projects at municipal or community level to demonstrate the advantages of the technology.

3.2 WASTE SECTOR

3.2.1 Landfill Technology

3.2.1.1 Barrier Analysis of Landfill Technology

3.2.1.1.1 General description of Landfill Technology

The term “sanitary landfill” is too often used to refer to a solid waste operation that is little better than an open dump. Actually, sanitary landfill means an installation where a satisfactory, nuisance-free solid waste disposal operation is being carried out in accordance with recognized standard procedures. The operation of a sanitary landfill requires skill and knowledge. It is a scientific method and should be treated as such. Engineering and planning is needed to operate a satisfactory sanitary landfill.

Sanitary land filling is a method of disposing of solid waste on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the solid waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at more frequent intervals as may be necessary.

Useful life of the sanitary landfill is a major consideration. One of the common difficulties experienced by municipalities is the early exhaustion of disposal sites and the absence of ready alternatives of additional land for solid waste disposal. The useful life of a site comes down to the question of sound planning and good operation, which in combination allow full development of site capacity. There are basically two methods of operating a sanitary landfill; the area method and the trench method. The method selected will depend upon subsurface conditions, drainage, and topography of the land.

In Area Landfill, the solid waste is placed on the land; a bull-dozer or similar equipment spreads and compacts the waste; then the waste is covered with a layer of earth; and finally the earth cover is compacted. The area method is best suited for flat areas or gently sloping land, and is also used in quarries, ravines, pits, or where other suitable land depressions exist. Normally the earth cover material is hauled in or obtained from adjacent areas.

In Trench Landfill, a trench is cut in the ground and the solid waste placed in it. The waste is then spread in thin layers, compacted, and covered with earth excavated from the trench. The trench method is best suited for flat land where the water table is not near the ground surface. Normally the material excavated can be used for cover with a minimum of hauling. A disadvantage is that more than one piece of equipment may be necessary.

3.2.1.1.2 Preliminary Targets for Transfer and Diffusion of Landfill Technology

Solid waste operations overlap in built-up areas, and municipalities are becoming involved with neighbouring communities. The cost and complexity of disposal methods raise the question of municipal cooperation in order to achieve economies. Development of common disposal sites is often indicated as a matter of mutual benefit.

State health authorities have recently established standards for solid waste disposal practice. This added dimension of official state interest is having an impact on prevailing methods of disposal and will affect the decisions of local officials with regard to pending and future policies for solid waste collection and disposal.

About 120,000 households, institutions and commercial enterprises are targeted for diffusion of the technology up to Gambia's development plan and Vision Year 2030. With 5 persons per household a total of 600,000 persons will have access to the technology. The expected demand will attract about 200 companies distributed across the country and about 1000 maintenance technicians and 100 suppliers of the process.

3.2.1.1.3 Identified barriers for Sanitary Landfill technology

The problem of designing the most economical solid waste collection and disposal program for a rural or urban area has become increasingly complex in recent years. The problem mounts each year because of several trends: population growth, new home construction, increased industrial activity, shortage of disposal sites, and a significant increase in the production of solid waste resulting from modern packaging and consumer consumption.

Population increases have resulted in solid waste problems in communities where previously no service was provided and where there has been little or no recognition of municipal responsibility. Municipalities with established solid waste collection and disposal services have found that community development means new problems. As growth presses to a municipality's borders and vacant land is developed, adequate solid waste disposal sites become less readily available. Frequently, existing methods must be improved or an entirely new system adopted.
In addition, poor management of the sector is due to a large extent to inadequate capacity of municipalities to address the problem. Urgent financial and human resources development, together with a substantial financial investment, is required to improve the sector.

Economic and financial barriers

Availability to attract financial resources is a prerequisite for the introduction of Environmentally Sound Technology (EST), due to the fact that the provision of design conditions and

achievement of the parameters and quantities of waste management demand will require a strong capital investment and time. Consequently, the high rate of interest (business loans offered by the local banks are within high scope) severely complicate the implementation of projects with technology involved. High transaction cost and transportation also complicate the issue as well as define duties and taxes that lead to the rise of additional costs. These barriers are indicated in AN22 in the Annex.

Non-financial barriers

In AN23 of the Annex, serious obstacles for the introduction of sanitary landfills is based on lack of skilled technical personnel for construction and maintenance as well as low awareness of the benefits of sanitary landfill as sources of reliable and clean energy. In addition, lack of proper policy to guide the process and absence of a strong legal framework to support.

3.2.1.1.4 Identified measures to adopt Landfill Technology

Identifying relevant measures is the process of analyzing necessary actions to be taken in order to overcome current barriers to the implementation of prioritized technologies. These measures should have sustained the diffusion.

Economic and financial measures (see AN25 in Annex) include:

- Reduce construction costs: The government will give waiver on import duty and other taxes on all the components that will be imported for the purpose of construction and operation and maintenance of sanitary landfills.
- The justification will be based on environmental and health benefits and poverty reduction among the small local communities.
- Reduce interest rates: The financial institutions will form partnership with the government to provide low interest loans for development of sanitary landfills in order to promote environmental conservation.
- Reduce maintenance costs: The government will give tax waiver to components that will be manufactured locally or imported for the purpose of maintenance of sanitary landfills.

Non financial measures (see AN25 in the Annex).

- **Make available skilled technical personnel:** Technical training institutions in the country will develop customized training courses for technicians who will undertake construction and maintenance of the solid waste management facilities.
- **Implement training and public awareness campaign for users**
  The responsible institutions within the government and municipalities, in collaboration with research centres and construction companies will conduct training and public awareness campaigns for households on the operation and maintenance of the sanitary landfills. The public awareness campaign will include explaining the benefits of solid waste management on the environment and health particularly for the benefits of our children.

- **Establish market links for sanitary landfills:** Market links will be developed within the households and between the households and the technology suppliers towards increasing the demand for the solid waste management products such as manure or energy.

Cost benefit analysis, evaluation of cost benefit ratio, payback period and net benefits were conducted to determine the viability of the measures and the technology as a whole. Table 15 below shows the results of the evaluation.

Table 15: Results of the CBA for Solid Waste Landfill

Type of technology	Benefit Cost Ratio (BCR)	Length of time (payback period)	Net Benefits
Existing Technology (randum dumping)	0.8250	1.2121	-35000
Adopting Technology (landfill)	1.1000	0.9091	55000

NPV values for Selected Technology

Year	Discount Rate	(Random dumping)	sanitary landfills
1	**0.01**	**-34653**	**54455**
2	**0.01**	**-34310**	**53916**
3	**0.01**	**-33971**	**53382**
4	**0.01**	**-33634**	**52854**
5	**0.01**	**-33301**	**52331**
6	**0.01**	**-32972**	**51812**
7	**0.01**	**-32645**	**51299**
8	**0.01**	**-32322**	**50792**
9	**0.01**	**-32002**	**50289**
10	**0.01**	**-31685**	**49791**
11	**0.01**	**-31371**	**49298**
12	**0.01**	**-31061**	**48810**
13	**0.01**	**-30753**	**48326**
14	**0.01**	**-30449**	**47848**
15	**0.01**	**-30147**	**47374**

From NPV values in Table above, it is evident that landfill technology is highly beneficial to the communities financially and is also beneficial for environmental conservation, and health. If more financial and technical assistance are made available the technology can be diffused to many more households resulting in even greater local and global benefits. Furthermore it contributes to global efforts to mitigate climate change

3.3 LINKAGES OF THE BARRIERS IDENTIFIED

The Mitigation Technologies (Direct Fuel Injection, Wind Turbines, and Sanitary Landfills) have common barriers applicable to all and include:

- Investment in technology considered risky because of non-availability of resident suppliers of auxiliary goods and services;
- Market control by industry incumbent
- Unskilled technical personnel and inadequate facilities for training;
- Weak research and demonstration of the technologies nationwide as the private and business sector entities have limited involvement in research and studies on these energy sources and technologies;
- High transaction cost due to high import duties on direct fuel injection, wind power and sanitary landfill products;
- Local industry and manufacturing of the energy mitigation technologies and related equipment are inexistent leading to limited expertise and information on grid connected power from wind and sanitary landfills; inadequate familiarity with private mini grid

The technologies also have common benefits of mitigating greenhouse gas from the energy sector and the national economy, contributing to the betterment of the health status and creating employment of the citizens.

3.4 ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS

Based on the common barriers to the penetration of the mitigation technologies assessed in this report, the following enabling environments are required for the promotion, diffusion and adoption of the technologies. The mitigation technologies reported here, while not currently pronounced due to comparable low emissions, will need more financial resources in the medium- to long-term period. The government will need to continue drawing down public resources, making public investments work better and initiating innovative financing mechanisms to leverage private sector investment into climate change mitigation technologies and projects. The government will need to allocate a larger part of the national budget to climate change financing which must be coordinated, managed and administered through the Gambia Climate Change Fund (GCCF), as the conduit for international aid financing. The creation of a suitable enabling environment will improve the financial allocation and flows to the energy and waste management sectors, improve the entrepreneurship of communities and business entities and the provision of support and more logistics at the local levels for the assumption of ownership of the technologies. The overall economy may become stable based on the suggested financial measures (low interest rates, favourable import duties and tax relief incentives) for the importation and supply of equipment and materials for the diffusion of the technologies will reduce costs considerably and encourage private participation in delivery, diffusion and uptake of these technologies.

3.5 REFERENCE

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ANNEX

Problem and Solution Trees used in the Barrier Analysis and Enabling Measures

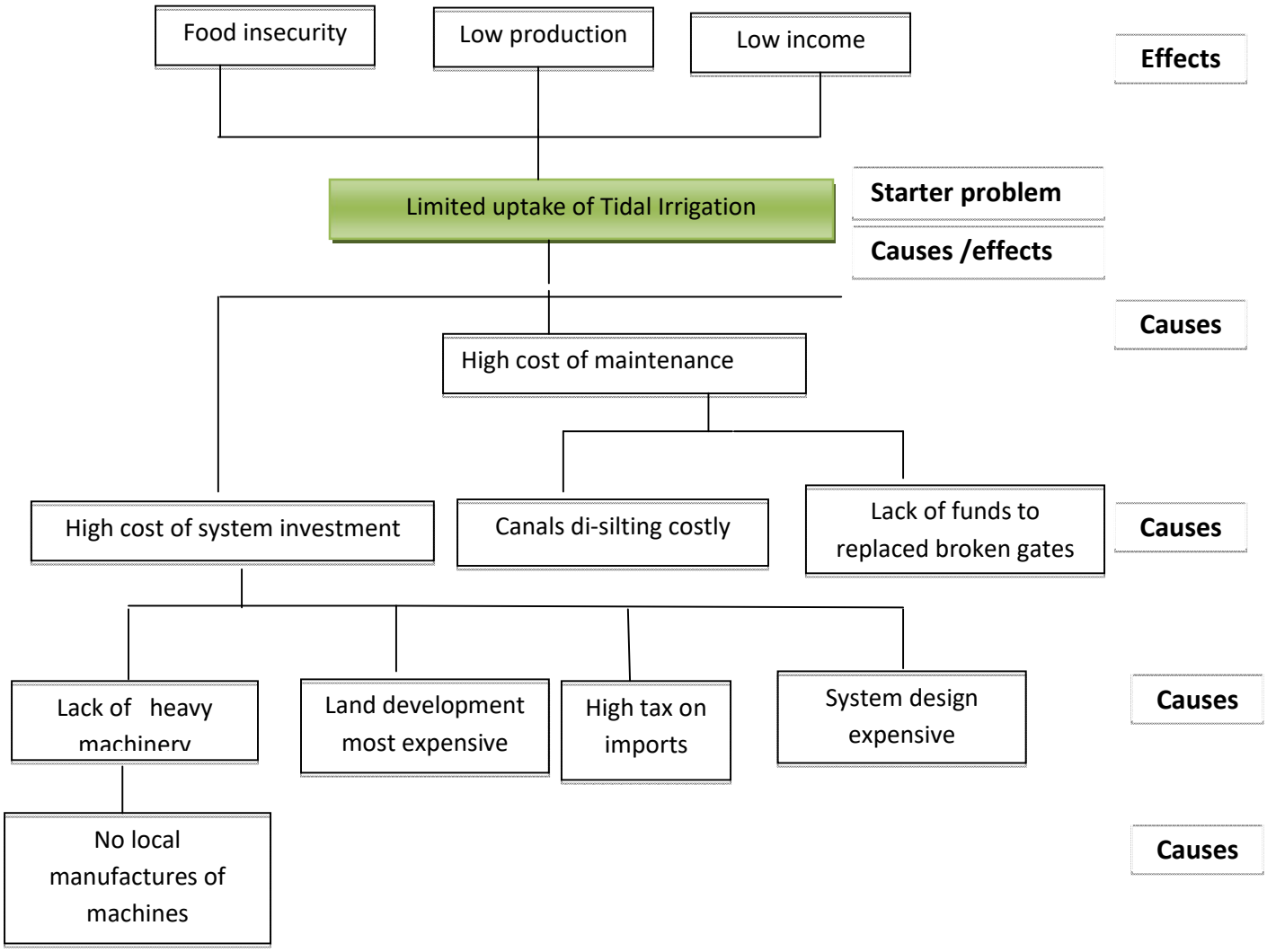

Figure AN1: A Problem Tree for economic and financial barriers on Tidal Irrigation

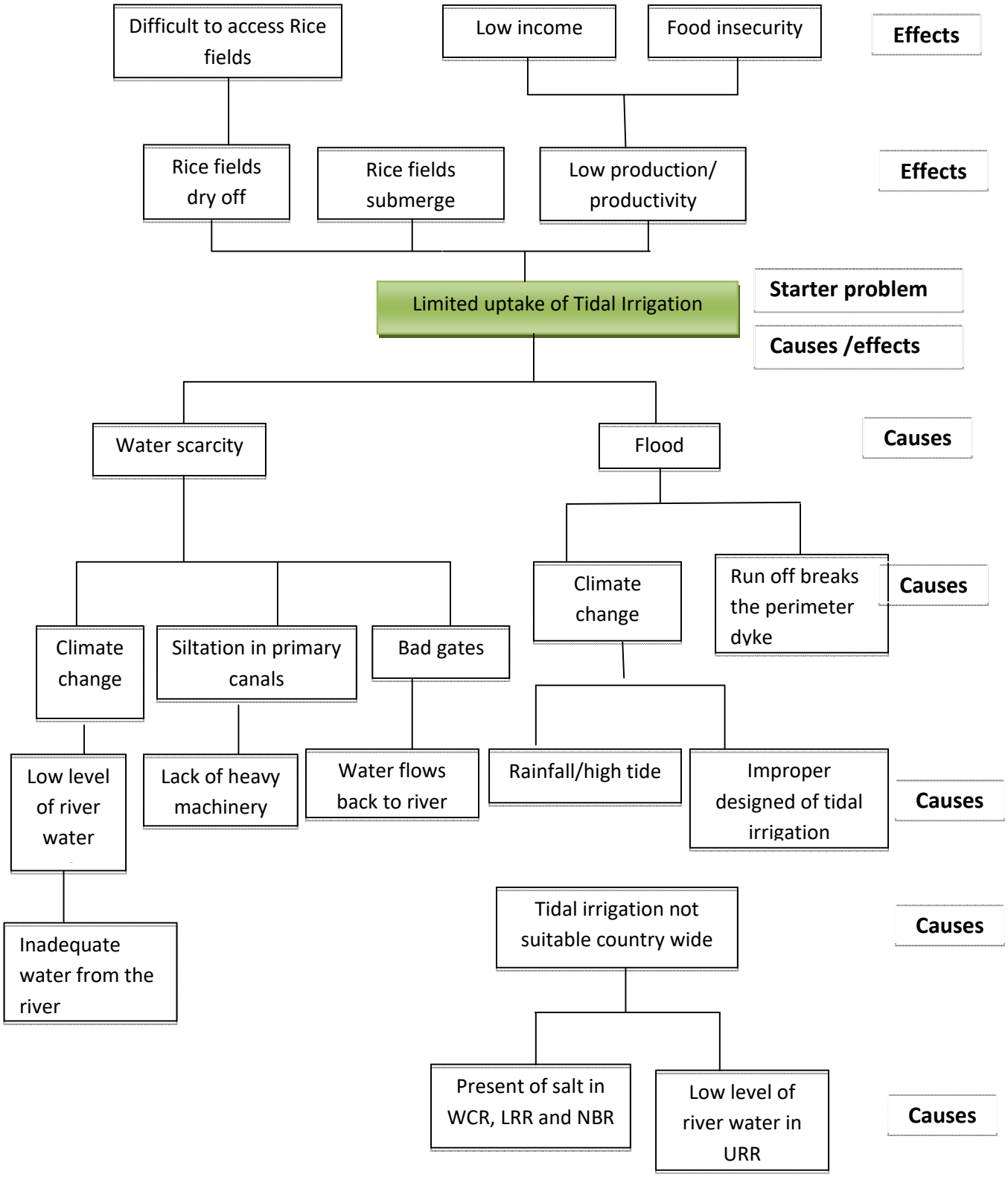

Figure AN2: A problem tree for non- financial of Tidal Irrigation

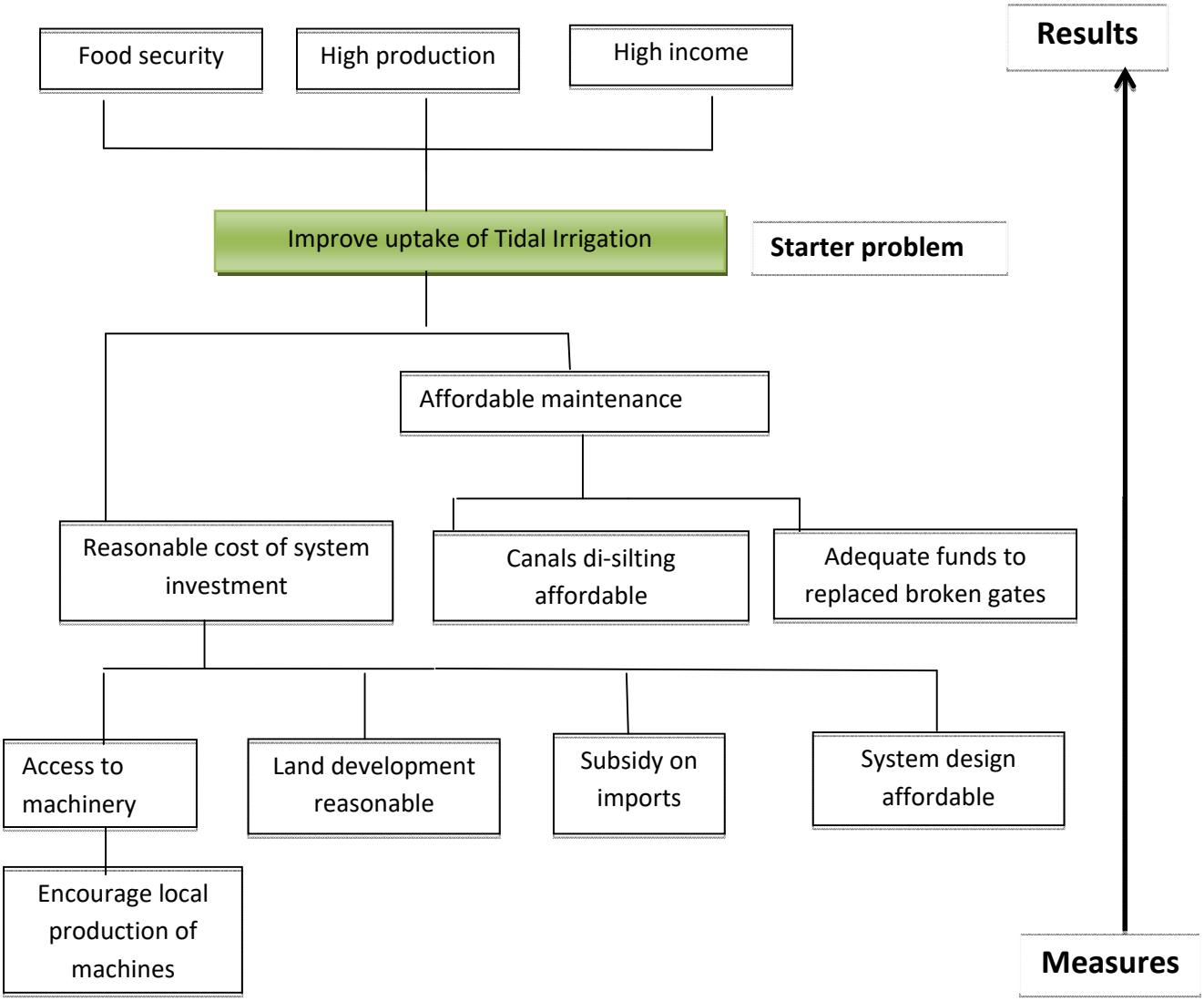

Figure AN3: A Solution tree for economic and financial measures of Tidal Irrigation

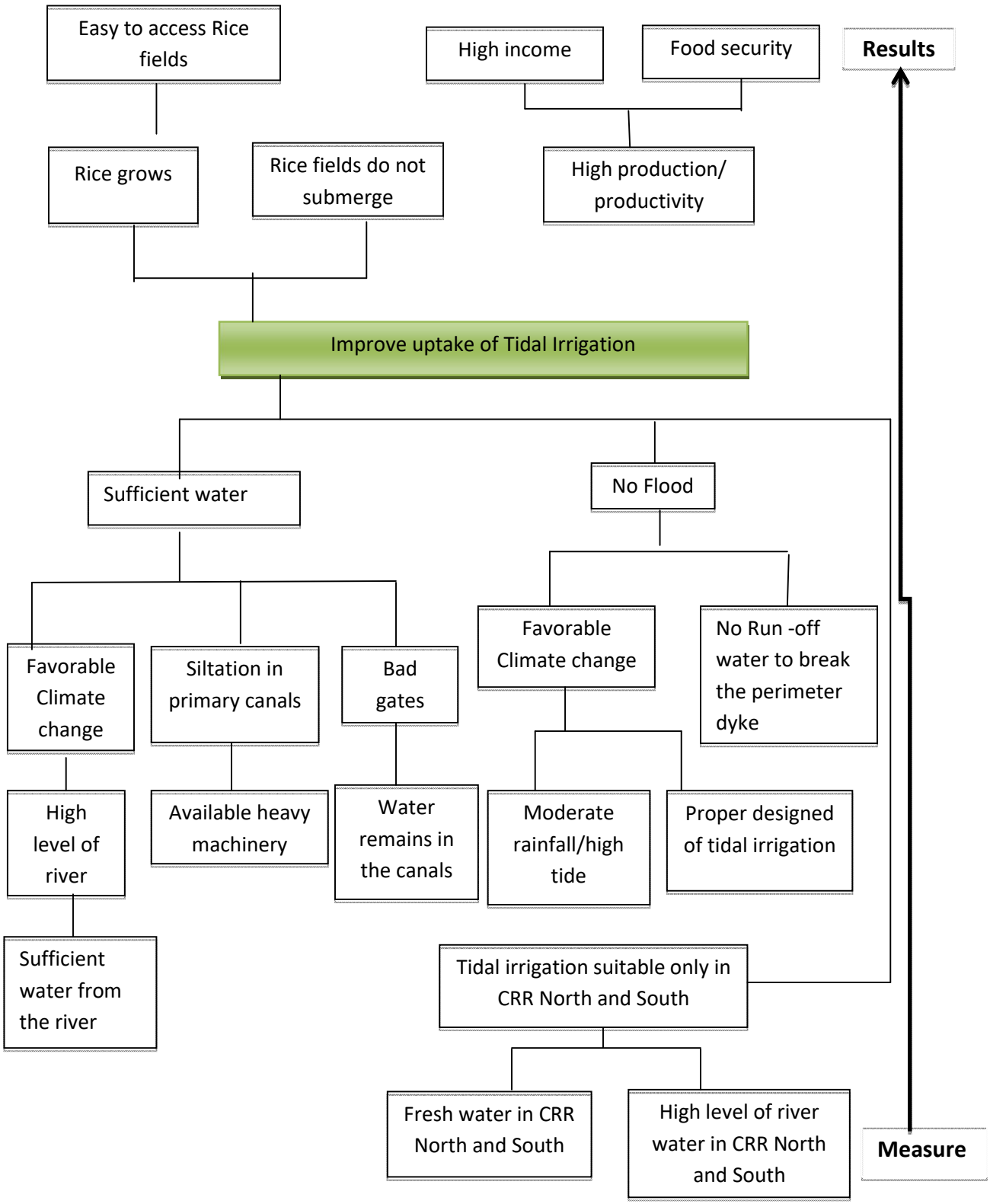

Figure AN4: Solution tree for non- financial of Tidal Irrigation

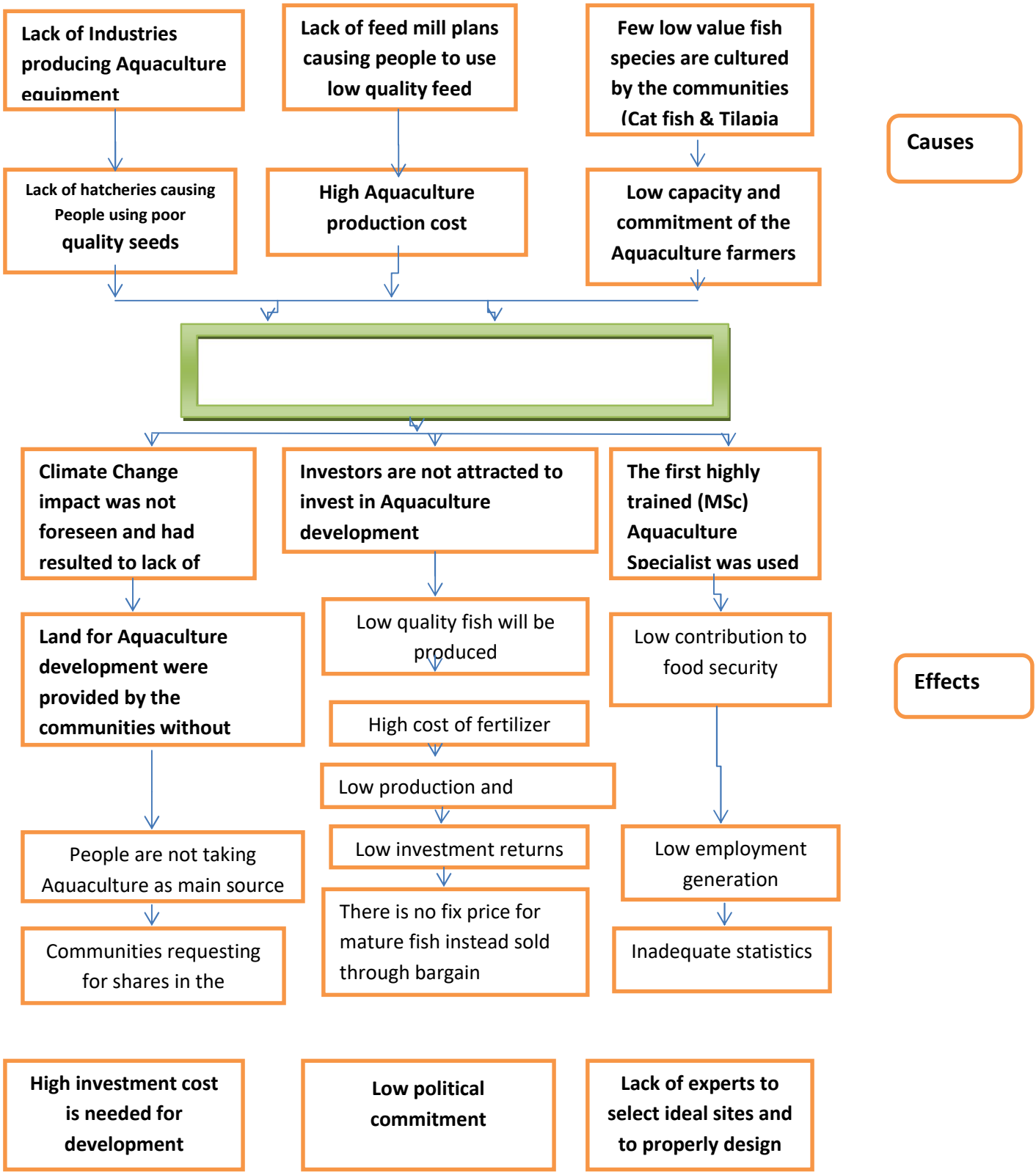

Figure AN5: Problem Tree for the assessment of barriers, causes and effects of Low Penetration of Aquaculture

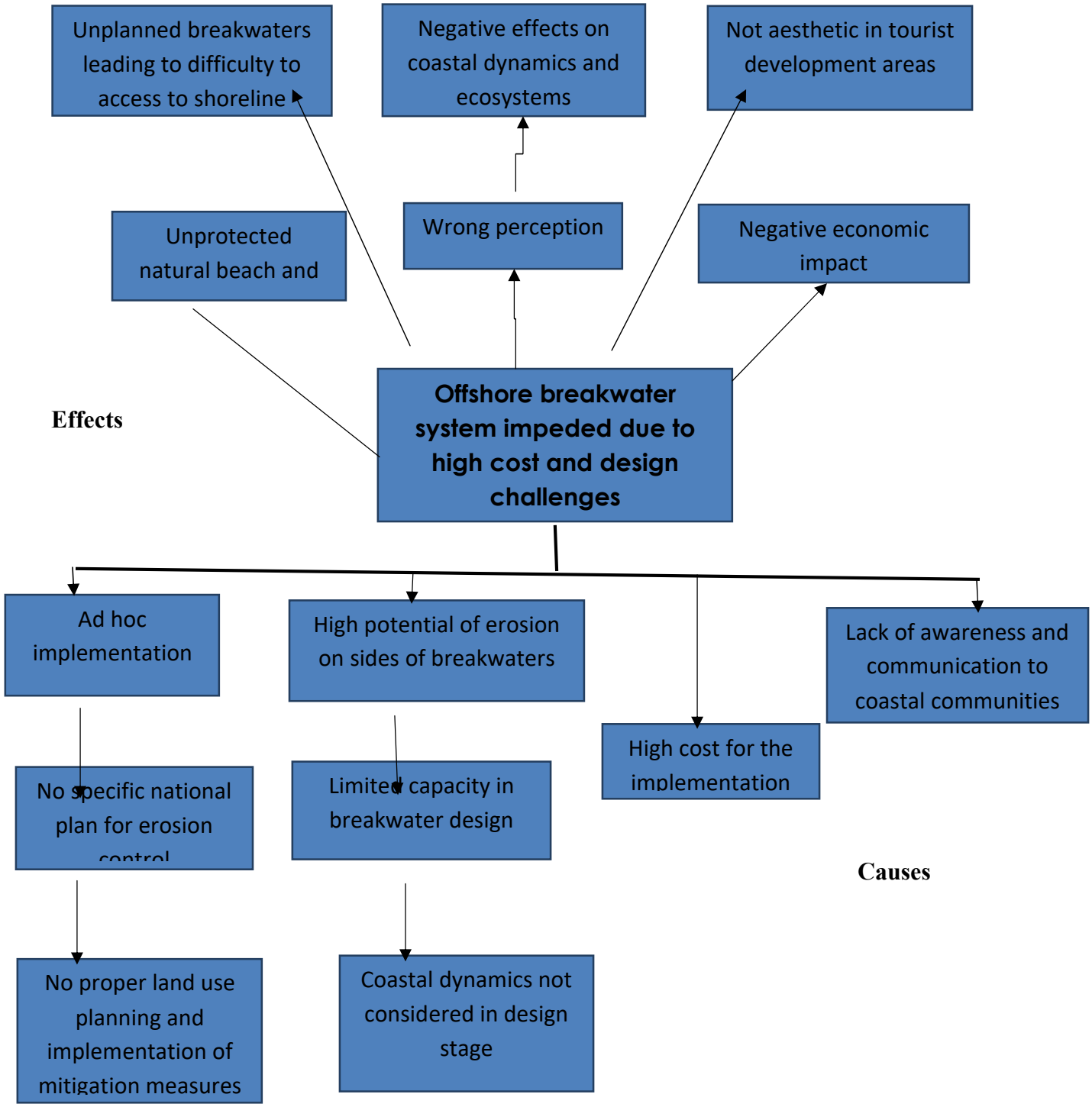

Figure AN6: Problem Tree for analysis of Barriers related to Breakwater Systems

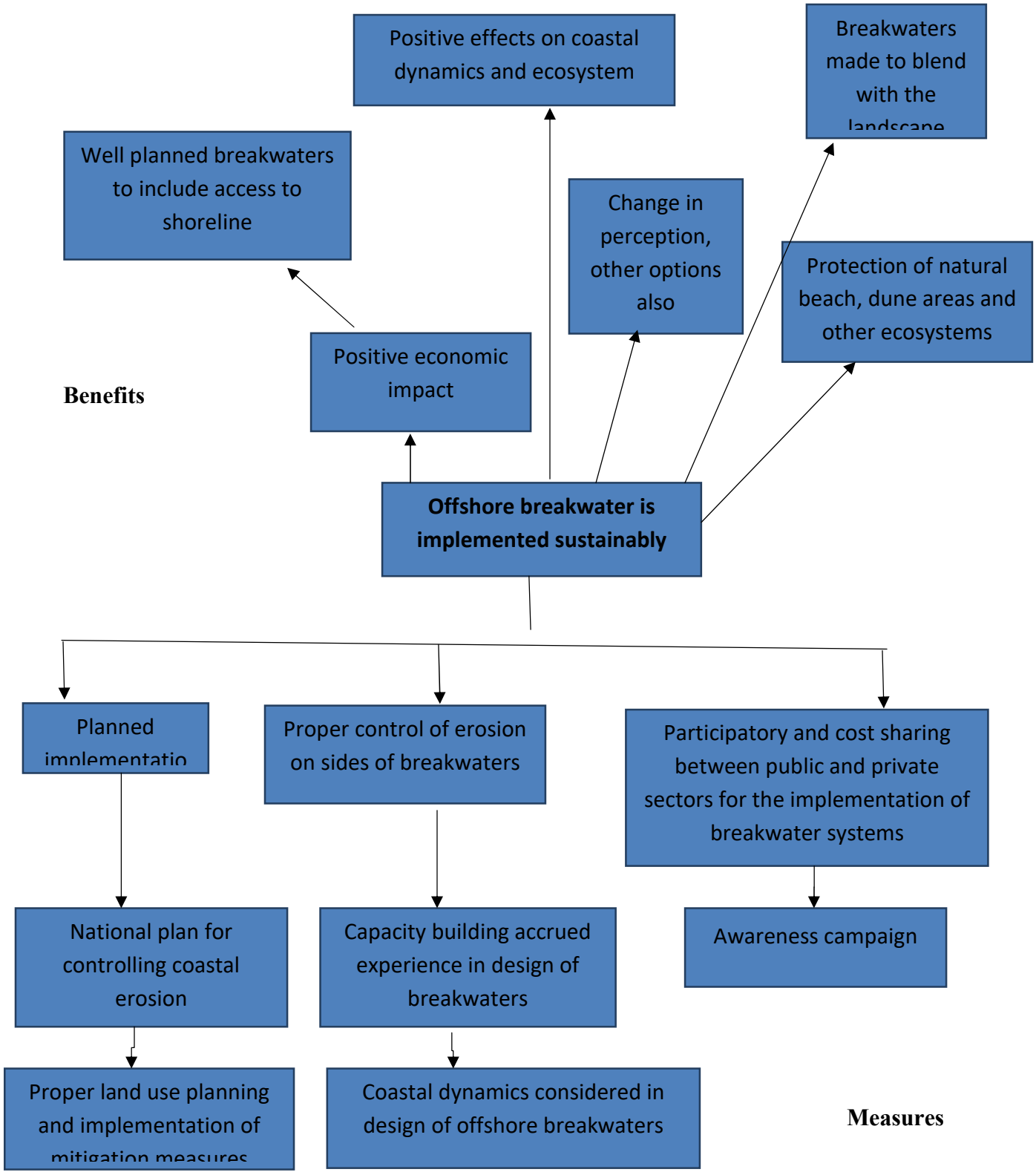

Figure AN7: Solution Tree determining Measures for adoption of Breakwater Systems

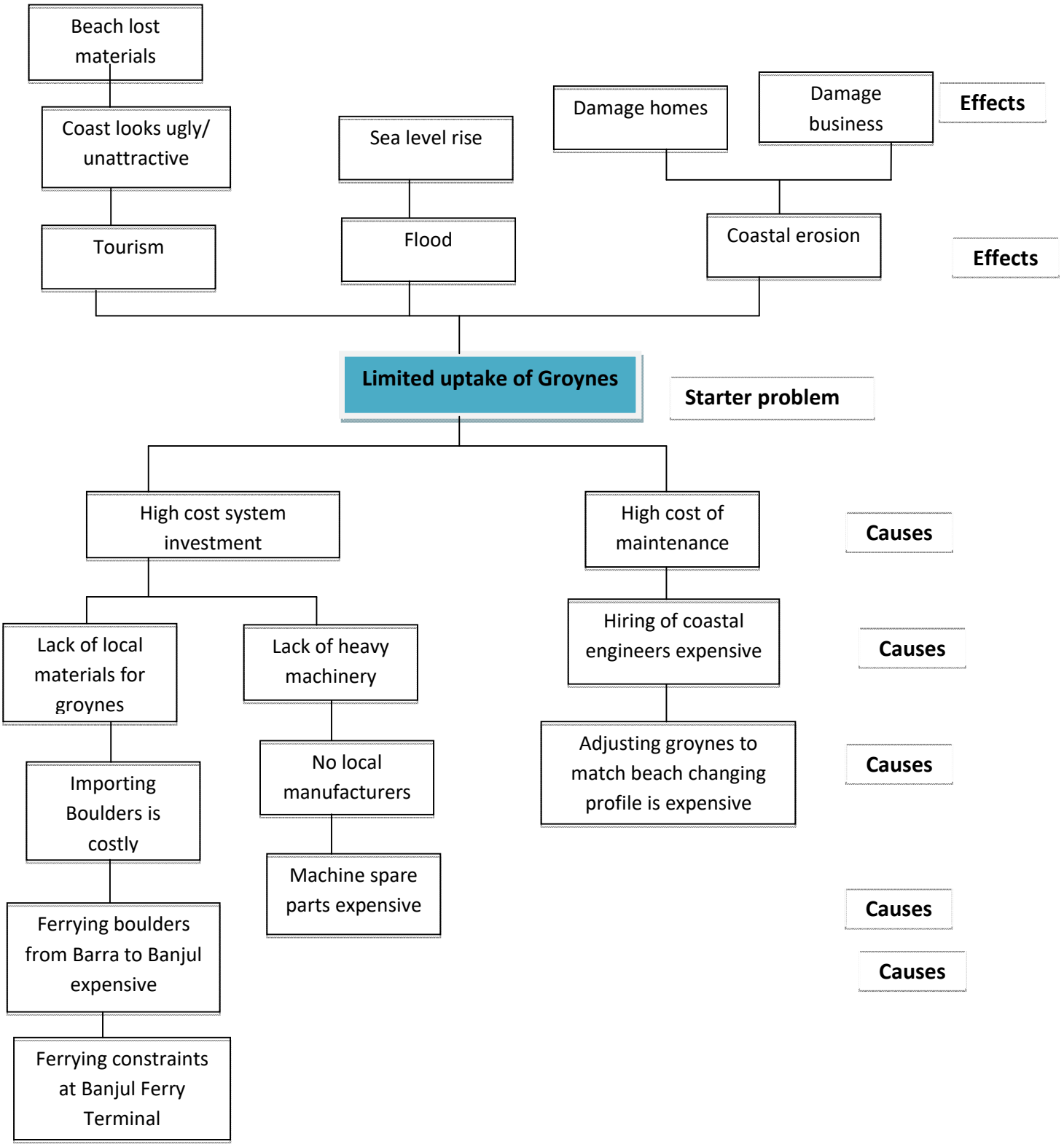

Figure AN8: Problem Tree used to identify Financial Barriers related to Groynes

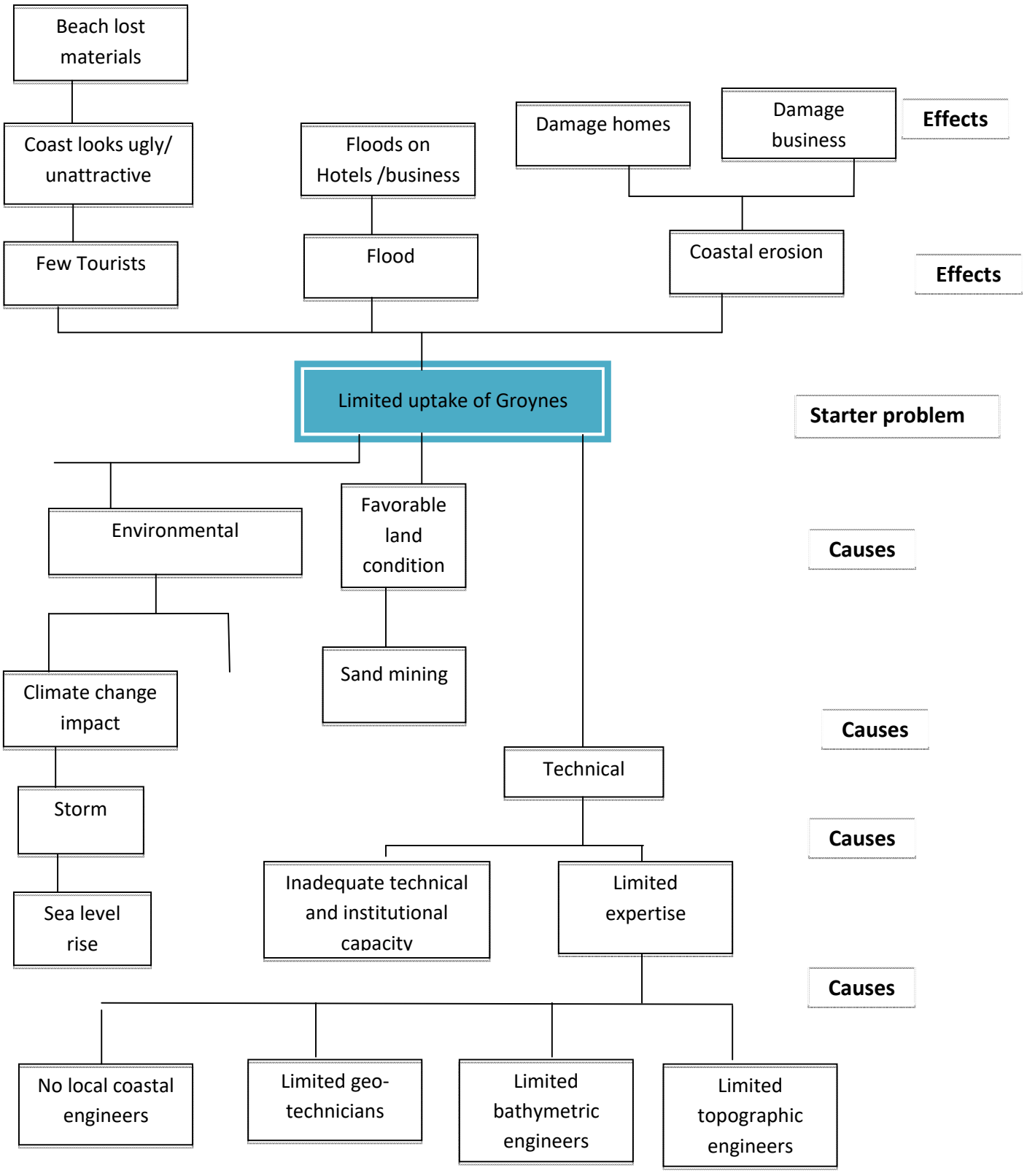

Figure AN9: Problem Tree to determine non-financial barriers to Groynes

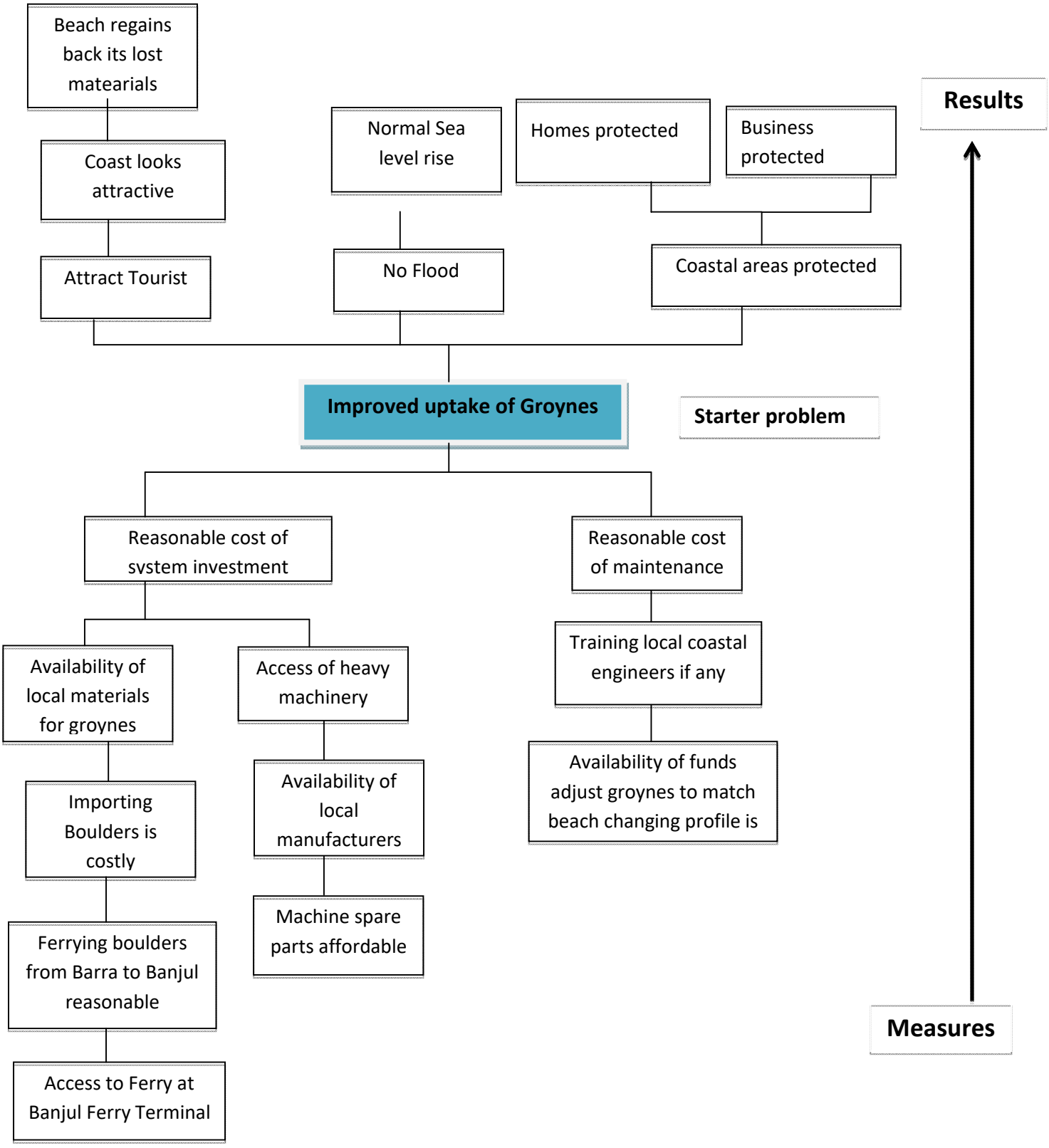

Figure AN10: Solution Tree to remove financial barriers to Groynes

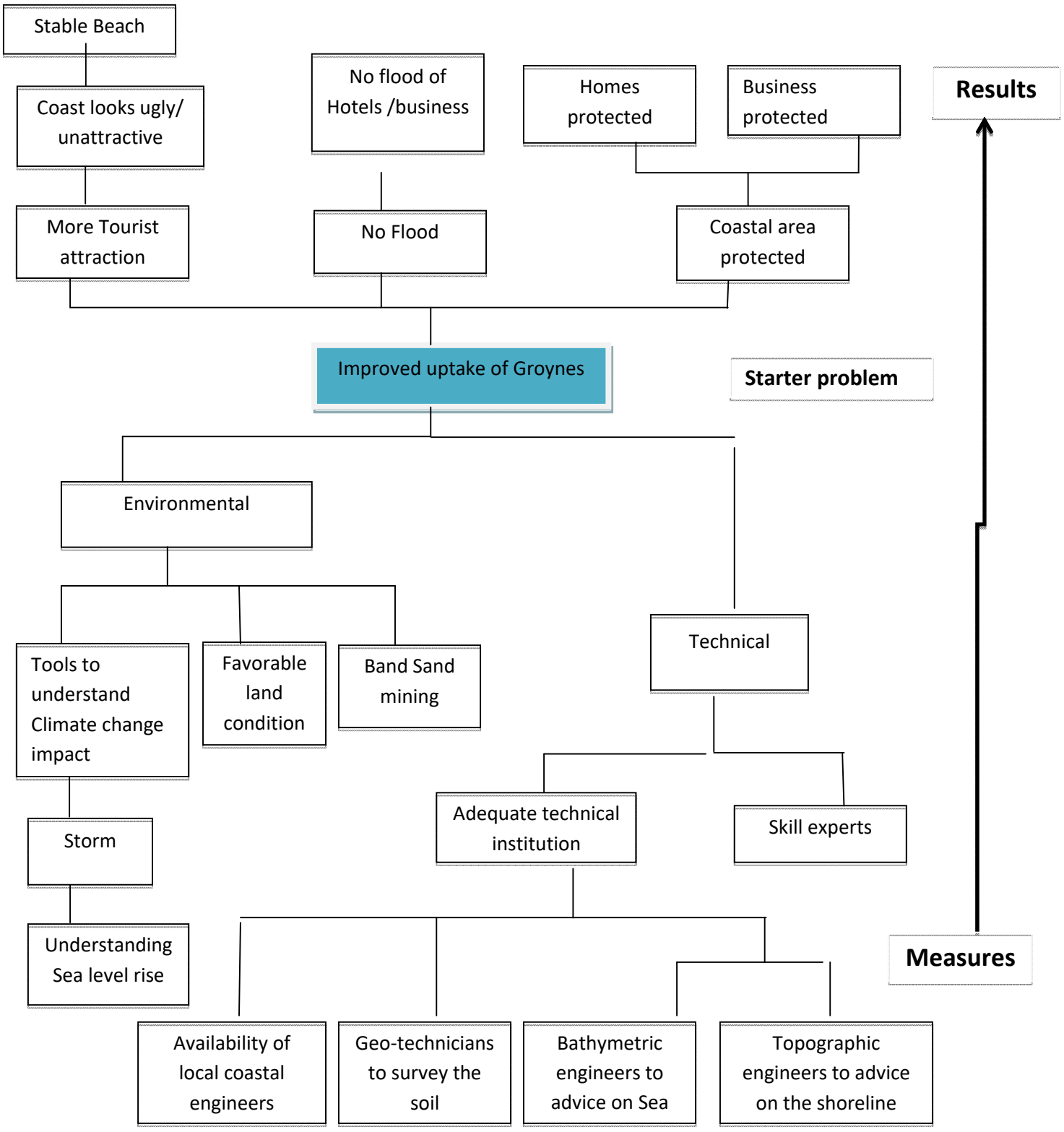

Figure AN11: Solution Tree to remove non-financial barriers to improve Groyes

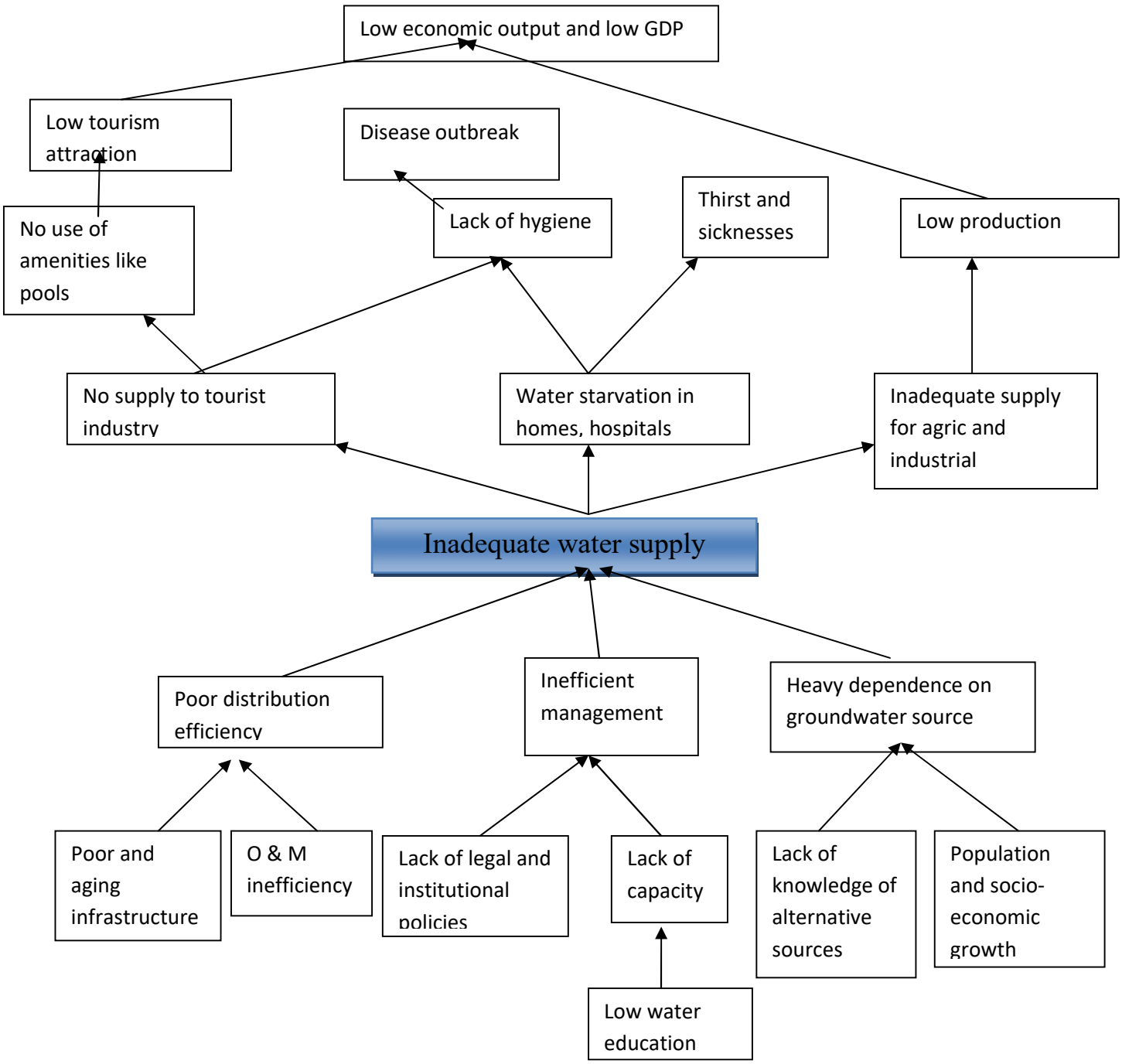

Figure AN12: Problem Tree to determine financial and non-financial barriers to Conservation Water Supply

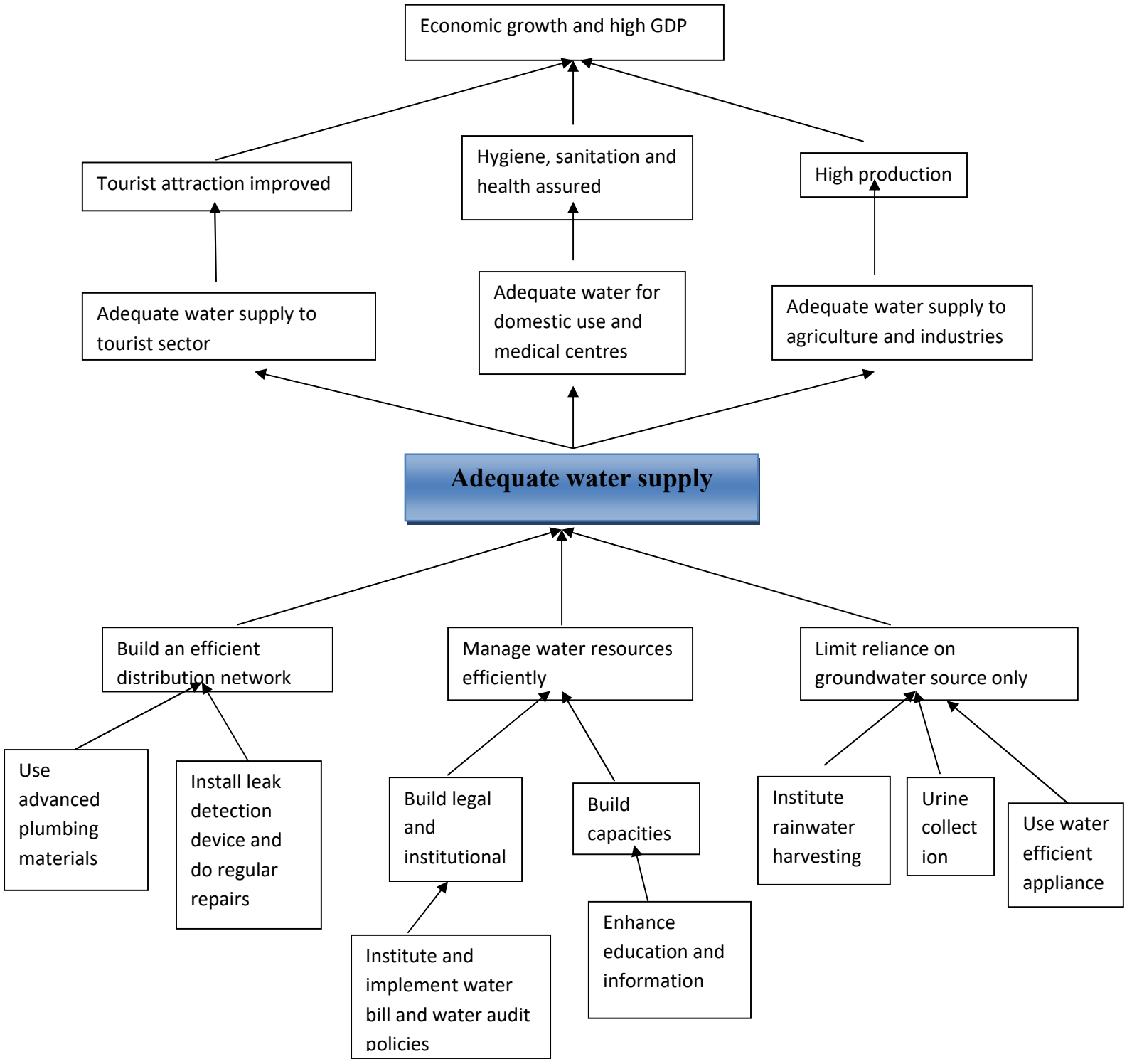

Figure AN13: Solution Tree to determine financial and non-financial measures to remove barriers to Conservation Water Supply

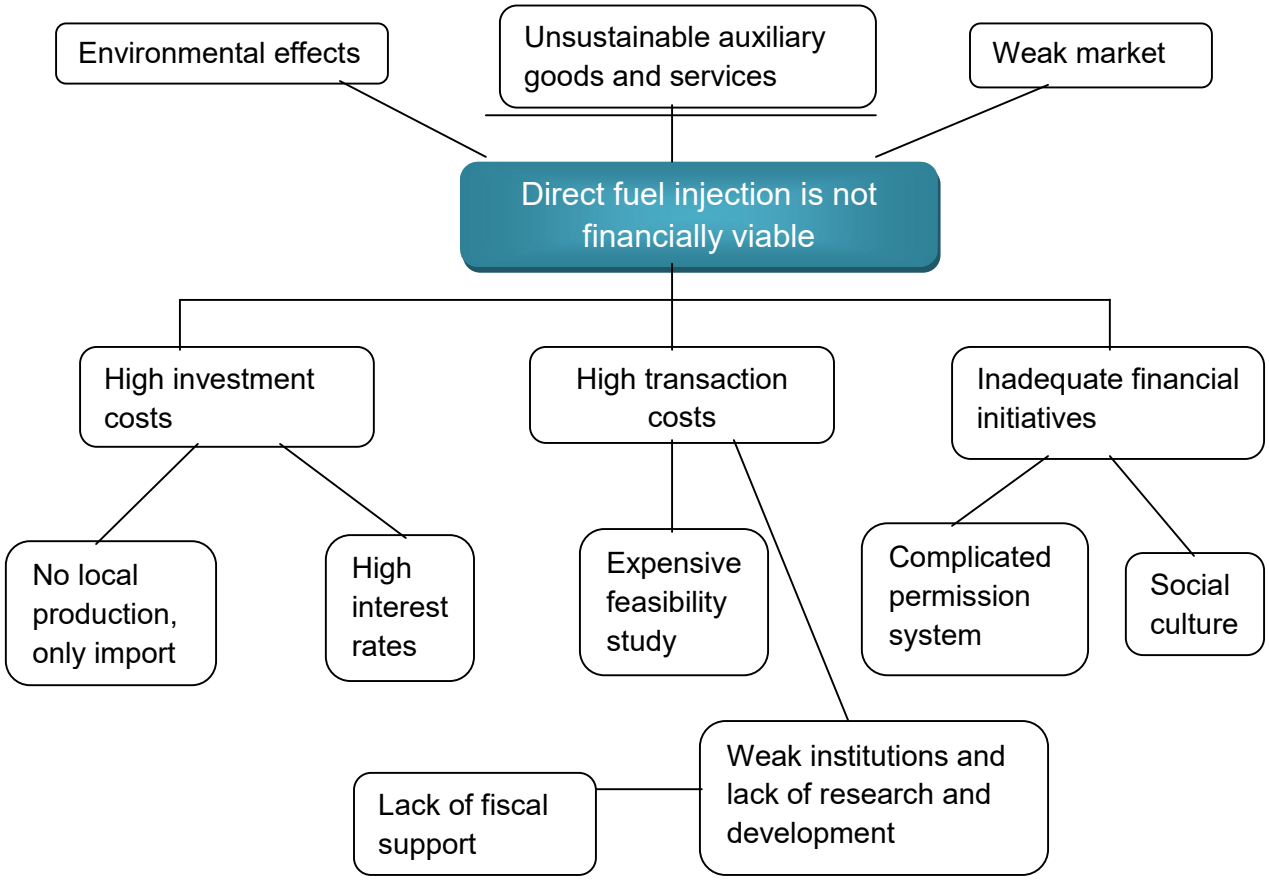

Figure AN14: Problem Tree to determine economic and financial barriers to viability of Direct Fuel Injection Technology

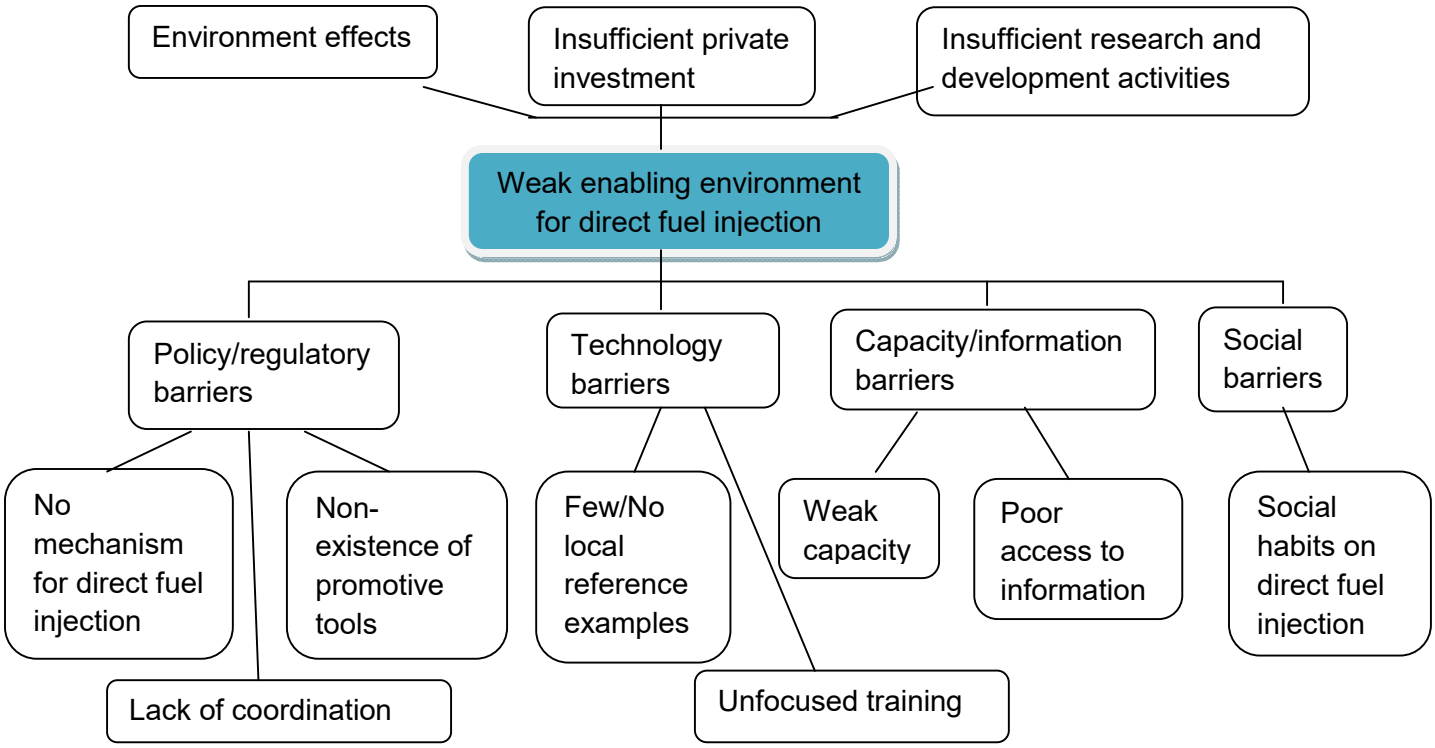

Figure AN15: Problem Tree to determine non-financial barriers to viability of Direct Fuel Injection Technology

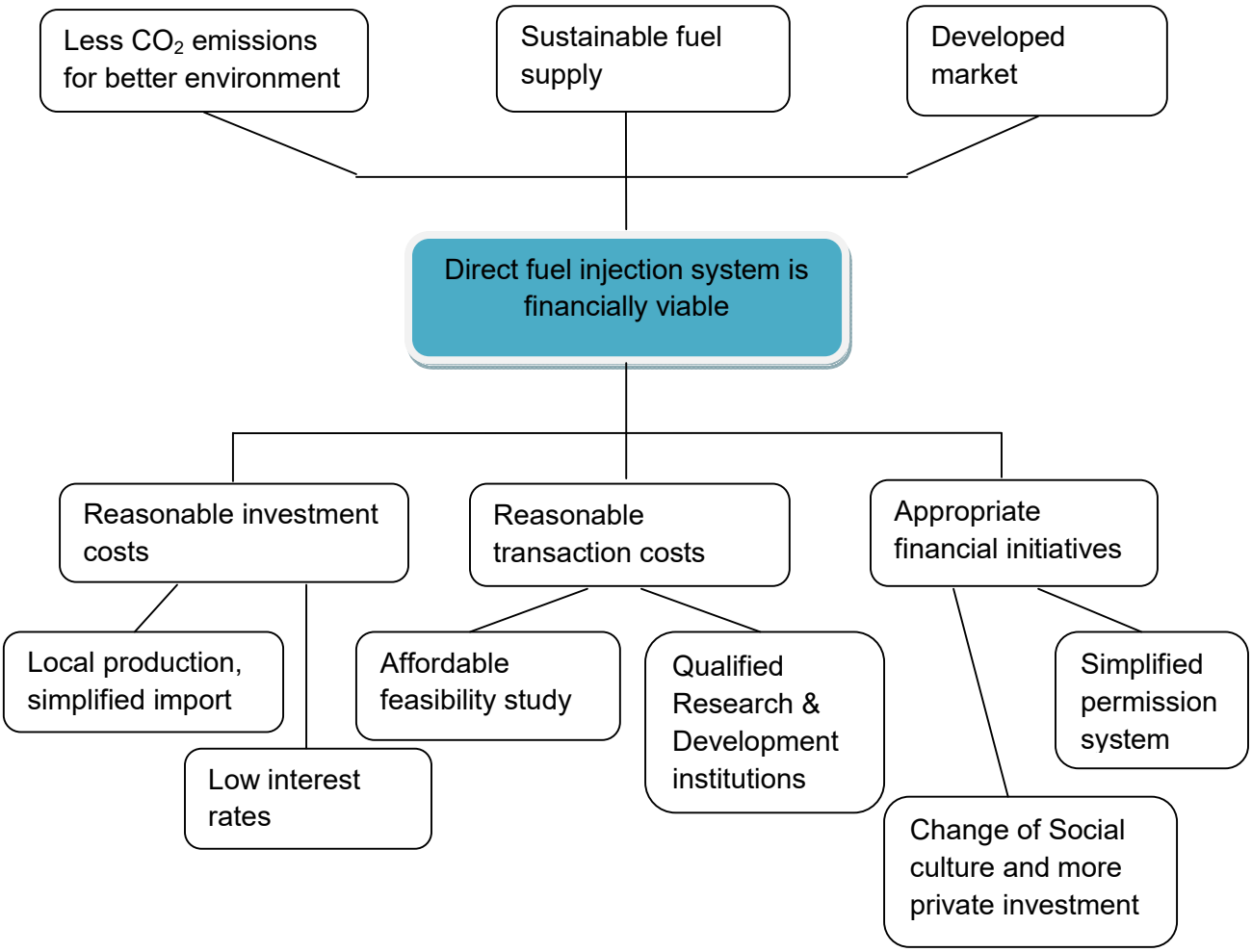

Figure AN16: Solution Tree to enable economic and financial measures for viability of Direct Fuel Injection Technology

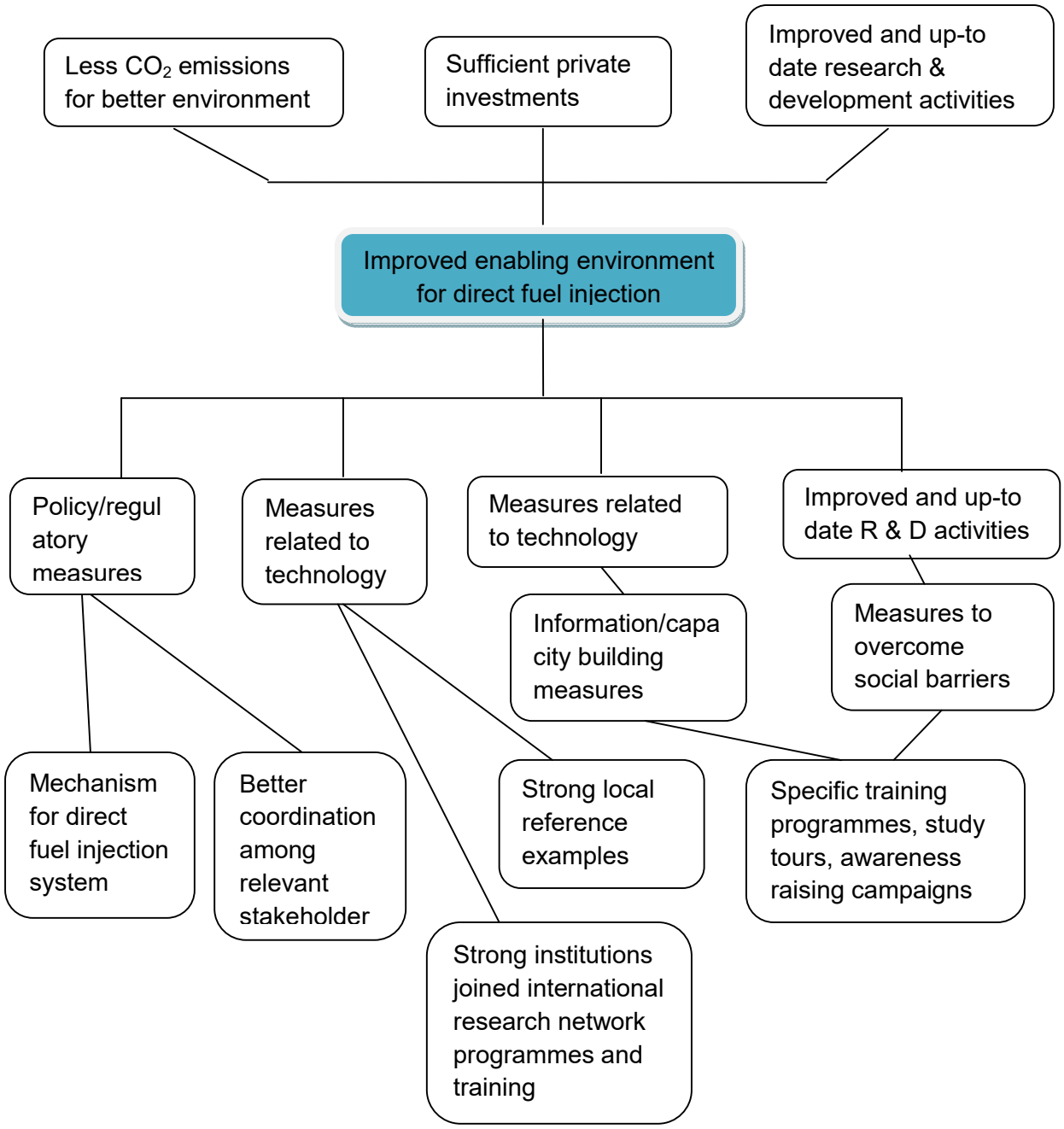

Figure AN17: Solution Tree to enable non-financial measures for viability of Direct Fuel Injection Technology

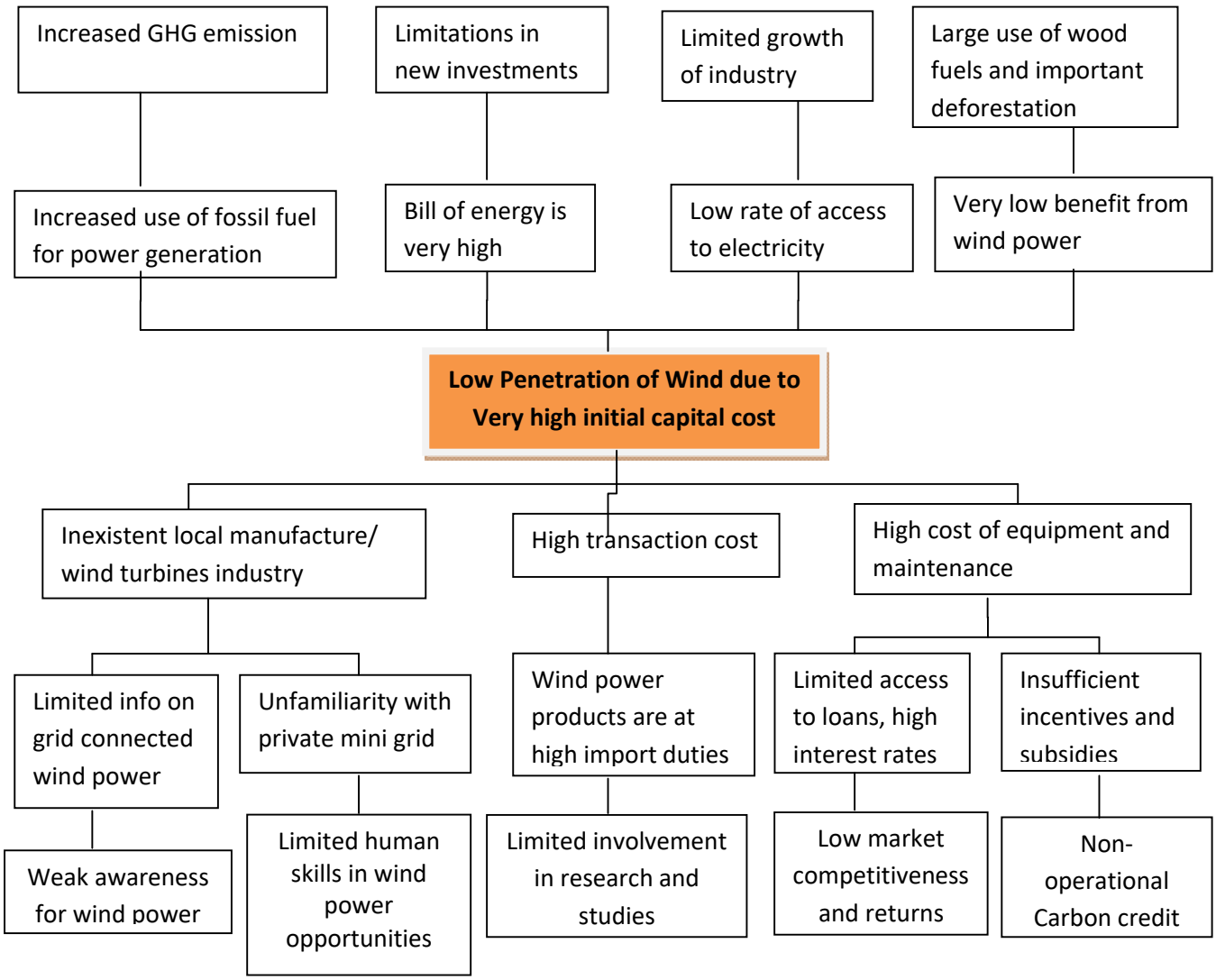

Figure AN18: Problem Tree to determine economic and financial barriers to Penetration of Wind Turbine Technology

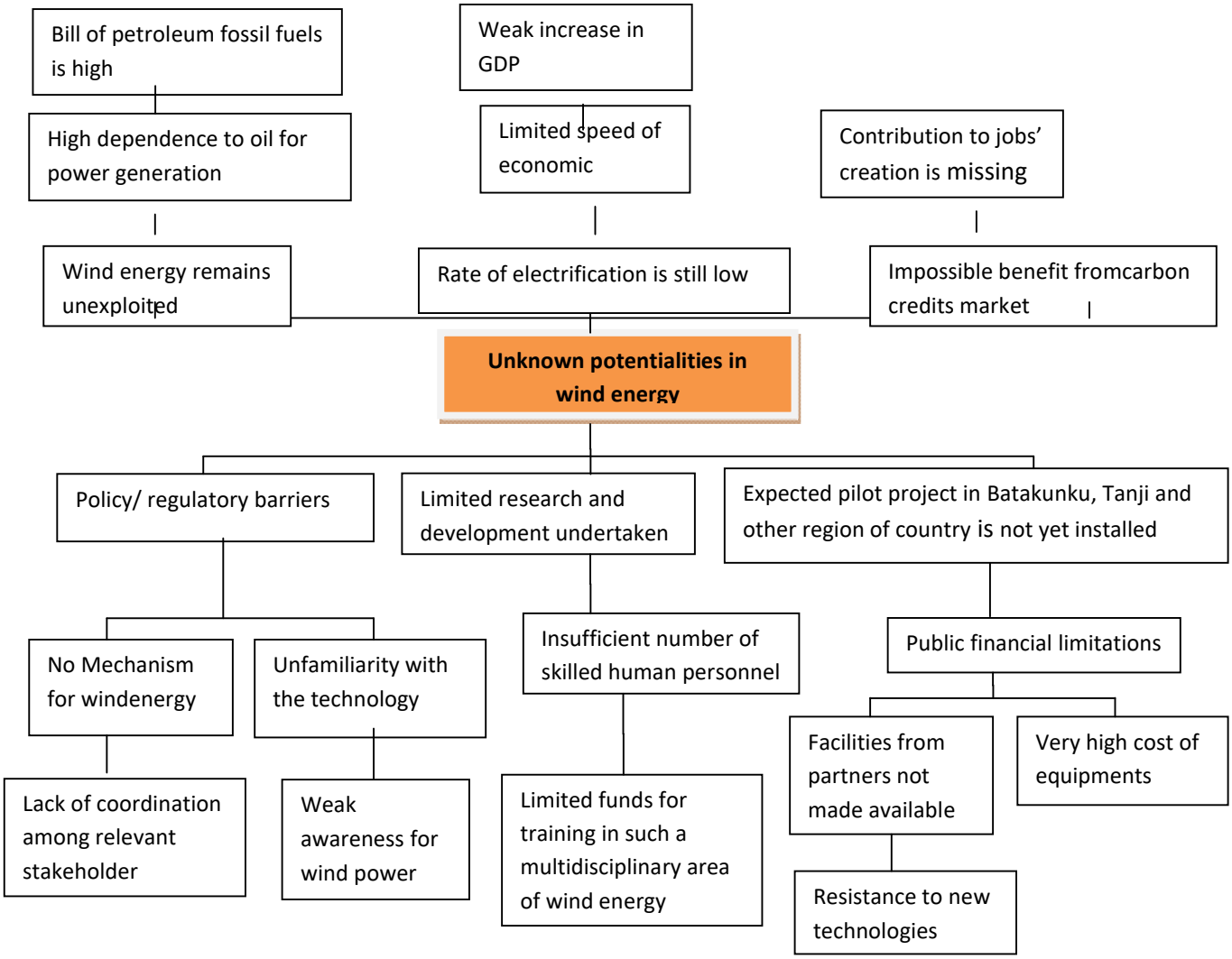

Figure AN19: Problem Tree on assessment of non-financial barriers to penetration Wind Turbine Technology

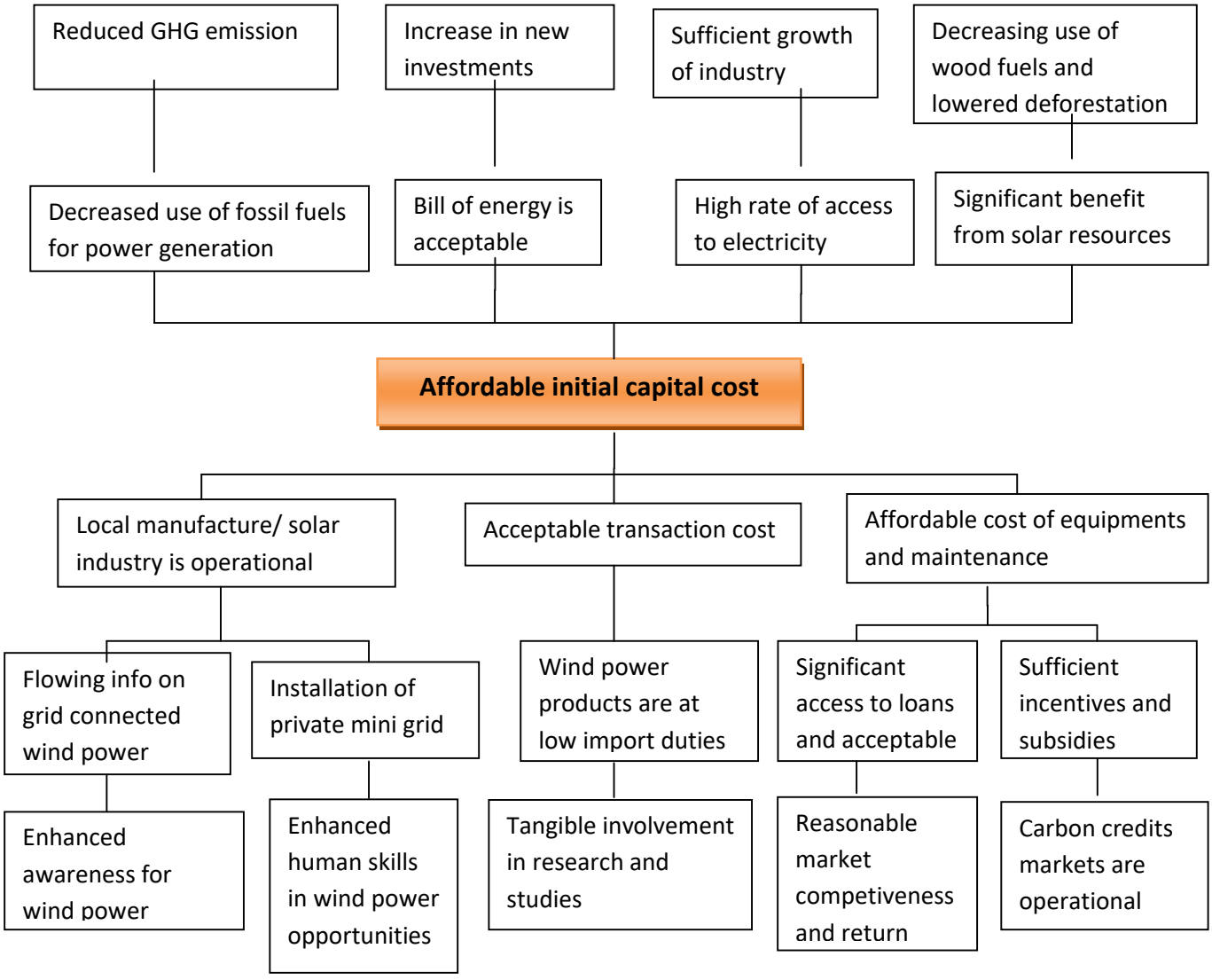

Figure AN20: Solution Tree for the assessment of measures to lift the economic and financial barriers to allow penetration of Wind Turbine technology.

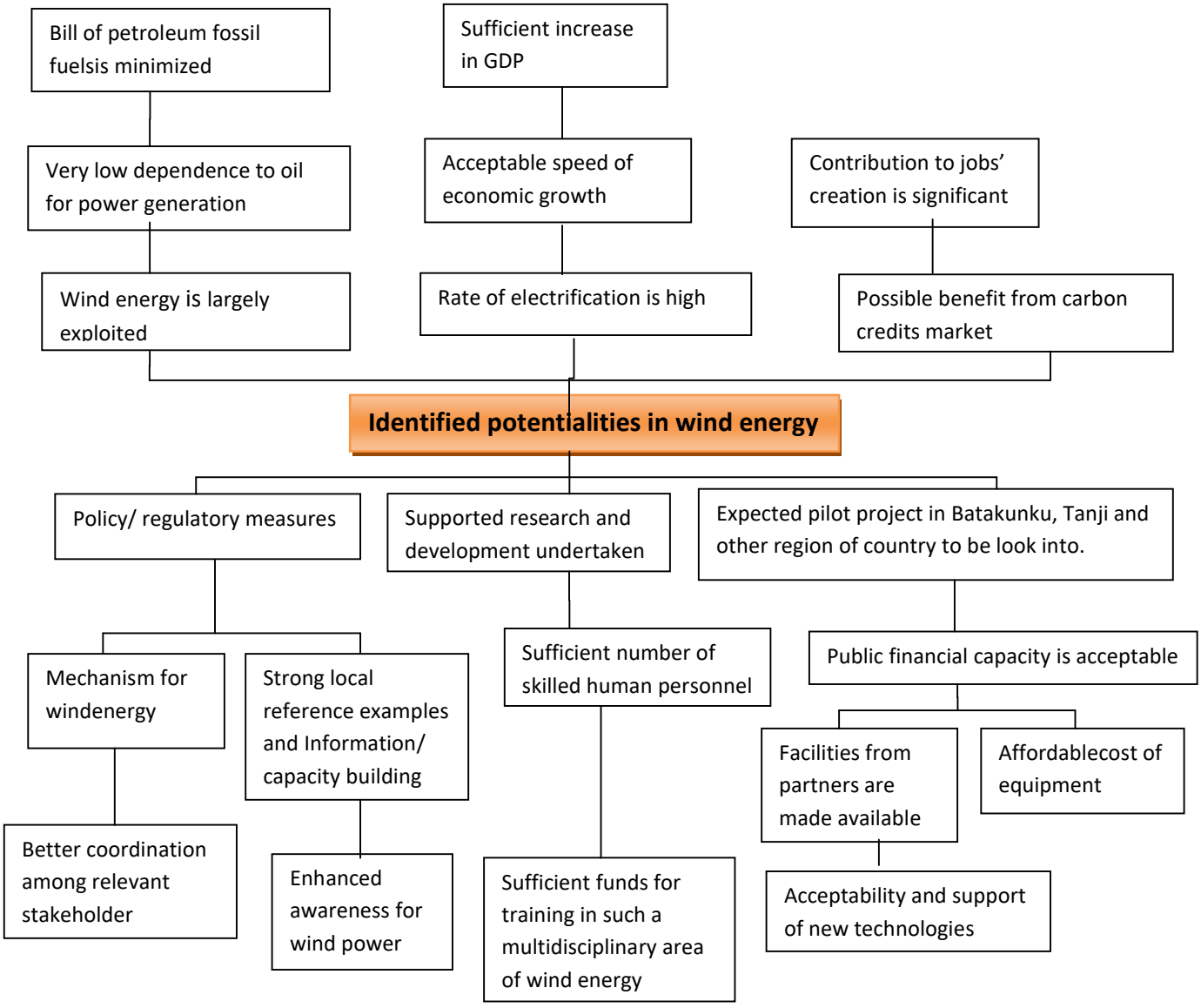

Figure AN21: Solution Tree for the assessment of measures to lift the non-financial barriers and improve penetration Wind Turbine technology in The Gambia

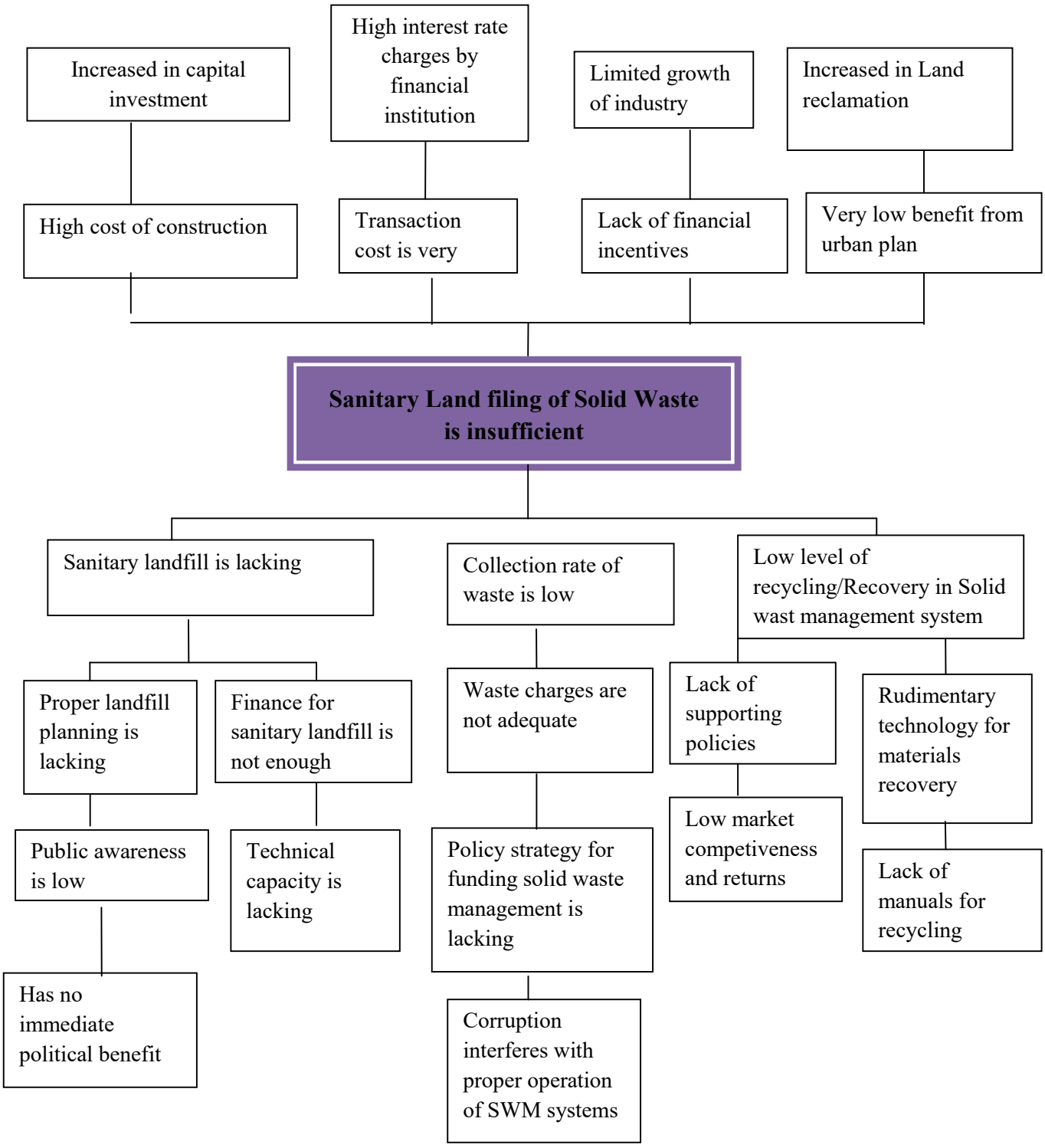

Figure AN22: Problem Tree to assess economic and financial barriers to the effectiveness of Sanitary Landfills in the Greater Banjul Area

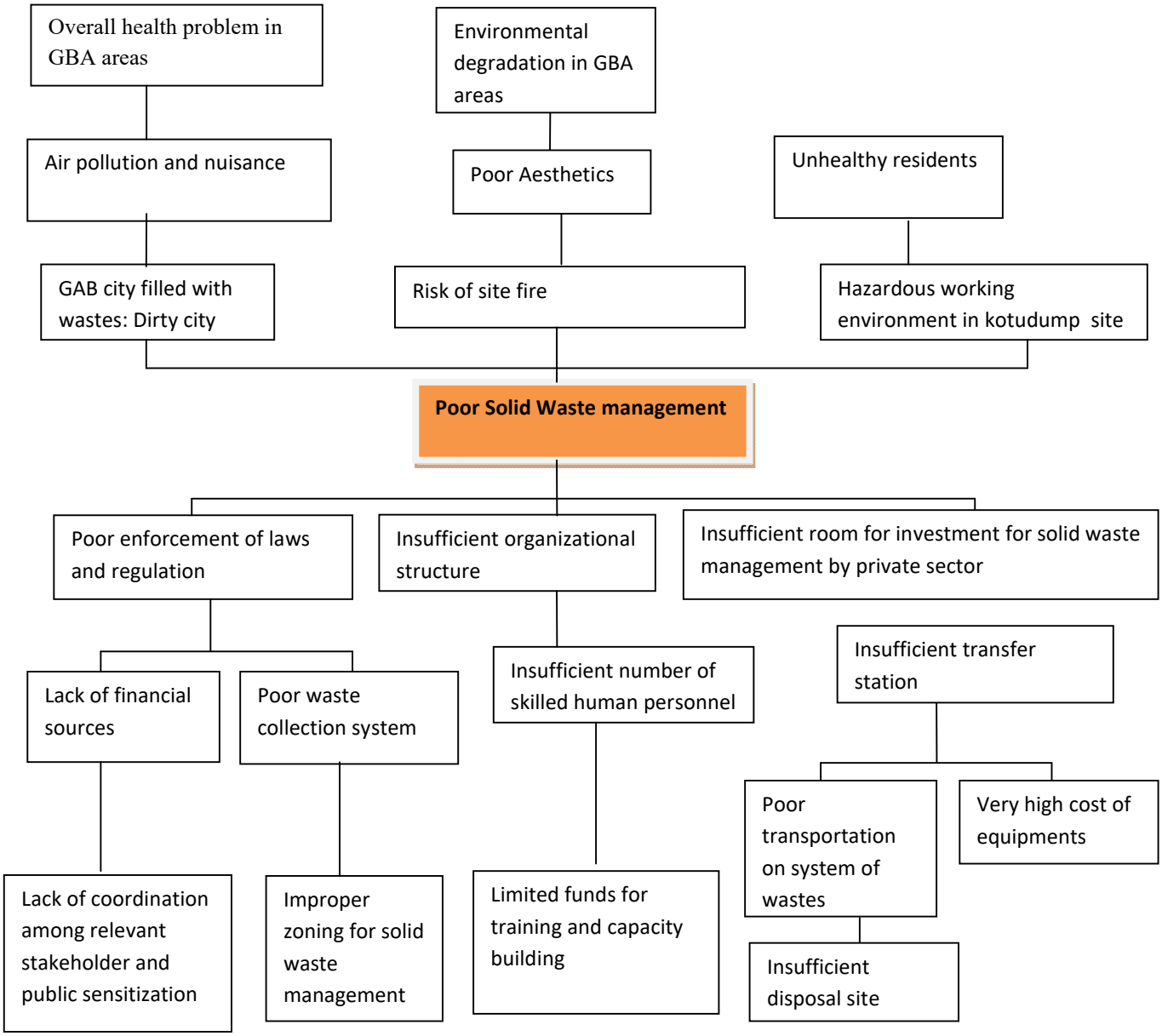

Figure AN23: Problem Tree to assess non-financial barriers to the effectiveness of Sanitary Landfills in the Greater Banjul Area

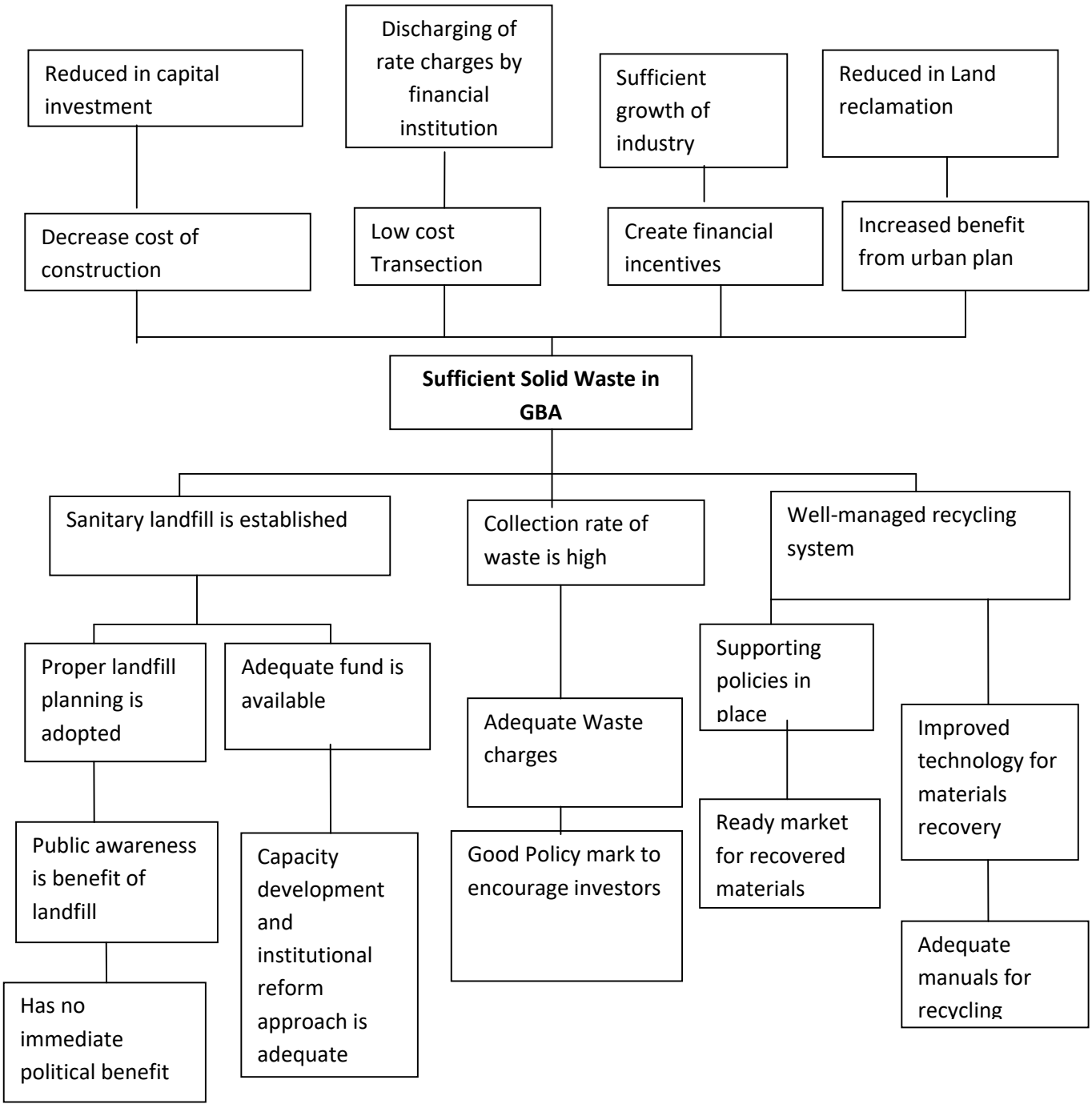

Figure AN24: Solution Tree to assess economic and financial measures to remove barriers to effective sanitary landfills in the GBA.

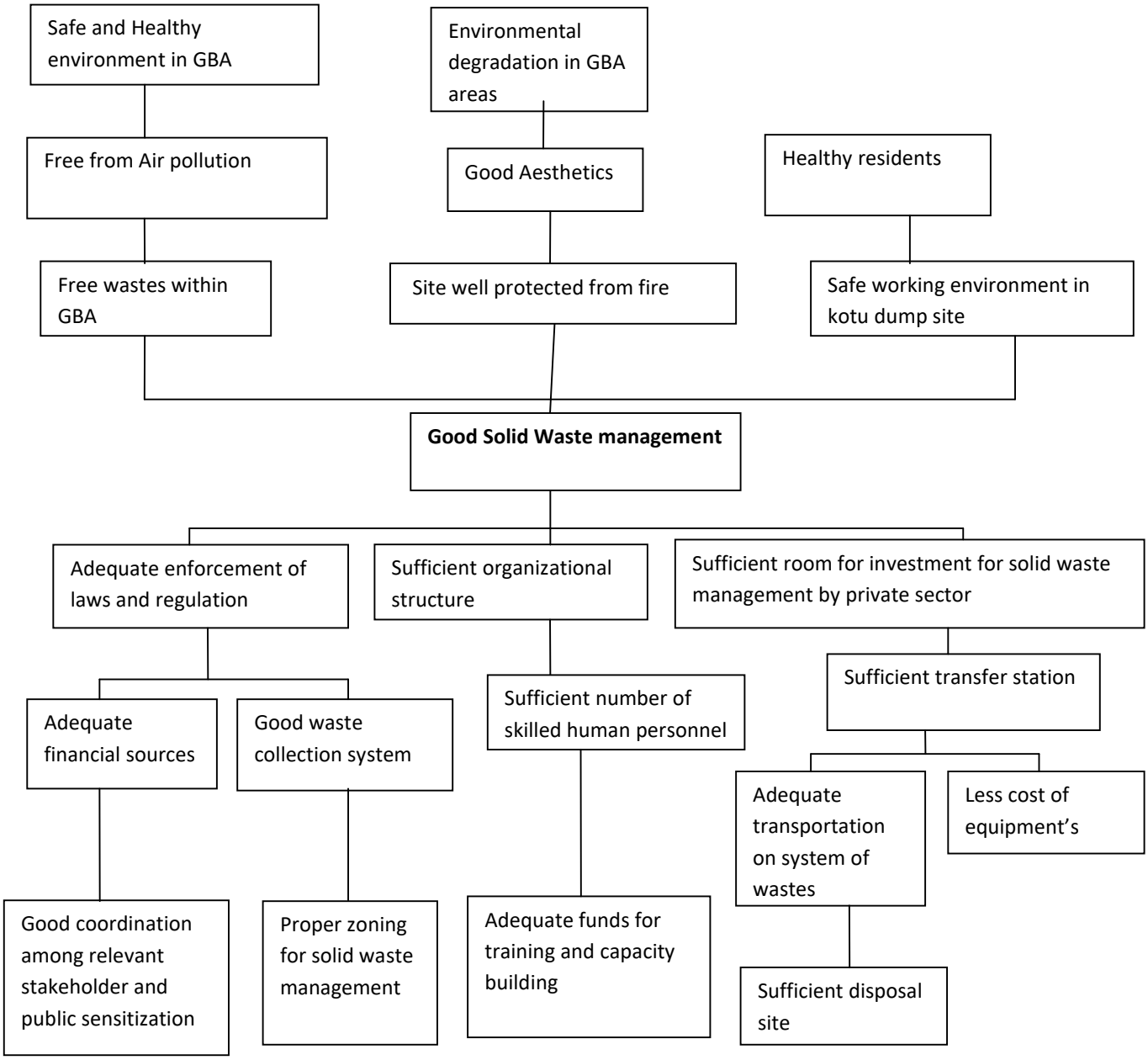

Figure AN25: Solution Tree to assess non-financial measures to remove barriers to effective sanitary landfills in the GBA.