The Republic of The Gambia
Office of the President
Energy Division

Renewable Energy Study for The Gambia

Inception Report

LI/GE5 24.0203     May 2005
# Table of Contents

1 INTRODUCTION 1  

2 BACKGROUND TO THE PROJECT 2  
2.1 General objectives of the study 2  
2.2 The Gambia – Brief Country Overview 2  
2.2.1 Economic Performance 3  
2.2.2 Agriculture 3  
2.2.3 Administrative Division 3  
2.2.4 Population statistics 4  
2.3 Energy Sector Overview 6  
2.3.1 Energy Resources 6  
2.3.2 Energy consumption 9  
2.3.3 Sector Organisation 10  
2.3.4 Sector reform 10  
2.3.5 Electricity Sub-Sector 11  
2.3.6 Traditional Energy and Biomass Energy sub-sector 14  
2.3.7 Renewable energy sub-sector 15  
2.3.8 The Petroleum Sub-sector 16  

3 PROGRESS OF WORK 17  
3.1 Kick off meeting 17  
3.2 Project manual 17  
3.3 Second Meeting 17  
3.4 Procurement of equipment 18  
3.4.1 Office 18  
3.4.2 Cars 18  
3.4.3 Measurement equipment including measurement masts 18  
3.5 Mobilisation of team 19  

4 FIRST RESULTS 22  
4.1 Collection of Climate Data 22  
4.2 Zero Map for Solar Incidence 23  
4.2.1 Methodology 23  
4.2.2 Results 23
4.3 Zero Wind Map
4.3.1 General methodology for the zero wind map based on KLIMM Model calculation
4.3.2 Approach for The Gambia
4.3.3 Results from the KLIMM calculation
4.4 Measurement Campaign Locations
4.4.1 Selected sites for wind and solar radiation measurement

5 METHODOLOGY OF WORK - FIRST PHASE - MASTERPLAN ELABORATION
5.1 Energy Demand Assessment
5.2 Renewable Energy Resource Assessment
5.2.1 Outline of General Strategy
5.2.2 Wind and Solar Energy
5.2.3 Fuel Wood, Biomass and Waste
5.2.4 Overall Renewable Energy Resource Assessment
5.3 Sector and Criteria Study
5.4 Social and Gender Analysis
5.5 Institutional Study
5.6 Economic and Financial Analysis
5.6.1 Steps in the Economic and Financial Analysis
5.6.2 Specific Aspects of Economic Analysis
5.6.3 Specific Aspects of Financial Analysis
5.7 Micro Credit Mechanism
5.8 Sector Environmental and Social Assessment
5.9 Preparation of a Renewable Energy Master Plan (REMP)

6 METHODOLOGY OF WORK – SECOND PHASE: FEASIBILITY STUDY
6.1 Definition of the Feasibility Study Project
6.2 Detailed Energy Demand Assessment
6.3 Technical Layout
6.3.1 Cost Assessment
6.3.2 Environmental and Social Impact Assessment Study (ESIA)
6.3.3 Environmental and Social Management Plan (ESMP)
6.3.4 Economic and Financial Analysis

May 2005
6.3.5 Institutional Arrangements, Financing Mechanism and Management Structure

6.3.6 Design and Tender Documents

6.4 Reports and Documents

6.5 Seminars and Workshops

6.5.1 Duration

6.5.2 Training methodology

6.5.3 Overseas Training

6.5.4 In country Training

7 UPDATED WORK PLAN

8 ANNEX A – SPECIFICATIONS OF THE WIND MEASUREMENT MAST AND STANDS

8.1 Scope of Work

8.2 Wind measurement mast

8.2.1 Overall design

8.2.2 Orientation and relative location of mast and stand

8.2.3 Anchor design and guying rope

8.3 Upper cross arm

8.4 Lower cross arm

8.5 Stand for pyranometers

8.6 Cross arm for pyranometer stand

8.7 Shadow roof for data logger
List of Tables

Table 2-1: Population statistics ................................................................. 5
Table 2-2: Generation and network infrastructure in the Gambia ................ 12
Table 2-3: Overview on the coverage of the rural electrification project ....... 13
Table 3-1: Equipment for solar and wind measurement campaign ............... 19
Table 4-1: Comparison between measured and calculated wind speeds ....... 26
Table 5-1: Overview Renewable Energy Resource Assessment .................. 50
Table 6-1: Overview of reports and documents to be submitted ................. 66
Table 8-1: Wind measurement tower and pyranometer stand - items and
quantities ...................................................................................................... 74

List of Figures

Figure 2-1: Map of The Gambia ............................................................. 2
Figure 2-2: Basic administrative division of The Gambia ......................... 4
Figure 2-3: Annual mean value of solar insolation: global incidence of solar
radiation on a horizontal plane ............................................................... 7
Figure 2-4: Annual mean value of direct solar insolation i.e. incidence of direct
normal solar radiation ............................................................................. 7
Figure 2-5: Annual mean value of diffuse solar insolation i.e. incidence of diffuse
solar radiation on a horizontal plane ...................................................... 8
Figure 2-6: Annual mean value of wind speed 50m above ground .............. 9
Figure 2-7: Fuel wood sale on a Gambian highway .................................. 14
Figure 3-1: Time Schedule for Key Personnel ......................................... 20
Figure 3-1: Organisation of Project Team ................................................ 21
Figure 4-1: Network of meteorological stations in The Gambia ................. 22
Figure 4-2: Calculation procedure for the wind potential estimation with the three
dimensional atmospheric model KLIMM ............................................. 24
Figure 4-3: Simulation method of the model KLIMM ............................... 25
Figure 4-4: Correlation between model results and measured data for a project in
Italy .......................................................................................................... 27
Figure 4-5: Land use map of the Gambia .................................................. 29
Figure 4-6: Topographic map of the Gambia ............................................ 30
Figure 4-7: Administrative map of the Gambia showing the locations of the wind
and solar measurement stations ............................................................. 31
Figure 4-8: Zero solar map of The Gambia: Mean annual solar radiation on a 17°
inclined surface pointing to the equator ................................................ 32
Figure 4-9: Zero wind map of The Gambia at 10m above ground .............. 33
Figure 4-10: Zero wind map of The Gambia at 50m above ground .......... 34
Figure 4-11: Zero wind map of The Gambia at 100m above ground ......... 35
Figure 5-1: Approach for the RE resource assessment in an overview ........ 40
Figure 5-2: The relation of theoretical, technical, economic and exploitable potential ......................................................... 41
Figure 5-3: Preliminary selection of conversion technologies for each type of renewable energy source and energy application .................................................................................. 42
Figure 5-4: Structure of financial model of Lahmeyer .......................................................... 55
Figure 5-5: General approach for an Electricity Master Plan .................................................. 59
Figure 7-1: Updated Work Plan Part 1 .................................................................................... 72
Figure 7-1: Updated Work Plan Part 2 .................................................................................... 73
Figure 8-1: General design of the lattice mast ....................................................................... 75
Figure 8-2: Orientation and relative location of mast and stand ............................................ 76
Figure 8-3: Anchor fixation and foundation .......................................................................... 77
Figure 8-4: Anchor Design .................................................................................................... 77
Figure 8-5: Upper cross arm layout ...................................................................................... 78
Figure 8-6: Position of the upper cross arm mounted to the mast ......................................... 79
Figure 8-7: Lower cross arm layout ....................................................................................... 80
Figure 8-8: Position of the lower cross arm mounted to the mast ......................................... 81
Figure 8-9: Design of pyranometer stand ............................................................................. 82
Figure 8-10: Design of pyranometer cross arm .................................................................... 83
Figure 8-11: Shadow roof design .......................................................................................... 84
Figure 8-12: Position of drilled holes for logger mounting ..................................................... 85
Figure 8-13: Position of drilled holes for solar nodule mounting .......................................... 85

Abbreviations

AIDB African Development Bank
APM Assistant Project Manager
DCD Department of Community Development
DoE Director of Energy
EIRR Economic Internal Rate of Return
FIRR Financial Internal Rate of Return
GBA Greater Banjul Area
GDP Gross Domestic Product
GoG Government of Gambia
GREC Gambia Renewable Energy Centre
GTZ German Agency for Technical Co-operation
IMSC Inter-Ministerial Steering Committee
LI Lahmeyer International
LPG Liquefied Petroleum Gas

May 2005
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Meteonorm</td>
<td>Meteorological Database Version 4.0 by Meteotest, Switzerland</td>
</tr>
<tr>
<td>NAWEC</td>
<td>National Water and Electricity Company</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>OMVG</td>
<td>Organisation pour la Mise en Valeur du Fleuve Gambie</td>
</tr>
<tr>
<td>OP</td>
<td>Office of the President</td>
</tr>
<tr>
<td>PM</td>
<td>Project Manager</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>RE</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>REIS</td>
<td>Renewable Energy Information System</td>
</tr>
<tr>
<td>REMP</td>
<td>Renewable Energy Master Plan</td>
</tr>
<tr>
<td>RETs</td>
<td>Renewable Energy Technologies</td>
</tr>
<tr>
<td>SMU</td>
<td>Study Management Unit</td>
</tr>
<tr>
<td>SSE</td>
<td>NASA Surface meteorology and Solar Energy Database</td>
</tr>
<tr>
<td>TAF</td>
<td>Technical Assistance Fund</td>
</tr>
<tr>
<td>TOE</td>
<td>Tons of Oil Equivalent</td>
</tr>
<tr>
<td>TOR</td>
<td>Terms of Reference</td>
</tr>
<tr>
<td>WIS</td>
<td>Wind Information System</td>
</tr>
<tr>
<td>WSIS</td>
<td>Wind and Solar Energy Information System</td>
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# Measures and Currencies

## Currency Equivalents

As in May 2005

1 EUR = 1.30 USD (United states of America Dollar) = 37 Gambian Dalasi

### Measures

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
<th>Definition</th>
<th>Conversion Factor</th>
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<tbody>
<tr>
<td>kV</td>
<td>kW</td>
<td>kilovolt</td>
<td>$10^3$ volts (V)</td>
</tr>
<tr>
<td>kW</td>
<td>MW</td>
<td>kilowatt</td>
<td>$10^3$ watts (W)</td>
</tr>
<tr>
<td>MW</td>
<td>GWh</td>
<td>Megawatt</td>
<td>$10^3$ kilowatts (kW)</td>
</tr>
<tr>
<td>kWh</td>
<td>km</td>
<td>kilowatt hour</td>
<td>$10^3$ watt hours</td>
</tr>
<tr>
<td>GWh</td>
<td>cm</td>
<td>Gigawatt hour</td>
<td>$10^6$ kilowatt hours</td>
</tr>
<tr>
<td>km</td>
<td>ton</td>
<td>kilometre</td>
<td>$10^3$ meters (m)</td>
</tr>
<tr>
<td>cm</td>
<td>ton</td>
<td>centimetre</td>
<td>$10^{-2}$ meters (m)</td>
</tr>
<tr>
<td>ton</td>
<td>TOE</td>
<td>Metric ton</td>
<td>$10^3$ kg</td>
</tr>
<tr>
<td>TOE</td>
<td></td>
<td>tons of oil equivalent</td>
<td>11.63 MWh</td>
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### Calorific Values

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel wood</td>
<td>1 kg ≈ 4.44 kWh</td>
</tr>
<tr>
<td>Charcoal</td>
<td>1 kg ≈ 6.94 kWh</td>
</tr>
<tr>
<td>Diesel</td>
<td>1 l ≈ 10.03 kWh</td>
</tr>
<tr>
<td>Petrol</td>
<td>1 l ≈ 9.16 kWh</td>
</tr>
<tr>
<td>Kerosene for illum</td>
<td>1 l ≈ 9.72 kWh</td>
</tr>
<tr>
<td>LPG</td>
<td>1 kg ≈ 11.81 kWh</td>
</tr>
<tr>
<td>Jet A1</td>
<td>1 l ≈ 9.96 kWh</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>1 l ≈ 10.72 kWh</td>
</tr>
<tr>
<td>Average for liquid hydro-carbonates</td>
<td>1 l ≈ 10 kWh</td>
</tr>
</tbody>
</table>
1 Introduction

Under funding of AfDB Lahmeyer International has been contracted by the Government of The Gambia, Office of the President, Energy Division to provide consulting services for the "Renewable Energy Study for The Gambia".

The study purpose is to develop and promote the use of renewable sources of energy in The Gambia, with particular emphasis on rural areas. The study further is meant to assist the Gambian authorities in preparing projects that will provide sufficient energy to the population and improve their access to social services such as education, health services and water supply. In consequence, the study is supposed to contribute to poverty reduction through the improvement of economic and social conditions of the population particularly in the rural areas. Finally, it is hoped the study will help stop the ongoing environmental degradation.

Through a profound resource assessment for solar, wind and biomass energy the potential of these sources in The Gambia will be assessed. The demand will be analysed in a bottom-up approach in order to give a reliable base for an energy demand forecast over the next 20 years. The demand assessment will cover electrical power demand in the several isolated grids, the electrical power demand in off grid areas as well as mechanical power and heat demands.

A Master Plan will be prepared in order to outline how Renewable Energies can best be utilised to fulfil the energy demands and how to develop the renewable energy sub-sector taking into account economic, financial, social and environmental criteria.

In a second phase a feasibility study and tender documents will be elaborated for a priority project to be implemented in the medium term.

This inception report presents

1) the methodology of the project in a higher degree of precision and detail compared to the consultants proposal
2) results and findings of the consultant's work
3) an updated time schedule for the project
2 Background to the project

2.1 General objectives of the study

The main goal of the study is to develop and promote renewable sources of energy as an alternative to conventional and traditional sources of energy especially in the rural areas of the country.

Given the background of the above mentioned overall study goal, the specific objectives the study are to

- assess the renewable energy resources of the country,
- prepare a master plan for the development of the country's renewable energy sub-sector,
- formulate policies, strategies and the required institutional framework for the development of the renewable energy sub-sector, and
- prepare a feasibility study and tender documents for a priority project which can be implemented in the medium term.

2.2 The Gambia – Brief Country Overview

Figure 2-1: Map of The Gambia

The Gambia is a relatively small state with a total surface of only 11,300 km² located on the Western African coast. Totally surrounded by its neighbour Senegal, the Gambia is mainly formed by the shores of the Gambia river.
Population amounts at 1.5 Mio and is growing at a rate of around 3%, which is one of the highest in Western African countries. A lot of refugees from Sierra Leone, Liberia and Senegal lead to rising unemployment rates. Three quarters of the labour force still are assigned to rural agricultural sector.

With a GNP per capita of USD 340, Gambia ranks among the poorest countries in the world. Nevertheless, The Gambia is very active in international programs to fight local poverty and enhance the infrastructure and the local industry. One of the major problems is – not unlike to other countries – the electrification of rural regions.

2.2.1 Economic Performance

During the 1990s, the Gambian economy fought to remain on the knotty path of economic diversification. Having no important mineral or other natural resources, Gambia hopes that the development of other crops and the expansion if its services sectors will eliminate its dependency on the production and processing of peanuts. Amid these problems, the country has developed an acceptable level of infrastructure, primarily an all-weather road system connecting the capital to every corner of the country.

Relative to the region, the country fared well during the last decade. GDP growth averaged three percent, inflation has remained below five percent, and although the standard of living has hardly improved, the population has been the least affected by the HIV/AIDS epidemic in the region.

The current economic situation of The Gambia is relatively stable. Based on the exportation of agricultural goods (mostly peanuts) and an important re-export sector, the economic growth has been constant on low level for the last five years (~5.9% p.a.). This development has been supported by favourable agricultural conditions and a robust performance in the tourism sector. Important gains in the implementation of budgetary expenditure reporting and controls, additional privatisation of public enterprises and the reduction in external tariffs continued to built confidence in the economy. However, the draught in 2002 and the global economic situation caused a deficit of 0.6%.

2.2.2 Agriculture

The agriculture sector in Gambia contributes 23% of the GDP and employs an estimated 74% of the labour force. The primary food crops produced are maize and rice. The primary meat products are beef and veal, chicken, game, lamb and pork. The largest (in value terms) agricultural exports in 1998 were groundnuts, fish, groundnut oil, groundnut cake and cotton. The total value of agricultural exports in 1998 was $14.0 million, while the total value of agricultural imports in 1998 was $96.4 million.

2.2.3 Administrative Division

At the highest level the Gambia is divided into 6 divisions (Banjul, Western, North Bank, Lower River, MacCarty Island and Upper River as shown in the following Figure 2-2) and 8 Local Government Areas (LGAs). The LGAs of Georgetown and
Kuntaur form the MacCarthy Island division, and Kanifing and Banjul form Banjul division. The other LGA's are also a division (Basse LGA/Upper River, Brikama LGA/Western, Kerewan LGA/North Bank, Mansa Konko LGA/Lower River).

The next level of administrative division is the district level, which comprises of a total of 39 districts, shown in Table 2-1 in the subsequent section.

2.2.4 Population statistics

The following Table 2-1 shows the results of the most recent population census dating from 2003. In general terms population grew by about 3% per year.
# Table 2-1: Population statistics

<table>
<thead>
<tr>
<th>LGA</th>
<th>area in km²</th>
<th>population in 15.04.2003</th>
<th>variation over the last 10 years</th>
<th>population density in 1/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>District</strong></td>
<td>census</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1 Banjul LGA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>District of Banjul Central</td>
<td>12</td>
<td>8,622</td>
<td>-5.0%</td>
<td>2,012</td>
</tr>
<tr>
<td>District of Banjul North</td>
<td></td>
<td>17,499</td>
<td>-15%</td>
<td></td>
</tr>
<tr>
<td>District of Banjul South</td>
<td></td>
<td>8,907</td>
<td>-21%</td>
<td></td>
</tr>
<tr>
<td><strong>2 Basse LGA (Upper River)</strong></td>
<td>2,069</td>
<td>183,033</td>
<td>-19%</td>
<td>88</td>
</tr>
<tr>
<td>District of Fulaudu East</td>
<td></td>
<td>89,444</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>District of Kantara</td>
<td></td>
<td>30,402</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>District of Sandu</td>
<td></td>
<td>19,321</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>District of Wuli</td>
<td></td>
<td>35,036</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td><strong>3 Brikama LGA (Western)</strong></td>
<td>1,784</td>
<td>302,987</td>
<td>62%</td>
<td>225</td>
</tr>
<tr>
<td>District of Foni Bintang Kemanf</td>
<td>15,844</td>
<td>15,084</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>District of Foni Bondolf</td>
<td></td>
<td>6,048</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>District of Foni Brefet</td>
<td></td>
<td>11,411</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>District of Foni Jarol</td>
<td></td>
<td>5,943</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>District of Foni Kansala</td>
<td></td>
<td>12,247</td>
<td>50%</td>
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<tr>
<td>District of Kombo Central</td>
<td></td>
<td>84,315</td>
<td>50%</td>
<td></td>
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<tr>
<td>District of Kombo East</td>
<td></td>
<td>28,145</td>
<td>34%</td>
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<tr>
<td>District of Kombo North</td>
<td></td>
<td>165,361</td>
<td>107%</td>
<td></td>
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<td>District of Kombo South</td>
<td></td>
<td>62,351</td>
<td>68%</td>
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<td><strong>4 Georgetown LGA</strong></td>
<td>2,634</td>
<td>186,739</td>
<td>21%</td>
<td>37</td>
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<tr>
<td>District of Fulaudu West</td>
<td></td>
<td>71,999</td>
<td>24%</td>
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</tr>
<tr>
<td>District of MacCarthy Island</td>
<td>5,468</td>
<td>5,468</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>District of Niamina Dankunku</td>
<td>6,000</td>
<td>6,000</td>
<td>-1%</td>
<td></td>
</tr>
<tr>
<td>District of Niamina East</td>
<td></td>
<td>19,034</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>District of Niamina West</td>
<td></td>
<td>8,630</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td><strong>5 Kanifing LGA</strong></td>
<td>75</td>
<td>322,410</td>
<td>41%</td>
<td>4,242</td>
</tr>
<tr>
<td>District of K.S.D.C.</td>
<td></td>
<td>322,410</td>
<td>41%</td>
<td></td>
</tr>
<tr>
<td><strong>6 Kerewan LGA (North Bank)</strong></td>
<td>2,266</td>
<td>172,808</td>
<td>10%</td>
<td>72</td>
</tr>
<tr>
<td>District of Central Bodulbu</td>
<td>4,999</td>
<td>4,999</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>District of Jokadu</td>
<td></td>
<td>17,900</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>District of Lower Bodulbu</td>
<td></td>
<td>15,157</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>District of Lower Nulmi</td>
<td></td>
<td>44,451</td>
<td>27%</td>
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<tr>
<td>District of Upper Bodulbu</td>
<td></td>
<td>65,370</td>
<td>0%</td>
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<td>District of Upper Nulmi</td>
<td></td>
<td>24,540</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td><strong>7 Kuntur LGA</strong></td>
<td>611</td>
<td>75,039</td>
<td>17%</td>
<td>125</td>
</tr>
<tr>
<td>District of Lower Salumun</td>
<td></td>
<td>13,524</td>
<td>-5%</td>
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</tr>
<tr>
<td>District of Nian</td>
<td></td>
<td>22,242</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>District of Nianilja</td>
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<td>9,205</td>
<td>27%</td>
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<tr>
<td>District of Sami</td>
<td></td>
<td>19,167</td>
<td>19%</td>
<td></td>
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<tr>
<td>District of Upper Salumun</td>
<td></td>
<td>15,970</td>
<td>20%</td>
<td></td>
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<td><strong>8 Mansa Konko LGA (Lower River)</strong></td>
<td>1,618</td>
<td>73,546</td>
<td>11%</td>
<td>45</td>
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<tr>
<td>District of Jarra Central</td>
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<td>6,484</td>
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<td>12,305</td>
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<tr>
<td>District of Jarra West</td>
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<td>24,416</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>District of Kiang Central</td>
<td></td>
<td>7,886</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>District of Kiang East</td>
<td></td>
<td>8,854</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>District of Kiang West</td>
<td></td>
<td>14,711</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
<td>11,200</td>
<td>31%</td>
<td>121</td>
</tr>
</tbody>
</table>
2.3 Energy Sector Overview

2.3.1 Energy Resources

2.3.1.1 Hydro-carbonates: Petroleum and Natural Gas

West Africa has significant oil and gas reserves. The largest crude oil reserves are located in Nigeria (about 31.5 billion barrels corresponding to 96% of the region's estimated proven crude reserves). Smaller reserves have been discovered in the Gulf of Guinea (offshore Benin, Cote d'Ivoire and Ghana), in the Atlantic Ocean (offshore Mauritania and Senegal) and in landlocked Niger.

Natural gas fields have been developed in Nigeria, Cote d'Ivoire and Senegal. So far, there has not been found oil in onshore or offshore Gambia, neither natural gas has been discovered.

2.3.1.2 Hydropower

The country has negligible hydropower potential within its borders. However, the Gambia, Senegal, Guinea and Guinea-Bissau are members of the Gambia River Basin Development Organisation (OMVG - Organisation pour la Mise en Valeur du Fleuve Gambie) whose aim is to harness the energy of the Gambia River basin and the Konkouré River basin. The total energy available to the OMVG on all potential production sites is estimated at 1440 GWh per annum.

2.3.1.3 Tidal Energy

Tidal energy prima facie should be of significant potential considering the extension of the in the Gambia River Bay and the related volume of periodic in and out flow. However this potential still has to be assessed in detail. Biomass

The country has a limited number of energy resources consisting of wood, agricultural and industrial residues, as well as solid waste. According to a natural resources forest inventory, nearly 45% of the area of the country in 1997 was covered by savannah woodland and 1% by close canopy forest.

2.3.1.5 Solar

The daily solar energy received is on average 5.8 kWh/m² equivalent to 21 MJ/m², as the following map (Figure 2-3) obtained from the NASA Surface Meteorology and Solar Energy Database shows. This value is low in comparison to other sources of information indicating about 7 kWh/m² (this is the value given in the ToR of the project).
Figure 2-3: Annual mean value of solar insolation: global incidence of solar radiation on a horizontal plane

Figure 2-4: Annual mean value of direct solar insolation i.e. incidence of direct normal solar radiation
According to the data from SSE and Meteonorm (see Table 2-2 below) the annual mean values of direct and diffuse solar radiation should vary significantly throughout the country. However the variation from one source of information to the other shows even larger variations indicating that measurement is required.

Table 2-2: Solar radiation data for The Gambia

<table>
<thead>
<tr>
<th>Type of radiation and source of information</th>
<th>Coastal area (13.5 N, 16.5 W)(^1) [kWh/m²d]</th>
<th>Midland area (13.5 N, 15.5 W) [kWh/m²d]</th>
<th>Upland area (13 N, 14.5 W) [kWh/m²d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct (SSE)</td>
<td>5.90</td>
<td>5.21</td>
<td>5.43</td>
</tr>
<tr>
<td>Diffuse (SSE)</td>
<td>1.93</td>
<td>2.07</td>
<td>2.04</td>
</tr>
<tr>
<td>Total (SSE)</td>
<td>5.93</td>
<td>5.61</td>
<td>5.72</td>
</tr>
<tr>
<td>Direct (Meteonorm)</td>
<td>3.23</td>
<td>2.91</td>
<td>2.84</td>
</tr>
<tr>
<td>Diffuse (Meteonorm)</td>
<td>2.34</td>
<td>2.38</td>
<td>2.17</td>
</tr>
<tr>
<td>Total (Meteonorm)</td>
<td>6.03</td>
<td>5.73</td>
<td>5.42</td>
</tr>
</tbody>
</table>

\(^1\) These 3 points were chosen as examples as they lay within the boundaries of The Gambia and are available in the SSE database
2.3.1.6 Wind

The wind energy potential in Gambia is rather moderate.

The following wind map from the World Wind Atlas gives a first overview on the average wind speeds along the western coast of Africa in a height of 50m above ground. Gambia is located right in the centre of the following map (Figure 2-6) and shows average wind speeds between 5.5m/s at the coast and 3 m/s inland.

![Wind Map](image)

Figure 2-6: Annual mean value of wind speed 50m above ground

However this potential could be sufficient for power production with modern wind energy converters or water pumping.

2.3.2 Energy consumption

The gross energy consumption of the Gambia in 2000 was 332,900 TOE (which represents 0.26 TOE on a per capita basis, compared to gross energy consumption per capita of 0.62 TOE for Africa and 1.68 TOE for the World. The net energy consumption of the country in 2000, estimated at 299,000 TOE, was met by firewood (230,000 TOE), petroleum products (62,300 TOE) and to a very
limited extent by electricity (6,700 TOE). The biggest energy consumers were households (83%) and the transport sector (13%).

To meet its commercial energy demand including electricity, The Gambia entirely relies on petroleum. About 11% of the Gambian Import Volume was linked to petroleum and other fossil fuels in 1998.

2.3.3 Sector Organisation

Presently the whole energy sector responsibility lies with the Office of the President (OP). The two Divisions overseeing energy issues are the Petroleum Division and the Energy Division.

The Petroleum Division is responsible for the promotion of the country’s hydrocarbon potentials, negotiating the award of exploration and production licences, negotiating bilateral and multilateral co-operation agreements and developing policies and strategies to enhance the development of the industry.

The Energy Division formulates energy policies and supervises the activities of the Gambia Renewable Energy Centre, a body responsible for research, development and utilisation of alternate energy resources. The Division collaborates with the Department of Forestry within the Department of State for Agriculture on policy for fuel wood supply and demand.

The National Water and Electricity Corporation (NAWEC), responsible for the nation wide generation, transmission and distribution of electricity is supervised also through the Office of the President.

Other Departments of State are involved in the traditional energy sector through the implementation programmes aiming at biomass conservation. Among these are the Department of Community Development (DCD) in the Department of State for Local Government and Lands, promoting the use of improved wood stoves. The Department of Fisheries and the Women's Bureau implementing programmes on improved fish smoking ovens and the Forestry Department and the Gambia-German Forestry Project working on forestry management, the preparation of national inventories of forest resources and wood fuel supply management.

2.3.4 Sector reform

Regulations for full privatisation of the electricity sector are still in the preparatory stage. Funded by the World Bank, studies in the institutional arrangements are fast pace and the resulting modalities are expected soon. Investors needn't wait till then though, there is a clearly defined role already in place for the private sector in partnership with NAWEC.

The provision of efficient, reliable and affordable energy that is sustainable and environmentally sound is the main objective in the government energy policy framework.

Regarding the electricity sector, the core problems and objectives of the government remain the following:
Increase of generating capacity that is presently inadequate and unable to meet the demand. The government therefore seeks foreign and local partnership in increasing the generating capacity:

- improving efficiencies so as to reduce the extremely high cost of energy estimated at an average of USD 0.15.

The Government continues to undertake measures at overcoming these problems through institutional strengthening and other restructuring efforts. In that regard, the Government welcomes local and foreign interest in the sector so as to achieve, in the short to medium term, the following:

- Reduce the cost of electricity
- Increase the accessibility and supply reliability of electricity nation-wide, and
- Mitigate the environmental impact of the power sector

Strategies laid down for the electricity include the creation of a more conducive legal and regulatory framework, the formation of a partnership with the private sector, and the participation of independent power producers (IPP’s). Negotiations are being intensified with donor agencies and private companies on all these.

Further, electricity boards can not guarantee stable deliveries and power failures are frequent. This is of course a major obstacle for business in The Gambia. Most serious businesses, therefore, have their own generators, non-regarding costs being high.

### 2.3.5 Electricity Sub-Sector

Electricity consumption in The Gambia was around 80 GWh in 2002 or slightly more than 50 kWh/Capita and year. Additional energy needs were covered with fire wood (1800 kWh/Capita) and petroleum products (480 kWh/Capita). The major consumer have been private households.

The average weighted electricity tariff of NAWEC in The Gambia is currently USD 0.15 per kWh and thus among the highest in the World but also relatively high in comparison to the neighbouring Senegal (USD 0.12 / kWh) and Mali (USD 0.11 / kWh).

The Greater Banjul Area (GBA) is supplied from the Kotu power station by diesel-run generators with a total installed capacity of 43.7 MW. Two 33 kV transmission lines with a total length of 25 km convey energy from Kotu to 33 kV/ 11 kV substations. Lines at a voltage of 11 kV (total length 181 km) from the substations carry electricity to 11 kV/ 400-volt substations at various locations in the GBA feeding low voltage lines to three phase and single-phase consumers at 400 and 230 volts respectively.

Six isolated power stations; located at Mansakonko, Farafenni, Kerewan, Janjangbureh, Bansang and Basse supply electricity to rural areas or of The
Gambia. All these power stations are equipped with diesel-run generators, which supply electricity for 12 to 15 hours per day to in total 15 rural towns and villages. The following Table 2-3 summarises the existing generation and network infrastructure.

**Table 2-3: Generation and network infrastructure in the Gambia**

<table>
<thead>
<tr>
<th>Area served</th>
<th>Power Station</th>
<th>Capacity [kW]</th>
<th>33kV lines [km]</th>
<th>11kV lines [km]</th>
<th>No. of villages/ district towns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater Banku Area</td>
<td>Koto</td>
<td>43700</td>
<td>25</td>
<td>181</td>
<td></td>
</tr>
<tr>
<td>sum urban</td>
<td></td>
<td>43700</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rural</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mansakonko</td>
<td></td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farafenni</td>
<td></td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerewan</td>
<td></td>
<td>142</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jarangkunchi</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bansang</td>
<td></td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barra</td>
<td></td>
<td>840</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sum rural</td>
<td></td>
<td>2272</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An AfDB financed rural electrification project currently under implementation will increase the installed generation capacity in the urban areas to 6200 kW, extend the MV-lines to a total of 228 km and electrify an additional 30 villages i.e. in total to 46 villages. The service of power supply will be increased to 24 hours. The following Table 2-4 shows which of towns and villages will be connected via MV-networks to the power stations of Basse, Bansang, Kau-ur, Farafenni, Kerewan or Barra-Essau.

After completion of the described Rural Electrification Project still 60% of the population in Gambia will live outside the areas with electricity supply. In these areas electricity cannot be supplied economically by conventional grid electricity.
Table 2.4: Overview on the coverage of the rural electrification project

<table>
<thead>
<tr>
<th>Area served</th>
<th>Power Station</th>
<th>Villages’ district towns served</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basse / Mannah / Kobo / Katokar</td>
<td>Basse</td>
<td>Allunhari</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Massangano Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gambiai Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basse Njaga - Gbaba Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Numuyal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sabi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gombissara</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dingnir</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kelfa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gomar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Misina</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kobra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatako</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dobad Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sangambarere</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kungolou</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wassu</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sukuta</td>
</tr>
<tr>
<td>Basassang</td>
<td>Bansang</td>
<td>Fatako</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dobad Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sangambarere</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kungolou</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wassu</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sukuta</td>
</tr>
<tr>
<td>Kauur / Warf Town</td>
<td>Kauur</td>
<td>Jan Kunda</td>
</tr>
<tr>
<td></td>
<td>Farafenni</td>
<td>Soma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pakalinding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tomatola</td>
</tr>
<tr>
<td>Kerewan</td>
<td>Kerewan</td>
<td>Saba</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Salukkenni</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Njaba Kunda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suara Kunda</td>
</tr>
<tr>
<td>Banj / Essau</td>
<td>Banj</td>
<td>Madonna Kanuma</td>
</tr>
</tbody>
</table>

Other ongoing projects and developments in electric power supply:

The OMVG is currently embarking on a major infrastructure project including two hydroelectric power plants in Senegal and Guinea and a regional integration of power grids in the four member countries. A hydro-electric study for the benefit of the Gambia River Basin Development Organisation (OMVG) countries is now to be launched to detail and prepare the bidding documents for the Sambangalou and Kaléta hydroelectric power schemes and the interconnection of the power grids of the four countries. The first of the two large dams is in Southern Senegal at River Gambia. The second dam is on the Konkouré River in central Guinea. The larger of the two projects is the Sambangalou dam, which will have a capacity of 50 MW and produce around 400 GWh of electricity per year.

The two new hydroelectric power plants shall be connected to a new regional network. The plant at Kaléta (Guinea) will be connected to the nearby Guinean town of Mamou and to the Bissau-Guinean capital, Bissau. The Sambangalou plant (Senegal) will further connect to The Gambia’s capital, Banjul. Works on this integrated hydro-electric power grid are to start in the course of 2005.

In October 2000, 14 ECOWAS members signed an agreement to launch a project to boost power supply in the region. The West African Power Pool (WAPP) agreement reaffirmed the decision to develop energy production facilities and...
interconnect their respective electricity grids. According to the agreement, the WAPP will be accomplished in two phases but is planned to be fully implemented by 2005. The first phase involves countries that are already interconnected, including Nigeria, Benin, Burkina Faso, Cote d'Ivoire, Ghana, Niger and Togo. The second phase involves countries which are yet to have interconnection facilities, which include Guinea, Guinea-Bissau, Liberia, Mali, Senegal, Gambia and Cape Verde. Under the agreement, WAPP is expected to harmonise the regulatory framework that governs the electricity sector in each member country. Nigeria and the ADB signed a $15.6 million loan agreement in December 2002 for the interconnection of NEPA (Nigerian Electric Power Authority) and Compagnie Electrique du Benin (CEB) networks. CEB is the electricity transmission company for Benin and Togo.

2.3.6 Traditional Energy and Biomass Energy sub-sector

Traditional biomass energy i.e. mainly fuel wood is The Gambia's major source of energy. 90% of the gross energy consumption in 2000 were extracted from the forests and Savannas. Fuel wood is also in 95% of the urban households the principal source of energy, in rural households it is estimated that the fuel wood dependency is almost 100%.

Traditional fuels are mainly used for cooking and is mostly in the form of fuel wood, the bulk of which comes from the natural forest and the savannah areas. As the production and sale of charcoal is banned it is used only to a very limited extent. However it is estimated that 20,000 tonnes of charcoal enters the country from Senegal.

The Forestry Department issues licences to a maximum of 40 woodcutters per district for the exploitation of deadwood only, which is transported in trucks by wholesalers to the Greater Banjul Area. Fuel wood is also unofficially imported by ox-carts and trucks from Senegal. In the rural areas, women and children (mostly) collect fuel wood from the forest or Savannah to meet household needs.

Figure 2-7: Fuel wood sale on a Gambian highway

On the demand side of traditional biomass a large number of improved stoves projects which have been implemented or are under implementation, comprising
elements to reduce woody fuel consumption, by introducing improved cooking equipment and promoting efficient cooking techniques.

On the supply side a forest management concept including the sustainable use of forest energy resources which consists of the integrated implementation of specified management plans for state owned forest parks and community forestry reserves with the active involvement of the local population has been implemented in the recent years.

The current forest area and rate of depletion cannot sustain the supply of fuel wood resulting in its scarcity and a 75% increase in its price over the last three years. Competition for land use, made more acute by a 3.2% increase in the rural population, and previous overexploitation is decreasing the country's forest cover. The latest available evidence indicates a decline in the extent of close canopy forest cover from 7% of the Gambia in 1980 to 1% in 1997.

2.3.7 Renewable energy sub-sector

The government is encouraging the use of other energy sources. There is also potential to develop the use of wind energy. Both for power generation as well as for windmills to drive water pumps and irrigation systems.

The Gambia Renewable Energy Center has been established and seeks to collaborate with interested companies, individuals, development charities, research entities for the development of renewable energy. In the past years already some experiences with renewable energies has been made.

Solar water heating systems have been promoted mainly in the tourist industry to substitute diesel oil-fired and electric water heating systems with centrally operated solar water heating systems in tourist hotels.

At the moment utilisation of solar photovoltaic power is increasing in the country for both industrial, commercial and domestic uses. Examples for this technology are PV units in remote areas for rural health care and telecommunication systems, as well as solar photovoltaic water pumps in use for potable water supply and for irrigating small landholdings. A small hybrid PV-Diesel System was commissioned in 2004 for supplying electricity to the Darsilami small health centre, around 40 km south of Banjul.

A number of private firms are designing and selling solar powered electricity systems for domestic use and solar driven water pumps for communities. Further, a company is negotiating with the Government on the setting up of a park of wind-driven electricity generators in the GBA.

Modern biomass technologies are being utilised to some limited extend. They base mainly agricultural residuals such as groundnut shells and straw and or saw dust from the timber processing industry as feedstock.

In March 2005 Italian investors met the GoG in order to proposed the construction of a 10 MW waste-to-energy power plant.
An ongoing project in Solar Energy

GAM-Solar Energy & Engineering Co. Ltd. is a renewable energy and engineering company based in The Gambia, dedicated to the promotion and marketing of clean energy technologies including solar home systems, solar water heaters and energy efficient light bulbs. E+Co and the Rockefeller Foundation supported GAM-Solar in 1999 with a $30,000 loan for the preparation of a business plan and $125,000 in equity for working capital to implement a solar home 8 village pilot project.

As a result of the pilot project, GAM-Solar’s new business strategy is the implementation of a solar energy and electrical lighting efficiency plan in The Gambia serving 5,000 customers in the residential and commercial sector over 5 years. GAM-Solar will offer three types of energy services: Photovoltaic (PV) solar electricity systems, solar water heating systems (SWH) and energy efficiency compact fluorescent light bulbs (CFLs). Solar energy will provide households and businesses with electricity through the installation of solar systems ranging in size from 12 to 120 watts and portable PV lanterns, both through cash sales and short-term credit. Credit will be offered to qualified organisations, including the Village Development Committees (VDCs), Teacher's Credit Union and other credit unions, NGOs and employers that can make periodic deductions from their members or employees salaries. GAM-Solar is also considering providing a line of income generation equipment tied to solar energy sources to these organisations. In May 2001, E+Co approved an additional $30,000 loan to GAM-Solar to purchase equipment.

2.3.8 The Petroleum Sub-sector

Two multinational and two national newcomers supply liquid petroleum products by tanker from overseas via the oil terminal at Banjul Port, where a storage depot covering of 17,000 m³ is able to stockpile about 23 % of the annual national consumption, but which is due to size and insufficient infrastructure is not sufficient to quickly unload cargoes of the fuel.

The products are distributed by trucks tankers to 43 retailing stations throughout Gambia and to the Jet fuel storage at the Banjul Airport.

Liquefied petroleum gas (LPG) is imported by two multinationals and three local firms by truck tankers from Senegal. The fuel is kept in limited storage facilities and sold in cylinders ranging in size from 2.5 to 52 kg. In addition, unofficial importation of LPG is undertaken by small traders who buy small quantities of small-size cylinders (2.75kg and 6 kg) in Senegal at a subsidised price and re-sell them to the in The Gambia, at the going prices fixed by the official importers.

A 2200 ton LPG storage facility, with unloading devices for of LPG supply by sea, is being constructed by a private company.

A major constraint of the petroleum sub-sector is the small size of the market for petroleum products resulting in a lack of competition and a limited size of imported consignments which means relatively higher cost of shipping.
3 Progress of work

3.1 Kick off meeting

A kick-off meeting has been held at the energy division in Banjul 10th of February 2005 with the participation of:

- Mr. Bah F. M. Saho, Director of Energy
- Mr. Peter Gibba, member of the SMU
- Mr. Momodou L. S. Ceesay, member of the SMU
- and Mr Enrique Rodriguez-Flores, LI Project Manager.

Main outcomes of the meeting are:

- The draft version of the project manual has been presented and accepted by the client.
- An assistant project manager has been added to the team. He will take the role of solar expert and assist the project manager. Mr. Klaus cv has been reviewed and accepted.
- The office for the project team is foreseen to be installed at the Gambia Renewable Energy Centre (GREC) in Kanifing. The building will be visited by LI.
- The client will provide wind and solar data from the meteorological stations in Gambia for the preparation of the solar and wind map.
- The local economist is no longer available. A substitute has to be found.
- Since the advance payment was not yet made, the project start date could not be at that time determined.

3.2 Project manual

The first draft version of the project manual has been presented to the client during the kick-off meeting. Comments and additional information from the meeting have been integrated and a final version of the project manual been edited. It will be delivered to the client together with the present inception report.

3.3 Second Meeting

A second meeting has been held at the energy division in Banjul 4th of April 2005 with the participation of:

- Mr. Bah F. M. Saho, Director of Energy
- Mr. Peter Gibba, member of the SMU
- Mr. Momodou L. S. Ceesay, member of the SMU
- and Mr Enrique Rodriguez-Flores, LI Project Manager.
Main outcomes of the meeting are:

- The 4th of April is the official start date for the study.
- The SMU through Peter Gibba of the Department of Water Resources will provide a detailed map 1:25,000 of The Gambia.
- The SMU would have to obtain the land permits for the erection of measurement stations (an area of 40m x 40m is required per station)
- A station wagon will be shipped from Germany and will be arriving in May. The measuring equipment were also ordered and would be delivered in six weeks time. The SMU will assist with the necessary paperwork to enable them to discharge the goods through Customs as soon as they arrive. LI is responsible to make available all the details and Bills of Laden, so that the process of applying for duty exemption can be started.
- Government has provided office space at GREC to be used for the study. The required refurbishment and upgrading will be done strictly within budgetary limitations.

3.4 Procurement of equipment

3.4.1 Office

The proposed office space for the project at the Gambia Renewable Energy Centre (GREC) in Kanifing has been visited and the extent of refurbishment necessary been assessed and a civil contractor was contracted by beginning of April. Meantime the refurbishment and upgrading is almost completed.

3.4.2 Cars

Two cars have been ordered to serve the project team.

- Toyota Hilux Double Cab, 2.8 Diesel, 4x4, 4 doors, 5 seats, AC and Radio, origin: Japan
  This first car is already in use for the project.
- Toyota Land Cruiser Prado, 3.0 Diesel, 4x4, 5 doors, 10 seats, AC and Radio, origin: Japan
  The second car is expected to arrive in the country by 07.05.05.

3.4.3 Measurement equipment including measurement masts

As specified in the ToR 8 wind and solar radiation measurement stations will be installed in Gambia and operated. The equipment described in the following Table 3-1 has been ordered to be delivered to Gambia until the first week of May. The masts for installation of the wind and solar measurement sensors were manufactured locally. The specifications for these masts have been worked out and are given in Annex A (see chapter 8).
Table 3-1: Equipment for solar and wind measurement campaign

<table>
<thead>
<tr>
<th>Pos</th>
<th>Qty</th>
<th>article</th>
<th>additional specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>Data Logger EOL2020</td>
<td>incl. accessories</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sensors</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>Anemometer</td>
<td>Vector 100L2 incl. 35m cable, connector, mechanical adapter</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Anemometer</td>
<td>Vector 100L2 incl. 15m cable, connector, mechanical adapter</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>calibration</td>
<td>MEASNET certified wind tunnel calibration</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>Wind Vane</td>
<td>Ornityon 207 incl. 35m cable, connector, mechanical adapter</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Temperature</td>
<td>Temperature Sensor EOL 307 with radiation shield</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>Pyranometer CM6b</td>
<td>Pyranometer incl. 10m cable</td>
</tr>
<tr>
<td>7a</td>
<td>6</td>
<td>Pyranometer CM3</td>
<td>Pyranometer incl. 10m cable</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>Shadow Ring CM121B</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td><strong>auxiliary components</strong></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Amplifier CT24</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>solar power supply</td>
<td>10W incl. battery, charge controller, solar module</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>cabinet</td>
<td>electrical cabinet incl. mounting equipment</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>memory card</td>
<td>memory card for parallel port / Eol 2020 data logger</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>Laptop plus Software</td>
<td>2 CDs</td>
</tr>
</tbody>
</table>

3.5 Mobilisation of team

As specified in LI Technical proposal and in concordance with the ToR a pool of experts will be mobilised to the Gambia during the life span of the study. After a first 4-week assignment of the PM last month (April), the supervision and coordination activities are at this time under the responsibility of the APM.

The mobilisation and assignments of the consultant’ experts will follow the staffing schedule presented below.
# Renewable Energy Study for The Gambia

## Time Schedule for Key Personnel

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
<th>Phase IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrique Rodriguez Flores</td>
<td>Project Manager &amp; Wind Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Werner Klaus</td>
<td>PM Assistant &amp; Solar Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norbert Ernstorfer</td>
<td>Expert for Demand, Economics &amp; Insti. Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jacob Richt</td>
<td>Wind Energy Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Michael Ortmann</td>
<td>Solar and Biomasse Energy Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martin Kaltschmitt</td>
<td>Biomasse Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enrique Riegelhaupt</td>
<td>Fuel Wood Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. von Hermanni</td>
<td>Waste Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nana Kanneh</td>
<td>Financial &amp; Micro Credit Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To be defined</td>
<td>Environmental Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Iza Mohamedou</td>
<td>Social &amp; Gender Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willio Njaga Sarre</td>
<td>Local Coordinator &amp; Renewable Energy Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alagie Conteh</td>
<td>Electrical Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To be defined</td>
<td>Legal Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To be defined</td>
<td>Social &amp; Gender Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To be defined</td>
<td>Economist / Financial Expert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Local Experts                       | Local Experts                                    |         |          |           |          |

*Figure 3-1: Time Schedule for Key Personnel*
Organization of Project Team

Consultant’s Study
Supervisory Committee
Dr. A. Wiese
Dr. H. Hermes

Energy Division, Gambia

Project Manager
Enrique Rodriguez-Flores

Assistant Project Manager
Werner Klaus

Technical Experts
Wind and Rural Electrification Expert
Enrique Rodriguez-Flores
Biomass and Waste Expert
Dr. Martin Kaltschmitt
Solar and Rural Electrification Expert
Werner Klaus
Fuel Wood & Forestry Expert
Enrique Riegelhaupt

Economic and Financial Experts
Expert for Demand, Economics & Instit. Analysis
Norbert Eisenabrger
Financial & Micro Credit Expert
Dr. Hajo Kasseling

Social, Environmental and Legal Experts
Environmentalist
N/N.
Legal Expert
N/N.

Core Team

Support Team

Figure 3-2: Organisation of Project Team

May 2005
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4 First Results

4.1 Collection of Climate Data

In order to define a measurement strategy and including the identification of solar and wind measurement, an analysis of the regional wind and solar regime has been made (see chapter 4.2 and 4.3 below). This includes the collection of historical wind and solar data. Therefore the authorities in the Gambia, which are responsible so far for the collection of such data have been identified.

The water resources (meteorological) department operates a network of meteorological stations throughout the country. The stations are shown in the following Figure 4-1.

![Network of meteorological stations in The Gambia](image)

*Figure 4-1: Network of meteorological stations in The Gambia*

Data has been collected by the project manager. This data has been analysed and processed by the wind and solar resource experts.

The data obtained includes
- hours of sunshine per day
- mean monthly wind speed
- prevailing wind direction per month

The data required would have
- solar radiation like daily sums of global and direct or diffuse irradiation or hourly irradiation data
- statistics or time series for wind speed and wind direction
- exact location (co-ordinates, height above sea level) of weather station and height above ground of wind speed measurement

Thus the data obtained does not provide the information required to be utilised for the preparation of the zero wind map and the zero solar map.

Consequently the consultant had to base its calculation on data from international databases.
4.2 Zero Map for Solar Incidence

4.2.1 Methodology
Annual sums of global solar radiation have been retrieved from the METEONORM database in a 10x10 km grid for the entire Gambia. A map has been prepared by creating a continuous field through steady interpolation of these values.

4.2.2 Results
According to the zero solar map (see the following Figure 4-8) which shows the geographical distribution of the annual sums of global solar radiation on an inclined plane (optimum inclination for maximum annual solar energy reception: 17°) in The Gambia one notes a slight gradient from 2080 kWh/m² year (equivalent to 5.7 kWh/m² day) in the Banjul area and North Bank District to 1880 kWh/m² year (equivalent to 5.1 kWh/m² day) at the eastern tip of the country.

These results from the METEONORM database in general show smaller values than the data from the NASA-SSE database mentioned in chapter 2.3.1.5 and the values given in the terms of reference.

The discrepancies in the data from international databases show that there is a need for a precise measurement campaign in order to obtain precise data on solar radiation. (See also analysis in chapter 2.3.1.5)

4.3 Zero Wind Map

4.3.1 General methodology for the zero wind map based on KLIMM Model calculation
Whenever only a limited number of measurement points or only data from the international databases is available like it is the case for The Gambia (see chapter 4.1) LI applies its three dimensional mesoscale atmospheric model KLIMM to calculate a first version of a wind resource map. In later stages of the study the data obtained during the measurement campaign will be incorporated and the map can be recalculated obtaining an exceptional high degree of detailed wind information.

Over the past years LI has successfully elaborated a large number of wind maps based on this KLIMM model approach. The main advantages of Lahmeyer's model KLIMM – which was developed together with the University of Mainz – are:
- It can be applied both in complex as well as in flat terrain, with different grid resolutions used for the calculation.
- The resulting information is three-dimensional, covering large areas.
- Only a few measurement sites are necessary to obtain precise data for large areas.
- The information of the regional wind conditions is readily available.
- High transparency of the results is achieved by presentation in form of wind potential maps or a computer information system.
The model can be upgraded into a wind information system or graphical systems, which allows the client to update the national wind map, print out zooms for certain regions or add new wind data into the map.

LI was engaged as a partner in a research project in which the KLIMM model was used as the basis for an online wind power prediction model. Consequently, the KLIMM model has now been extended as a base for wind power prediction.

The KLIMM model, which will be used in this project, is a three dimensional numerical mesoscale model of the atmosphere which allows simulating wind situations at any point in the atmosphere. Combined with an analysis of typical weather situations as well as locally measured wind resource data, the long-term annual wind speed for any location can be calculated. KLIMM has already been applied successfully in several projects. Numerous comparisons between measured and simulated wind velocities show a difference of less than 8%. Other methods of wind prediction usually show significant larger deviations.

As listed in Figure 4-7 the model only requires the following input data to compute the desired results:

- Geodetic height data (satellite or geographic maps),
- Information on land-use (satellite or topographic maps),
- Measured geostrophic wind at one location (meteorological office),
- Measured wind velocities at a few number of wind monitoring stations (meteorological office, airports or additional wind monitoring stations).

![Diagram](image)

**Figure 4-2: Calculation procedure for the wind potential estimation with the three dimensional atmospheric model KLIMM**

Figure 4-3 shows the simulation method of KLIMM. As can be seen, it is a „top-to-bottom“ approach. Starting from the distribution of the geostrophic wind, the model calculates the wind direction and the wind velocity for each grid cell.
Geostrophic wind distribution

Calculated local wind direction and velocity distribution

Measured local wind direction and velocity distribution

Figure 4-3: Simulation method of the model KLIMM

The collected information and all gathered wind resource data at individual sites will be fed into the KLIMM model. The results of the KLIMM calculations are:

- the long-term annual mean wind velocity,
- the wind direction distribution at any point of interest in any height above ground and
- Wind Speed Frequency distribution for each sector at any point of interest.

It is also possible to import these results into e.g. WindPRO for the calculation of more precise energy yield predictions.

The prediction accuracy of a wind map modelling at a specific site cannot be the same as the result of a long-term wind measurement. However, with the results of KLIMM it is possible to predict the average mean wind velocity in sites without wind measurements at a reasonable accuracy.

For the validation of the model long-term comparisons with measured wind data have been carried out in the course of projects. The results of the various comparisons are summarised in the following table. Generally, deviations of less than 8 % occur for various regions of complex terrain and at different heights above ground (see the following Table 4-1).
### Table 4-1: Comparison between measured and calculated wind speeds

<table>
<thead>
<tr>
<th>Measurement Site</th>
<th>Height above Ground</th>
<th>Wind Velocity/Measurement</th>
<th>Wind Velocity/Model</th>
<th>Deviation / Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koramshar</td>
<td>30 m</td>
<td>5.5 m/s</td>
<td>5.5 m/s</td>
<td>- 0.13 %</td>
</tr>
<tr>
<td>Behbahan</td>
<td>30 m</td>
<td>4.8 m/s</td>
<td>4.7 m/s</td>
<td>- 1.27 %</td>
</tr>
<tr>
<td>Dezfull</td>
<td>30 m</td>
<td>4.2 m/s</td>
<td>4.1 m/s</td>
<td>- 1.34 %</td>
</tr>
<tr>
<td>Masjed - Soleymansar</td>
<td>30 m</td>
<td>2.9 m/s</td>
<td>3.0 m/s</td>
<td>+ 1.05 %</td>
</tr>
<tr>
<td>Italy / Sardinia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aglientu</td>
<td>40 m</td>
<td>6.1 m/s</td>
<td>5.7 m/s</td>
<td>0.9 %</td>
</tr>
<tr>
<td>Arzachea</td>
<td>40 m</td>
<td>4.2 m/s</td>
<td>4.2 m/s</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Benetutti</td>
<td>40 m</td>
<td>3.5 m/s</td>
<td>3.9 m/s</td>
<td>1.1 %</td>
</tr>
<tr>
<td>Bitti</td>
<td>40 m</td>
<td>8.0 m/s</td>
<td>7.4 m/s</td>
<td>0.9 %</td>
</tr>
<tr>
<td>Domus de Maria</td>
<td>40 m</td>
<td>5.3 m/s</td>
<td>5.1 m/s</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Giave</td>
<td>40 m</td>
<td>4.6 m/s</td>
<td>4.4 m/s</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Luras</td>
<td>40 m</td>
<td>6.3 m/s</td>
<td>5.5 m/s</td>
<td>0.9 %</td>
</tr>
<tr>
<td>Macomer</td>
<td>40 m</td>
<td>5.1 m/s</td>
<td>5.2 m/s</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Ozieri</td>
<td>40 m</td>
<td>4.1 m/s</td>
<td>4.5 m/s</td>
<td>1.1 %</td>
</tr>
<tr>
<td>Putifigari</td>
<td>40 m</td>
<td>6.6 m/s</td>
<td>6.2 m/s</td>
<td>0.9 %</td>
</tr>
<tr>
<td>Sadali</td>
<td>40 m</td>
<td>5.1 m/s</td>
<td>4.6 m/s</td>
<td>0.9 %</td>
</tr>
</tbody>
</table>

A comparison between model results and measured data for a project site in Italy is shown in Figure 4-4.
4.3.2 Approach for The Gambia

As the required wind statistics could not have been obtained the KLIMM model calculation for the zero wind map had to be based on Climate Recalculation Data published by NCEP (The US hosted National Centres for Environmental Prediction) data. This data is for example also the base data for the World Wind Atlas and is available in a grid resolution of 2.5° world wide.

For the topographic data the consultant information base is published data from the NASA Shuttle Radar Topography Mission which provides topographic data on a grid of 100 m x 100 m resolution. The land use data is extracted from the MOD12Q1 V004 database. These input data for the KLIMM Model is shown in the land use map of The Gambia (see Figure 4-5) and the topographic data (see Figure 4-6).

These data has been verified and prepared for processing. The wind map has been computed in the high grid resolution of 250 m x 250 m throughout The Gambia.

4.3.3 Results from the KLIMM calculation

Some of the results of the KLIMM Model calculation are given in the maps given in Figure 4-9, Figure 4-10 and Figure 4-11 showing the mean annual wind speeds at the height of 10m, 50m and 100m above ground. The numeric data is available from the Wind and Solar Energy Information System (WSIS) which will be handed over to the client. It is a computer database including a graphic user interface for
easy data access. It allows to obtain the exact numeric value for Wind in several heights and solar radiation at each point in The Gambia.

The wind energy situation in The Gambia

The zero wind map confirms the preliminary overview obtained from the World Wind Atlas data with regard to the energy potential which seems to be moderate in The Gambia. The average wind speeds along the coast are much higher than the inland wind speeds and the main wind direction is predominant west.

Although this preliminary result could encourage the use of wind energy for power production with modern wind energy converters or water pumping, a precise measurement campaign for obtaining more accurate information is absolutely necessary.
Figure 4-5: Land use map of the Gambia
Figure 4-6: Topographic map of the Gambia
Figure 4-7: Administrative map of the Gambia showing the locations of the wind and solar measurement stations
Figure 4-8: Zero solar map of The Gambia: Mean annual solar radiation on a 17° inclined surface pointing to the equator
Figure 4-9: Zero wind map of The Gambia at 10m above ground
Figure 4-10: Zero wind map of The Gambia at 50m above ground
Figure 4-11: Zero wind map of The Gambia at 100m above ground
4.4 Measurement Campaign Locations

Following the proposed methodology, the Consultant and SMU team embarked on a nation wide site identification and selection process of suitable areas for the measuring of renewable energy (solar and wind) resources potential.

The Department of Water Resources meteorological observation stations were visited and inspected including sites where this organisation has not yet established its presence.

Selection Criteria

In selecting a site, the following criteria listed below were considered:

- The site shall be rich in wind and solar isolation renewable resources and representative for a further mapping taking in consideration as main input for this the prepared zero solar and wind maps
- The site shall be free from obstacles such as tall buildings, trees that may distort renewable resources behaviour pattern
- The site shall be located in an environment secured against burglar and vandalism

4.4.1 Selected sites for wind and solar radiation measurement

Eight sites have been identified and proposed for selection as GREC stations for the installation of measurement instruments of renewable resources. The sites are proposed to be located in Kanuma, Kerewan, Yalla, Njau, Sare Sofie, Fatoto, Sibanor and Jambajelly. Four sites each are selected on both banks of the river and their exact locations are given in the following Table 4-2. The position of the stations is also shown in the Figure 4-7 on page 31.

Table 4-2: Position of identified measurement station

<table>
<thead>
<tr>
<th>Code</th>
<th>Site</th>
<th>Elevation (m.a.s.l.)</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREC 01</td>
<td>KANUMA</td>
<td>10</td>
<td>13.48189° N</td>
<td>16.48643° W</td>
</tr>
<tr>
<td>GREC 02</td>
<td>KEREWAN</td>
<td>20</td>
<td>13.49219° N</td>
<td>16.09440° W</td>
</tr>
<tr>
<td>GREC 03</td>
<td>YALLAL</td>
<td>35</td>
<td>13.55378° N</td>
<td>15.69944° W</td>
</tr>
<tr>
<td>GREC 04</td>
<td>NJAU</td>
<td>22</td>
<td>13.74594° N</td>
<td>15.21304° W</td>
</tr>
<tr>
<td>GREC 05</td>
<td>SARE-SOFFIE</td>
<td>20</td>
<td>13.41866° N</td>
<td>14.52027° W</td>
</tr>
<tr>
<td>GREC 06</td>
<td>FATOTO</td>
<td>22</td>
<td>13.39663° N</td>
<td>13.89375° W</td>
</tr>
<tr>
<td>GREC 07</td>
<td>SIBANOR</td>
<td>27</td>
<td>13.20991° N</td>
<td>16.19671° W</td>
</tr>
<tr>
<td>GREC 08</td>
<td>JAMBANJELLY</td>
<td>14</td>
<td>13.28351° N</td>
<td>16.72891° W</td>
</tr>
</tbody>
</table>
SMU shall facilitate the provision of land use rights for the proposed eight sites to enable the consultant proceed with the installation works of equipment.
5 Methodology of work - First Phase - Masterplan Elaboration

5.1 Energy Demand Assessment

The forecasting activities in the course of the Project, will be executed in two distinct but interrelated steps:

1. Development of a general demand forecast for the entire Gambia, which will be used in order to identify those areas, where the implementation of renewable energy measures is possible. This forecast will cover different customer categories and all relevant types of energy services, like cooking, lighting, pumping, cooling, industrial heat etc. The planning horizon is 2025.

2. Detailed analysis of the expected demand development for those areas (projects) and demand types which are identified as most promising and are selected for further detailed analysis in the course of the Feasibility Study.

Taking into consideration the highly fragmented electricity supply system in the Gambia, the large variety of different energy sources as well as consumption patterns of different consumer groups, a top-down analysis approach will provide little suitable outcome. The consultant will therefore base his demand forecast on a well-proven bottom-up approach (as delineated in the following paragraphs). Furthermore, the demand analysis and forecast will be strongly guided by the structural requirements (e.g. formats) of the renewable energy master plan task:

- Geographic analysis structure: Similarly to the assessment of the different renewable energy potentials in Gambia, the demand analysis and forecast will be based on the basic geographic division of Gambia into the 39 districts.

- Existing isolated grid areas and cross-district electricity supply in the GBA and the six independent supply systems outside GBA will be considered.

- Consumer structure: The demand analysis will be based on a distinction of different consumer groups, each characterised by specific consumption patterns. Consumer groups will be defined by electricity access, income level and household location i.e. rural/urban.

- Energy sources and needs: The analysis will give special weight to those types of energy consuming activities which can be served by renewable energy sources whereas those energy forms which do not offer such potentials (e.g. high temperature process steam for industrial purposes) will be studied in much less detail.

The 20-year planning horizon will be subdivided into 5-year-periods. The demand forecast will follow this structure. Starting from the base year data, assessed in the geographic, social and technical structure as delineated above, demand projections will consider:

- Population increases due to carefully assessed growth rates per consumer group;

May 2005

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- Migration effects (international, cross-district migration and urbanisation trends within a district);
- Income structures of different consumer groups over time as well as related energy consumption pattern.

The resulting demand forecast will comprise different scenarios each reflecting a different set of assumptions.

Besides this demand forecast, the consultant will assess possibilities to influence demand development and consumption patterns. Based on the baseline demand projection, the Consultant will identify the most critical supply gaps arising in the future and will focus his analysis on these priority areas for policy action.

It is evident, that the general forecast in the first phase, which is assumed to be covering the entire country, all consumer groups, and the development and interrelations between all possible sources of energy, like fuel wood, kerosene, candles, batteries, electricity, gas, etc. can only be executed on a generalised level. Selected field investigations will be executed for such areas, which during an initial assessment of available information and data, like the previous forecasts, demographic data, income distribution, environmental data, etc. are identified as typical for a larger part of the overall population and which are therefore deemed exemplary for this group of customers.

For the second (feasibility) phase more detailed field investigations will be executed, in order to reconcile the assessments made in the first phase forecast, and in order to identify and consider those specific aspects and developments on project-level which might not have been reflected in the first phase exercise on country and district level.

For electricity the following more detailed investigations will be executed.

- an estimate of the peak requirements for the identified areas and consumer groups (considering technical losses in the future network as well as the coincidence factors to be applied to the loads in the individual load centres served by potential sources of electricity supply)
- load curves for the potential sources of supply
- alternative high and low demand scenarios.

Peak demand, minimum demand and load curves will provide the necessary information for the layout and design of the sources of supply.

The whole effort will finally resulted in the creation of a tailor made, comprehensive forecasting model on spreadsheet basis for all sources of energy. Its design will be determined by the master plan exercise.
5.2 Renewable Energy Resource Assessment Outline of General Strategy

The overall approach for this task is given in the following figure. It resumes the consultants approach for the preliminary identification of the most interesting Renewable energy technologies to be considered in the RE Master Plan for the Gambia.

![Diagram](image)

**Figure 5-1: Approach for the RE resource assessment in an overview**

In the first step the theoretical potential for renewable energies will be assessed. It refers to the physical, meteorological or biochemical energy available in a certain region and at a certain time or period, i.e. the radiation energy received at a certain
place, the potential energy of water running down a certain river or the kinetic energy of wind in a definite area and time.

The **technical potential** is defined as the share of the theoretical potential which can be utilised given the technical and also non technical (legislation, ecological) restriction, which are insuperable like the technical restrictions. The technical potential always is related to a certain technology, thus different there exist technical potentials depending on the chosen technology.

The **economic potential** describes that part which is under micro or macro economic criteria utilisable in an economic way. This means that the economic potential depends on the cost of fuel or unit costs from alternative energy systems as well as on financing parameters like interest rate, depreciation time and equity capital. It also depends on the seize and total number of the systems to be implemented, thus demand side factors are relevant for the analysis.

The **exploitable potential** denominates the share of renewable energy which can be expected to be utilised considering restrictions like production capacity, market structure, operability of competing systems, subsidies, etc. The exploitable potential might be due to subsidies larger than the economic potential.

An overview on the special potentials is given below.

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**Figure 5-2**: The relation of theoretical, technical, economic and exploitable Potential

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May 2005
The technological potential is related to certain conversion technologies i.e. technologies allowing to use a natural resource to provide heating, lighting, mechanical power or electrical power for example. Therefore the consultant will assess the technologies applicable and appropriate under the special conditions of The Gambia. In a second step the technical potential will be assessed for each type of conversion technology.

The following matrix shows our preliminary selection of technologies which the Consultant will consider for the technical potential assessment:

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**Figure 5-3: Preliminary selection of conversion technologies for each type of renewable energy source and energy application**

Other technologies like micro-hydro and geothermal energy can prima face be ruled out as the Gambia does not dispose of the required resources.
The output of chapter 5.2 will be a renewable energy database quantifying the theoretical, technical and economic potential (per conversion technology see matrix in Figure 5-3 above) per division.

Furthermore the renewable energy opportunities to be considered for the RE Master Plan will be identified.

5.2.2 Wind and Solar Energy

5.2.2.1 Purchase of the Measurement Equipment

Immediately after receipt of the advance payment the Consultant has send out the official order of meteorological measurement equipment (see chapter 3.4.3). The measurement equipment satisfies the specifications given in the proposal.

The mast height of the stations was chosen considering the desired accuracy of the wind prognosis, cost and necessary work for installation. The Consultant will install eight masts of 30 m height each for wind measurement and also eight small tables for the solar radiation measurement.

Regarding the mast type, our assessment has revealed that locally made lattice masts are available in The Gambia. Therefore we decided to use this types instead of tubular aluminium masts. The lattice type mast allow easier access to the sensors which is advantageous during the operation period. In any case we can assure that with both types of masts the objectives of the project can be achieved entirely.

The download of data will be done manually and using GSM data remote transfer systems. A laptop for data download will be delivered.

Solar radiation sensors

There are different types of solar irradiation sensors on the market. The Consultant decided to fully equip two stations with high precision pyrometers to measure global and diffuse radiation. The remaining sensors will be equipped by class II radiation sensors:

- Two high precision pyrometers (class I according to the ISO 9060 / WMO standards) for measuring the irradiance on the horizontal plane resulting from radiant fluxes in the wavelength range from 0.3 to 3 micrometers, i.e. solar radiation. (Manufacturer: Kipp & Zonen, Type: CM 6b)

- Two high precision pyrometers (class I according to the ISO 9060 / WMO standards) with shadow ring for measuring the diffuse solar irradiance on the horizontal plane. (Manufacturer: Kipp & Zonen, Type: CM 6b + CM 121)
Six precision pyrometers (class II according to the ISO 9060 / WMO standards) for measuring the global solar irradiance on the horizontal plane. (Manufacturer: Kipp & Zonen, Type: CM 3)

As referring to the ToR, the assessment of the solar resource is limited to the use of photovoltaics and low temperature solar thermal technologies. By measuring also the diffuse component of the solar radiation at 2 sites also the direct normal insolation can be calculated allowing to assess the potential for high temperature solar applications like solar thermal power generation.

5.2.2.2 Installation of the measurement stations

Installation can start after the following three milestones have been achieved successfully:

- All equipment delivered and out of custom
- Measurement strategy defined
- Detailed sites for the measurement stations identified

Only after these milestone has been achieved, our team will start with the installation of the equipment. The Project Manager and/or his Assistant will supervise and co-ordinate the entire installation activity. This will be done as follows:

1. The installation team will consist of
   - The Project Manager or Assistant Project Manager
   - The local co-ordinator
• Up to three additional helpers, who will be assigned on short term basis to assist in the foundation preparation, mast mounting and local transport

2. The PM or APM will supervise and co-ordinate the first installation full time.

3. In the second installation, the co-ordination task will be overtaken by the local co-ordinator, whereby the PM or APM will remain in the supervisory role on site.

4. The installations No. 3 to 8 will be executed without the permanent presence of the PM or the APM, who will only at the end of the 8th installation mission execute a travel along all measurement systems to approve all installations and issue the Certificate of Installation. During the installation of stations N. 3 to 8, the local co-ordinator will supervise and co-ordinate the installation activities.

It is assumed that the total installation period takes a period of four weeks. The time depends not so much on the actual installation time per measurement station, but to a much greater extent on the logistics and required curing time for the civil works. Our experience shows that it is possible to install up to one system per day if
• everything is properly prepared,
• the team is sufficiently experienced and
• there is full support on community level available.

Each of the eight installations will be performed according to the following subsequent working steps.
• Site preparation, this means digging holes for the anchors and the centre base, foundation of the anchors and the centre
• Transport of the team and the measurement equipment to the respective locations
• Erection of the mast
• Installation of the measurement equipment on the mast (sensors, cables, data logger, power supply equipment)
• Commissioning of the measurement station

After installation, all measurement stations will be checked and approved by the Project Manager. A Certificate of Installation will be issued for each station, verifying that the system has been installed according to the required standards and requirements. First data and review the operation of the station will be carried out.

5.2.2.3 Data Collection and O&M of the stations

Data collection will start at each measurement station after commissioning. Data download need to be performed regularly. Based on the offered systems and on our experience of similar measurement campaign, we suggest that the data...
download shall be done every 6 to eight weeks. The stations for measurement of
global and diffuse radiation have to be visited more frequently to adjust the shadow
ring to the actual path of the sun.

The data download will be executed by the local co-ordinator, who will receive a
theoretical training before the installation and a practical training during the
installation and commissioning of the measurement stations.

Usually the measurement stations are maintenance free. However, during each
visit of the stations, the local co-ordinator will also carry out a station inspection.
For this he will fill out and sign a station inspection protocol. In case of
identification of failures or problems with the stations, these will be reported in the
inspection protocol and immediate repair action will be initiated after analysis by
the project manager. The station inspection protocol will be archived so that later a
complete documentation of the entire measurement campaign for each station will
be at hand at the end of the project.

Data collection will be done by exchanging the data logger memory on site and
taking it back to the office in Banjul, by using the provide lap top and by remote
data transfer through the GSM system.

5.2.2.4 Data Archiving
The Consultant will develop a computer based wind and solar data base. This data
base will be installed in the computers of the project, which will later be handed over
to the client. A manual will be prepared with explanations of the structure of the data
base and how to use it.

5.2.2.5 Data Analysis
For a proper analysis of the expected long term average wind speed and seasonal
characteristics, as well as for the estimation of the long term solar mean radiation,
a measurement period of at least one year is recommended. However, we assume
that the historical data will provide sufficient reliable information about the seasonal
characteristics, so that a measurement period of less than a year is sufficient.

Given the foreseen time period of measurement, we propose that two interim data
analysis and one final data analysis will take place.

For all eight stations, the Consultant will analyse the data in order to make a long-
term prediction of the annual wind speed and the solar radiation. In order to
achieve this, the Consultant will perform the following:

- Data processing of the measured wind and solar data
- Plausibility checks with available software routines
- Calculation of the data recovery rate per each sensor
- For wind speed: Calculation and visualisation of the frequency distribution,
  Weibull parameters, wind shear, turbulence, wind rose
- For wind and solar data: Calculation and visualisation of daily and seasonal
  characteristics
For wind and solar data: calculation of the long term annual expected mean wind velocity and solar radiation

Each analysis will be compiled and documented in a Wind and Solar Data Analysis Report (WSDAR).

This analysis will also incorporate an important training and transfer of know-how to the local partners and SMU members. The first data analysis will be carried out in The Gambia together with the SMU meteorologist and the local co-ordinator & renewable energy expert of the Consultant team.

The second and third data analysis will be carried out by the local meteorologist alone, the resulting report will be quality audited by a Lahmeyer expert.

5.2.2.6 Wind and Solar Potential Assessment

Based on the historical data and the data collected in the 8 meteorological stations, the Consultant will assess the potential of wind and solar resources in The Gambia. The basis of this assessment will be the analysed and evaluated data from measurement campaign.

**Wind Energy**

Due to the fact, that The Gambia is mostly flat with only little elevation (max. 53 m a.s.l.), the data gained from eight stations could – considering a proper distribution of the same stations – should provide a dense grid of evaluation nodes.

By using this data grid, we will be capable to predict yearly summaries for almost every location within the countries limits. One station would – theoretically – collect data for a cell of 25 km x 25 km, which will provide an adequate data density for a good technical and/or financial feasibility study.

In addition to the ground measurements of wind speed, the Consultant will also provide an potential analysis based on the KLIMM mesoscale model, where the local wind speed are calculated from atmospheric wind measurement data. Lahmeyer International has been one of the developers of this KLIMM model and already has been able to prove its advantages in various projects, especially for wind energy resource assessments in large areas.

The wind potential assessment, based on whatever data, will result finally in a Wind Potential Assessment Report, which will include all relevant information of the measurement campaign and the wind potential assessment. It also will include a wind resource map for the entire Gambia.

**Solar Energy**

Similar to the Assessment of the Wind Resources, the solar energy potential will be assessed based on the historical and measured data. Again, the grid of stations – considering 8 operative stations – is very dense, so that a high accuracy of interpolated data will be expected.

The main aspect of the potential analysis will be the evaluation of the micro and local climate, mainly considering clouds and sky covering during the rainy season (June to November), the pre- and post rainy seasons and expected frequencies of
coverage ratios. Based on this long term examination of the historical data, a good forecast for every location within the countries limits can be done by adjusted bi-cubical or statistical interpolation of three or more close meteorological stations.

The solar energy potential assessment, based on whatever data, will result finally in a Solar Energy Potential Assessment report, which will include all relevant information of the measurement campaign and the solar energy potential assessment.

5.2.3 Fuel Wood, Biomass and Waste

The approach to determine the country's bio-mass, particularly fuel wood potential and waste potential is as follows:

The consultant team includes experts for fuel wood, for bio-mass and for waste with extensive experience in potential assessment and energy applications of such resources. The bio-mass, fuel wood and waste resource potential will be executed by these experts. They will be assisted by the local co-ordinator in particular in the field of data collection.

Our bio-mass, fuel wood and waste potential analysis will include the following main resources:

- Fuel wood across the country and actual import
- Wood waste from wood industry
- Agricultural residues
- Animal dung
- Solid and liquid municipal and industrial waste

At the beginning of this sub-activity, the wood-fuel, bio-mass and waste experts will together prepare a questionnaire in the home office, with the aim to receive an overview of the available data and information about the available bio-mass in the country. This questionnaire will be transmitted to the local co-ordinator, who will approach the respective authorities and collect as much as possible information about the bio-mass resource.

The bio-mass expert will then execute a mission to the Gambia during which he will carry out the following:

- Develop a computerised data base in which the data of bio-mass and waste resource will be systematically archived. This will include e.g. resource classification, description of resource, location of the resource, daily, monthly and annual amount in t, percentage of what is potentially available for energy generation purpose. This data base will also include existing practice of wood import.
- Assess the spatial distribution (maps) of the tree-based vegetation types in relation to the location of the local populations; Determine the precise demand for tree products in terms of wood-energy, species preferences
- Assess the available resources through three components: literature review on key components, assessment of available information on species preferences
amongst the rural stakeholders; and collection of missing data (this will be determined by practices)

- The data base will be installed in the computers of the project, a brief description will be prepared and both will be handed over to the client so that he will be able to update the data base after project completion by himself.
- The bio-mass resources will then be ranked according to their suitability for energy generation purpose.
- For the most priority resources, the bio-mass and the waste expert will identify and propose suitable technologies for energy conversion. The local mission of the bio-mass expert will be supported by remote assistance of the waste expert from Lahmeyer head office. These technologies will be described and analysed with regard to the general application constraints in the Gambia and necessary technology adaptations.
- As one part of the latter activity, the bio-mass expert will review the previous experiments of the Livestock Services Division of the Department of State for Agriculture with regard to bio-gas production out of animal waste. Lessons learnt will be formulated. We would like to highlight here that our foreseen bio-mass expert has particular experience in bio-gas technology and that we expect that the expert from the Department of State for Agriculture will particularly benefit from this experience.
- Another area of special attention is the analysis of sustainability of fuel wood utilisation. The actual fuel wood utilisation will be assessed, the maximum amount of sustainable fuel-wood will be estimated and both compared. The Consultant will document and assess wood supply organisation. Based on the resource assessment described above, he will match the assessed resource use needs with the availability of the resources. Then he will identify the key constraints, opportunities and threats together with other members of the relevant stakeholders. The improvement of current activities and practices will be considered, to develop the project framework and draft management plan. To this end, the Consultant will review all available data on the agents involved, prices charged and value added at the various stages in the wood supply chain in The Gambia. Interviews will be held in order to attain secondary data and to complete information on wood supply organisation and price structures available in documented format. The assessment will take into account, as far as applicable, legal factors, such as wood cutting quotas, will point out pitfalls in the organisational structure and will comment on technical and commercial capabilities emerging from the interviews. Socio-economic indicators, including the involvement of women and possibly children in wood supply activities such as the collection, sale and transport of wood as well as general gender responsibilities and agents' incomes will be accounted for. This will then also result in formulation of recommendations with regard to the informal import of wood.
- The wood fuel, the bio-mass and the waste expert will prepare at the end of this subjectivity a Bio-mass, Woodfuel and Waste Potential Assessment Report, in which the main results and conclusions of this sub activity will be
included. This report will be submitted to the Project Manager, who will be responsible for the preparation of the Overall Resource Assessment Report.

5.2.4 Overall Renewable Energy Resource Assessment

Summarising the previous sections, the individual renewable energy resources will be assessed by the following team experts:

Table 5-1: Overview Renewable Energy Resource Assessment

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Resource</th>
<th>Responsible experts</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wind and Solar</td>
<td>- Project Manager / Assistant Project Manager</td>
<td>- 8 measurement stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Local Co-ordinator</td>
<td>- 8 measurement campaign</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Wind and Solar Data Base</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Preliminary Wind and Solar Resource Assessment Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Final Wind and Solar Resource Assessment Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Local Co-ordinator</td>
<td></td>
</tr>
</tbody>
</table>
5.3 Sector and Criteria Study

The sector and criteria report aims at eliminating to largest possible extent the likelihood of fundamental changes and revisions of the proposed study work during later project phases. Therefore, the Consultant will compile the most important input data on which its further analysis will be based for approval and confirmation by the client. This relates especially to policy-dependent market data such as tariffs or sector legislation as well as projections of official Government entities on how these policies will develop in a baseline scenario.

Furthermore, the report will specify planning assumptions and will justify chosen methodological approaches proposed and prepared by the Consultant. In this context, the report will especially clarify the link between the REMP and further planning tools which may exist or may be developed in the future, given that the REMP is not meant to and cannot replace a (non-existing) conventional energy master plan for The Gambia.

To steer the Renewable Energy Study through the different project phases, the report will identify critical steps, which may require formal approvals before important decisions with relevance for the final study outcome are taken. Therefore, the report serves as a tool for both the client and the consultant to enhance mutual agreement on how to handle the projects and how to direct it towards effectiveness and quality.

5.4 Social and Gender Analysis

Social analysis is an analytical approach that focuses on attitudes, values, behaviour processes and the responsiveness of organisations to the needs of the poor. The aim of the social analysis is to ensure that the identified project will account fully for the social dimension throughout the project cycle. It will identify potential barriers, costs and benefits of its implementation, as well as the effected groups and their involvement.

Gender analysis aims at understanding and documenting the differences in gender roles, activities, needs, and opportunities in the sub-sector. It highlights the different roles and learned behaviour of men and women based on gender attributes and their variances according to factors such as culture, ethnicity and income.

Methodology

The social and gender analysis will involve:

- the review of all available documentation and secondary data in a desk study
- semi-structured interviews with key persons at the institutional and community level
- observation at site and, where necessary,

May 2005
focus group discussions and surveys in order to refine the information acquired.

The social and gender study will be implemented in a joint co-operation between

- The project manager
- The international social and gender expert
- The local social and gender expert
- The environmentalist, who executing the social and environment sector analysis.

The Consultant's social and gender expert will structure and guide this part of the consulting services and will supervise the execution of the task by the local social and gender expert. Interviews will be carried out by him and partly the project manager. The report will be structured by the international expert, then in detail elaborated and prepared by the local expert and finally quality assured by the international expert.

5.5 **Institutional Study**

As one important part of the project, the Consultant will carry out an assessment of the institutional set-up in the Republic of The Gambia with regard to renewable energy sector development. The ToR describe in detail the various items which need to be addressed and we confirm that our institutional analysis will cover the different items as given therein.

The main purpose of the institutional study is to identify information, resource and capacity constraints which limit the subsector’s stakeholders’ ability and effectiveness to further develop the use of renewable energy sources in The Gambia. Therefore, the entire analysis will be guided towards the identification of suitable measures to improve this institutional planning framework. This bottleneck and solution-focused approach will be given priority in comparison to a mere descriptive analysis of the present situation.

The institutional study will basically be carried out by

- The Expert for Demand Assessment, Economics and Institutional Analysis, who will be supported by the team of experts;
- The local legal and institutional expert.

The institutional study will be based on an inventory of all institutions and organisations that are or should be involved in the renewable energy planning and market development process in the Gambia (government bodies, parastatals, donors, NGOs, community-based organisations, selected industry players and scientific institutions). The inventory will comprise homogeneously structured profiles specifying the institutions’ key decision-makers, organisation charts where available, its official function and role in the planning process.
In a next step, the Consultant will define an interview program, which aims at analysing each institution’s activity with regard to:

- The match between formal responsibility on the one hand and project work and/or planning & co-ordination activity put into practice on the other;
- The adequacy of resources and information access to perform its assigned planning or execution task in an effective way;
- Recipients of the planning output and how it is processed in the next step.

The interviews will be documented and summarised. This will then enable the expert team to draw conclusions and elaborate recommendations for changes and improvements in the institutional set up with regard to:

- information gathering, storage and processing needs as well as required research support
- supportive policy measures and standards
- necessary modifications in the legal and institutional sector structure as well as the sector's legislative and regulatory environment.
- Capacity building needs among government entities, private sector players and/or local communities

The expert team will prepare an Institutional Study Report at the end of this sub-activity.

5.6 Economic and Financial Analysis

An Economic and financial analysis of the master plan as well as of the individual pilot project will be carried out with the aim to:

- Analyse and verify the economic feasibility of the project from the point of view of the national economy
- verify its financial soundness, by determining the financial viability of the project and analysing its impacts on the financial situation and performance of the utility.
- assess the economic robustness of the project against variations in key parameters by a sensitivity analysis

The differences in the economic and the financial analysis result from the point of view concerning the relevant project costs and benefits.

The economic analysis represents an evaluation of the overall costs and benefits that are expected for the whole of the country respectively it's economy, based upon economic prices, without taxes and duties imposed. The overall costs incurred, like production costs, environmental costs, social cost etc. are compared with the overall benefits like energy produced, improvement in production and efficiency, reduced environmental damage, improved health conditions, etc. Although some of the aspects are difficult to be calculated, wherever possible, approximate money values are to be assessed and included in the cost/benefit comparison of the economic analysis.
The financial analysis, however, reviews the impact of the project on the financial situation and performance of the executing agency. It therefore uses all costs at market prices, including taxes and duties, and compares it with the financial benefits resulting from the energy produced. The analysis also reviews the cash flow over the project period, to ensure, that the project financing is in line with the cash requirements, so that a negative impact on the financial position of the executing agency is avoided.

5.6.1 Steps in the Economic and Financial Analysis

The proposed Project consists of two distinct phases:
- Phase 1: The development of a Preliminary Renewable Energy Master Plan
- Phase 2: Execution of a Feasibility Study for such project selected from the portfolio of the Master Plan, which is expected to provide the most promising results.

For both steps, Economic and Financial Analyses will be executed. The analysis approaches will, however, differ in scope, depth and methodology.

The methodological approach to the financial and economic analysis of Phase 1 is strongly guided for the structural needs and the logical reasoning of the underlying master planning task. Based on the matrix of relevant demand-supply-options (see chapter 5.9 on the preparation of the master plan itself), the consultant will assess and analyse the needs and group the demand-supply options accordingly:

- Mutually exclusive resource utilisation options, i.e. renewable energy projects competing for the same limited resource (e.g. locally available biomass), need to be compared based on their respective marginal benefits in order to reach optimal resource allocation. The marginal benefits derive from the respective financial and economic cost benefits that one additional unit of the limited resource generates under each utilisation scheme (comparison of economic cost savings).

- Competing supply options using unlimited resources (e.g. wind, solar) but satisfying the same demand need to be compared based on a suitable financial indicator such as the IRR in order to determine the most advantageous option. In the case of such selection among different technically viable options, the financial and economic analysis will need to distinguish between:
  - Substitution of existing technologies by new, more efficient / sustainable technologies (IRR/NPV comparison);
  - Satisfaction of demand that has not been served so far (cost-benefit analysis, willingness to pay).

For each constellation, the best suited indicator (IRR, NPV, unit cost comparison) will be chosen to determine a ranking among all available options as well as quantitative allocation criteria in case of resource constraints. The calculations will be based on generic project data reflecting the specific circumstances of the Gambian market as well as – where necessary and appropriate – local conditions of specific districts. The use of suitably prepared generic data bases avoids distortions within the planning process, which would derive from data material that
would be extrapolated from an insufficient sample group of real-world projects. Furthermore, the usually higher implementation costs of existing pilot projects would suggest unrealistically high cost structures of promising long-term options.

Both, the financial and economic analyses will follow the same structure, however, using different input data as far as price distinctions are concerned or as far as external costs and benefits need to be considered (see additional explanations below).

In Phase 2, one selected pilot project will be analysed in greater detail. Furthermore, the input data in this case will need to strongly reflect the project-specific framework conditions. This in-depth analysis will be based on a financial model that has been successfully applied by Lahmeyer staff in numerous previous projects. The model will be based on this proven general financial model, however, will be adapted in detail to the specific circumstances of the Gambian market. The following figure delineates the structure of the general financial model.

Figure 5-4: Structure of financial model of Lahmeyer
Besides the calculation of the financial and economic indicators listed in the ToR, the model permits also to calculate more complex financial parameters, such as the Debt Service Coverage Ratio, Liquidity Ratio, etc. It will be designed to reflect and analyse complex multi-loan financing structures and the subsequent sensitivity analysis will provide information about those areas where further improvement and change would most effectively contribute to the financial viability of the project.

The consultant will base the selection of indicators to be analysed and parameters to be varied under the sensitivity analysis on his comprehensive project assessment experience as well as international standards and best practices.

5.6.2 Specific Aspects of Economic Analysis

The economic analysis, with its view towards the national economy recognises external benefits, such as the consumer surplus quantifying the savings of those consumers that through improved energy supply get the same or an even better service at a lower relative cost. Savings from improved efficiency in production, savings in cost through improvement of health conditions, improvement of education etc. will also be considered.

Costs resulting from environmental damage, as well as losses in agricultural production through the construction of e.g. transmission lines and power plants are part of the overall analysis. Those costs and benefits were, where possible assessed and expressed in monetary terms.

Similar to the cost side, the benefits of a project have direct and indirect components as well. The direct benefits are represented by the energy produced by the project. Indirect benefits typically include the consumers rent, possibly higher agricultural production and impulses to socio-economic development, reduced losses to industry and commerce, and savings in foreign currency. Environmental benefits also count among the indirect benefits. Those effects and benefits are assigned quantitative weight and monetary values, to the extent possible.

5.6.3 Specific Aspects of Financial Analysis

For the assessment of the financial viability of the Project, and similar to the methodology used in the economic evaluation, a cash flow of costs and benefits is prepared over the lifetime of the Project. Typically the project cash flow in the financial analysis differs in several aspects from those in the economic analysis:

- the cash flow is presented from the viewpoint of the executing agency, not from the viewpoint of the national economy: only direct costs and revenues incurred by the executing agency are considered.
- all costs are expressed in market prices; i.e. costs include taxes as well as custom duties, where applicable.
- financing requirements of the project are considered (in general terms for the First Phase, with more specific assumptions for the Second Phase of the Project).
The criteria (financial indicators) used for the assessment of the financial feasibility of the Project are the Financial Internal Rate of Return (FIRR), and the Present Value (NPV), Benefit/Cost Ratio and the Payback Period. The discounting technique is applied for their calculation.

A sensitivity analysis will be carried out to test the effect of changes in major assumptions on the evaluation criteria. The parameters to be tested in the sensitivity analysis usually include the following:

- different financing scenarios, resulting in different interest rates, loan conditions, etc.
- change in project cost, also considering e.g. changes in government taxation,
- change (increase) of tariff.

The sensitivity analysis will indicate the robustness of the project in relation to possible changes in its basic parameters, and will allow to identify those area where there are the options to make the project financially viable.

### 5.7 Micro Credit Mechanism

At the World Bank, the term micro finance is commonly defined as ‘the provision of financial services, including savings and credit, to low-income clients, including the self-employed’. The main objective of micro credit concepts in the context of this study, is to promote and supply renewable energy resources to rural households of The Gambia.

The study on micro credit mechanisms in the context of this master plan study aims at identifying ways to provide the necessary financing to increase the affordability and accessibility of renewable energy applications to a broad group of users. As a starting point, and as part of the financial and economic analysis of the master plan (phase 1), the Consultant will assess the necessity to provide additional subsidies to improve the affordability of different technologies for end users. Furthermore, the target users’ willingness to pay for the related energy services will be assessed.

Based on these study results, the Consultant will analyse the possibilities to use micro finance as a vehicle to develop the renewable energy market in The Gambia, especially on household, community and small enterprise level. Therefore, the Consultant will:

- Prepare an inventory of micro-finance institutions presently operating in The Gambia;
- Assess their finance instruments, mechanisms;
- Assess their capacities to get involved in the renewable energy investment program;

Throughout the inventory preparation and micro finance market analysis the Consultant will co-operate closely with The Gambia's microfinance program, the Social Development Fund as well as its related community-based organisations (CBO), micro finance institutions (MFI), NGOs and public service institutions (PSI).
This assessment will imply interviews with selected micro finance practitioners on barriers, which need to be removed in order to introduce further supportive micro finance schemes. From these analyses, the Consultant will derive proposals and recommendations for appropriate and suitable mechanisms, instruments, and institutions implementing micro-credit components in the proposed renewable energy investment program. Due to the importance of micro credit schemes, the results will be summarised in a distinct report.

5.8 Sector Environmental and Social Assessment

The purpose of this Sector Environmental and Social Assessment (SESA) is to assess beneficial and adverse effects which could be associated with the implementation of plans or programs during the early stages of the development process. It also aims to determine means to reduce or avoid adverse impacts or to increase benefits. Consequently, the SESA shall be carried out for plans or programs which may result in significant adverse environmental and/or social impacts. Therefore it is a must that such SESA is part of the actual project.

The SESA provides a baseline overview of prevailing environmental and social conditions which are key for reliable impact assessments and monitoring environmental and social changes over time. It allows to address cumulative environmental and social effects of numerous individual projects.

Guiding Principles

The SESA will be according to the guidelines of the AFDB and will have the following guiding principles:

- Early integration of environmental and social effects in the conceptual or planning stages of the plan or program.
- Focus on broader environmental and social issues rather than on site-specific impacts in order to resolve conflicts that cannot be addressed project by project.
- Comparison of alternative options to recommend a realistic plan or program.
- Flexible process as plans and programs can be highly variable in their potential impacts, which may range from highly speculative to readily quantifiable.
- Part of a global analysis including environmental, social, economic, political, and technical considerations to validate the proposed plan or program.
5.9 Preparation of a Renewable Energy Master Plan (REMP)

The preparation of the Renewable Energy Master Plan (REMP) will be based on:

(a) the demand analysis and forecast as described in section 5.1 and
(b) the energy resource assessment as described in 5.2.

From (a) will result the need and requirements for additional power and heat supply. From (b) will result a list of various supply options. The techno-economic analysis of the various renewable energy supply options in front of the background of the present and forecasted demand will enable the Consultant to define finally the investment plan for the next 20 years.

The following figure gives an overview on the planned steps for the REMP.

![Diagram of the planning process for an Electricity Master Plan]

**Figure 5-5: General approach for an Electricity Master Plan**

The planning tasks delineated above will result in two main outcomes:

- demand characteristics per 5-year-period and district throughout the entire forecasting period;
- renewable energy supply options per district, type of energy need and availability per 5-year period.
Making use of compatibly structured data bases, the two inputs will be put together and consolidated into a methodologically sound demand-supply-balance indicating present supply gaps as well as available alternatives to close the gaps as well as to substitute present supplies wherever necessary.

The different options will be ranked according to the outcomes of the financial analysis (IRR, NPV, LEC, unit cost comparison). Based on this ranking as well as under consideration of mutually exclusive implementation constraints, a least-cost investment plan is derived. For this task, a heuristic approach is used, which will carefully address:

- Resource availability constraints;
- Substitutive interrelations between demand-supply-options;
- Investment needs.

The development of the Master Plan will be guided by the concepts of Least Cost Planning (LCP) and Integrated Resource Planning (IRP).

The investment plan will be broken down into five-year investment plans; the investment plan is consisting of individual renewable energy projects. The above mentioned procedure will be applied for both off-grid renewable energy applications as well as those applications, which will be connected to one of the existing isolated grids in the Gambia.

The first preliminary version of the master plan will be ready after the first versions of the renewable energy resource study on wind, solar and biomass are ready. The REMP will be updated and finalised after the final wind data analysis, the final solar energy analysis and after the update of the respective reports.
6 Methodology of Work – Second Phase: Feasibility Study

6.1 Definition of the Feasibility Study Project

Based on the results and achievements of the Draft REMP, it will be possible to identify priority renewable energy projects. In the workshop after the Draft REMP, these priority renewable energy projects will be presented and discussed. The Consultant will prepare a recommendation regarding the most suitable project for the feasibility study. Selection criteria will be:

- The economic competitiveness of the project.
- The model character of the project and the resulting feasibility study for further renewable energy projects.
- The fulfilment of basic environmental and social criteria; the project has to be sustainable.

Possibilities of projects which may be proposed are:

- Supply of electricity and heat in isolated villages in one region, or falling under a certain cluster of villages (e.g. with a certain distance to the existing electricity supply areas) with renewable energy systems, either through individual systems (SHS = Solar Home Systems) or with a centralised hybrid system and village electrification.
- Connection of one or several wind park to one of the existing larger grids; extension of the existing diesel power systems to wind-diesel systems.
- Biomass or Waste-to-energy plants, preferably connected to one of the existing grids.

6.2 Detailed Energy Demand Assessment

Our general approach for energy demand assessment has already been described exhaustively in the methodology description of phase I (section 5.1). The general methodology for the feasibility study project will be the same, however the depth of the analysis and demand assessment will be much deeper. More detailed analysis of individual consumers will be made in the feasibility study area in order to achieve a more precise demand assessment.

6.3 Technical Layout

The Consultant will select the appropriate technologies for satisfaction of the determined electricity and heat demand. A technical concept will then be elaborated, which will included the determination of the main technical parameters (e.g. in case of a wind park, turbine class selection, mast height, no. of turbines, micro siting, optimum arrangement of the wind turbines in the wind park area, grid connection layout.)

The type of technologies can be one or several. E.g. in case the feasibility study is “Village Electrification with Renewable Energy” it can consist out of a centralised...
Wind/Diesel/PV hybrid system, several SHS for remote houses and even solar thermal collectors for heat supply for specific consumers.

The layout will consider the respective electricity and heat generation technology as well as the necessary system to transport the electricity to the consumer (distribution grid e.g.).

The technical concept will also include the appropriate measurement equipment in order to measure the consumption per customer.

The respective standard and regulations in particular those for safety and security for customers and operation personnel will be considered.

This technical layout will be summarised in a technical description of the project.

### 6.3.1 Cost Assessment

Based on the technical project description it will be possible for the Consultant to estimate the investment and O&M cost for the complete project. Such cost will be estimated based on the Consultant's extensive cost data bank for renewable energy technologies and the expert know-how of the different renewable energy experts in the project.

A list with the major project components will be prepared and the cost for each component be estimated.

**Investment Cost:**

The total list of investment cost will include the following:

- Cost ex work for each component, including spare parts
- Transport and delivery
- Civil infrastructure works on site
- Electrical infrastructure works on site
- Installation and commissioning of the various components and the complete systems
- Planning, engineering, project management, permission procedure
- Training for operation personnel
- Soft cost for public awareness campaigns, EMP implementation etc.
- Contingencies

**O&M Cost:**

The O&M cost will consist of:

- Cost for operation personnel
- Maintenance contracts with suppliers
- Routine maintenance of the local maintenance personnel
- Administration
6.3.2 Environmental and Social Impact Assessment Study (ESIA)

For the feasibility study project an environmental and social impact assessment study shall be carried out. This will include the main components as describe in the following paragraphs. At the beginning of the ESA the Consultant will assess jointly with the SMU which of the components which are mentioned downunder need to be addressed in particular for the feasibility study project and which could be covered in more general terms.

6.3.2.1 Human Environment

The components to consider in the human environment include the elements and characteristics of the social, cultural and economic environments as well as infrastructures and services and land use patterns in the project area and its zone of influence: Social Environment, Population, Gender, Health, Civil Society, Societal Framework, Cultural Environment, Economic Environment, Infrastructures and Services, and Land Use Patterns.

6.3.2.2 Natural environment

The natural environment includes the physical components (climate and air, geology and soils, surface and ground water) and the biological components (ecosystems, vegetation and wildlife) of the study area and its zone of influence.

The biological components refer to existing ecosystems, biological diversity, biotopes or particular habitats, zones to be protected as well as to conservation or protection measures according to the existing legislation. It is important to focus on the degree of biological diversity and endemic species as well as on the scientific or conservation interest of the study area.

6.3.3 Environmental and Social Management Plan (ESMP)

The purpose of the ESMP is to define and reach an agreement with the project sponsor concerning mitigation/enhancement, monitoring, consultative and institutional strengthening measures to be undertaken during project implementation and operations. The ESMP shall be incorporated in the loan documents signed between the Borrower and the Bank.

The ESMP's scope and level of details shall be proportional to the number and complexity of the measures required to ensure the project's environmental and social sustainability.

The following components constitute the minimal contents of an ESMP:

6.3.3.1 General Information

Project Number, starting date of implementation, project completion date, date of operation, period covered by the plan
6.3.3.2 Objectives of the ESMP

This section shall specify that the ESMP aims to bring the project into compliance with applicable national environmental and social legal requirements and the African Development Bank's environmental and social policies. Other objective of the ESMP is to outline the mitigating/enhancing, monitoring, consultative and institutional measures required to prevent, minimise, mitigate or compensate for adverse environmental and social impacts, or to enhance the project beneficial impacts. It shall also address capacity building requirements to strengthen the Borrower's environmental and social capacities if necessary. The ESMP will cover the encompass the following sections:

- Context
- Beneficial and Adverse Impacts
- Enhancement and Mitigation Program
- Monitoring Program
- Consultations
- Complementary Initiatives
- Responsibilities and Institutional Arrangements
- Estimated Cost
- Implementation Schedule and Reporting

6.3.4 Economic and Financial Analysis

Reference is made here to section 5.6, wherein our general approach for economic and financial analysis has already been described in detail. The difference in depth between our foreseen analysis in the Master Plan phase (REMP) and in the feasibility study phase has also been discussed in the respective section already.

6.3.5 Institutional Arrangements, Financing Mechanism and Management Structure

Based on the technical description of the project, the results of the economic and financial analysis and the results of the environmental and social impact study and plan, the Consultant will first of all define and recommend a suitable institutional set-up and a management structure for the implementation of the project. Several companies and non-governmental and governmental institutions will be involved and their responsibilities and the relations, the decision making process between these bodies will be proposed.

The Consultant will base his recommendation on his experience and knowledge of a number of other similar projects in Africa and elsewhere in the world under comparable conditions. Prior to written recommendations he will consult with the various involved bodies to identify the interests of each party which may be affected and to consider as much as possible the opinion of the local population.
After having identified and defined a suitable institutional set-up for the project, the Consultant will develop possible financing mechanism in order to finance the complete project – from planning, over construction to operation over the complete lifetime of the project. The various possible donors and their actual criteria for financing of infrastructure projects will be assessed, particularly with regard to projects which may result in low economic return figures. Possibilities like micro financing institutions will also be taken into consideration.

6.3.6 Design and Tender Documents

Based on the results of the feasibility study, particularly the technical description, the Consultant will carry out the technical design of the project. The local conditions will be considered particularly.

Our methodology is based on the assumption that the detail design is usually performed by the contractor(s) who will be selected based on the tendering of the project. Therefore, our methodology includes a general and conceptual design which will be as detailed as usual in feasibility study phase. However, we assure that our design will include all necessary calculations, construction drawing, dimensioning, single line diagrams etc. bills of quantity, which may be necessary in order to prepare the tender documents for the project.

Beside the technical design works, which will finally result in a Design Report, there are some other side tasks included under this sub-activity:

- A detailed implementation schedule will be prepared, including the necessary time for project funding, procurement and community participation
- Recommendations for implementation arrangements
- Preparation of terms of reference and cost estimation for the consultant, who will later supervise and manage the project implementation. This will include also specification of the expert team, the qualifications of companies and experts and job descriptions for the key experts.

The Consultant will prepare a set of draft tender documents for the feasibility study project. The feasibility study report and the design report will allow to decide into how many lots the project should be divided or if the tendering as one turnkey contract my be advisable.
6.4 Reports and Documents

The Consultant will submit to the client several Sub and Main Reports. The following table shows the complete list of documents which will be prepared and either during the course of the project or at the project completion date handed over to the client.

Table 6-1: Overview of reports and documents to be submitted

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Content</th>
<th>Submission date relative to kick-off</th>
<th>Submission date</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Progress Reports</td>
<td>Brief information on the progress achieved during the last 3 months of work</td>
<td>+ 3.0 + 6.0 + 9.0 + 12.0</td>
<td>04.07.05 04.10.05 04.01.05 04.04.05</td>
</tr>
<tr>
<td>1</td>
<td>Project Manual</td>
<td>Procedural guideline for the project implementation</td>
<td>+ 1.0</td>
<td>04.05.05</td>
</tr>
<tr>
<td>2</td>
<td>Inception Report</td>
<td>First findings</td>
<td>+ 1.0</td>
<td>04.05.05</td>
</tr>
<tr>
<td>3</td>
<td>Measurement Strategy Report</td>
<td>Locations of measurement sites Duration of measurements, relocation of sites etc.</td>
<td>+ 1.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Technical Documents Measurement Equipment</td>
<td>Technical specifications, O&amp;M manuals, site visit checklist</td>
<td>+ 3.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Review of Sector and Criteria Report</td>
<td>Results of energy sector and criteria review</td>
<td>+ 3.0</td>
<td>04.07.05</td>
</tr>
<tr>
<td>6</td>
<td>Institutional Study Report</td>
<td>Results of institutional analysis</td>
<td>+ 4.0</td>
<td>04.08.05</td>
</tr>
<tr>
<td>7</td>
<td>Micro Credit Report</td>
<td>Results of micro credit analysis and recommendations</td>
<td>+ 4.0</td>
<td>04.08.05</td>
</tr>
<tr>
<td>8</td>
<td>Wind and Solar Resource Assessment Report</td>
<td>Compilation of first wind and solar data analysis report; assessment of the overall solar and wind resource in The Gambia</td>
<td>+ 5.5</td>
<td>20.09.05</td>
</tr>
<tr>
<td>9</td>
<td>Financial and Economic Studies Report</td>
<td>Results of the financial and economic study of the REMP</td>
<td>+ 5.0</td>
<td>05.09.05</td>
</tr>
<tr>
<td>10</td>
<td>Social and Environmental Report</td>
<td>Results of the environmental and social sector review</td>
<td>+ 5.0</td>
<td>05.09.05</td>
</tr>
<tr>
<td>11</td>
<td>Biomass and Waste Resource Assessment Report</td>
<td>Results of the biomass, fuel wood and waste to energy studies</td>
<td>+ 4.0</td>
<td>04.08.05</td>
</tr>
<tr>
<td>12</td>
<td>Draft Masterplan Report</td>
<td>REMP</td>
<td>+ 6.5</td>
<td>19.10.05</td>
</tr>
<tr>
<td>13</td>
<td>Overall Renewable Energy Resource Report</td>
<td>Compilation of No. 5 and No. 7</td>
<td>+ 6.0</td>
<td>04.10.05</td>
</tr>
<tr>
<td>14</td>
<td>Draft Feasibility Study Report</td>
<td>Feasibility Study, technical, economic, financial, environmental and social</td>
<td>+ 12.0</td>
<td>04.04.06</td>
</tr>
<tr>
<td></td>
<td>Assessment and management plan</td>
<td>Update of Wind and Solar Resource Assessment Report</td>
<td>Update of report No. 8</td>
<td>+ 13.5</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------</td>
<td>----------------------------------------------------</td>
<td>------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>15</td>
<td>Final Master Plan Report</td>
<td>Update REMP</td>
<td></td>
<td>+ 13.5</td>
</tr>
<tr>
<td>16</td>
<td>Final Designs Report and Tender Documents</td>
<td>Final design and tender documents</td>
<td></td>
<td>+ 13.0</td>
</tr>
</tbody>
</table>
6.5 Seminars and Workshops

The project programme incorporates three seminars/workshops at certain milestones:

- after one month of the project start
- after seven month of the project start
- after twelve month of the project start

Each seminar workshop will be one entire day and will include:

- a presentation of the actual project status
- the presentation of the main results so far achieved
- an outlook for the next project phase

A discussion round in which critical results will be discussed between the seminar/workshop participants will be openly discussed.

It is assumed that from the Consultant side the project manager or his assistant, the respective local experts which had an input in the respective phase and the eventual other international expert, who may be in The Gambia at that time, will participate. Other participants will be the entire members of the SMU and as necessary the members of the inter-ministerial steering committee. We suggest to invite the members of the inter-ministerial steering committee at least the presentation session in each seminar/workshop. Selected other decision-makers and stakeholders from public and private sector may be invited on short term basis.

For further training elements, we refer to section 6.5.2.

6.5.1 Duration

Starting from the notice to proceed, the project will have a total duration of 14 months, whereby we will start our services latest one month after the notice to proceed.

6.5.2 Training methodology

The way and methodology how the Consultant will execute the project, incorporates already extensive collaboration with the SMU. We believe that the SMU should be involved in all activities of the project. This will be for the benefit of the project as well as for the benefit of the members of the SMU and therefore contribute to a long term sustainability of the project results. Examples are the wind and solar measurement campaign, the wind and solar data analysis, the Environmental and Social Management Plan etc. Another important element are the three seminars/workshops, which are incorporated in the project after the 1st, the 7th and the 12th of the project.

However, to increase the success and guarantee more longer term sustainability, additional training components are suggested by the Consultant, which are described on the following pages.
The Consultant would like to highlight herewith that the described training programs have been designed and proposed specifically with regard to this Renewable Energy Study. The options are not standardised training seminars, but tailor-made in order to achieve longer-term sustainability for renewable energy projects in The Gambia.

6.5.3 Overseas Training

Duration: Two weeks in total

Location: Germany and Central Europe, several locations

Objectives:
- to enable the participants to improve their international network in renewable energy scene
- to make successfully implemented projects visible to the participants and with this to improve motivation
- to bring first hand information about suppliers and their technologies to the participants

Content proposal:
- Welcome; Introduction into renewable energies: Market, potentials, technology trends and cost; one day in LI Head office (one day)
- Visit of one wind park under construction (one day)
- Visit of one wind park in operation, together with the operator control building (one day)
- Visit of two wind turbine manufacturer, one gearbox type, one gearless type (two days)
- Visit of the PV manufacturing facilities of one of the major German cell and module manufacturers (one day)
- Visit the worlds largest grid connected PV power plants close to Leipzig as well as stand alone systems operational in Germany (one day)
- Visit of one biomass power plant near Berlin (Königswusterhausen) (one day)
- Visit of a waste to energy power plant near Mainz (one day)
- Closing session in LI office in Bad Vilbel: Questions/Answers, Lessons Learnt (one day)

Participants: eight participants

Trainer(s)/Co-ordinators: The project manager or an equal representative of him will accompany the entire team in the two weeks, organise the visits and travel plan and establish the necessary contacts.

Training Handouts: for each participant:

6.5.4 In country Training

Duration: Two weeks in total, ten working days with six times 45 minutes lessons, seven days of trainer's presentation, three days case study workshop (for each technology one case study)

Location: GREC, Kanifing, The Gambia

Objective:

- to enhance the knowledge of renewable energy technologies
- to bring the project content and results closer to the private and public sector in the Gambia, which is not directly involved in the project

Content:

- Technologies to be covered: wind, photovoltaic, solar thermal power and biomass
- For each technology:
  - Resource analysis
  - Energy conversion technology description
  - Description of the main components of the energy conversion chain
  - Environmental risks and benefits associated with the technology
  - Overview investment and O&M costs
  - Economic parameters
- For each technology: one case study under typical conditions in the Gambia, criteria and conditions defined by the trainer, elaboration of the case study in small work groups
- General overviews for financing possibilities for renewable energies
- CDM possibilities for renewable energy technologies

Participants: maximum 20, engineers, scientists, technicians.

Trainer(s): Two trainers will in parallel be available in each session; the Project Manager or Assistant Project Manager will be available part time, experts for the individual technologies fulltime

- Project Manager or Assistant Project Manager
- Wind Expert –, Five working days
- Solar and Biomass Expert – Five working days
Training Handouts for each participant:

- The complete Power Point Presentation of the trainers with table of Content, systematically ordered on CD Rom
- Certificate of participation
## Updated work plan

### Figure 7-1: Updated Work Plan Part 1

![Updated Work Plan Part 1](image-url)
Figure 7-2: Updated Work Plan Part 2
8 Annex A – Specifications of the wind measurement mast and stands

8.1 Scope of Work
The scope of work is including the fabrication of the equipment itemised in the following Table 8-1, the transport of the equipment to 8 sites distributed throughout Gambia and the erection of the masts and stands including the respective foundations.

Table 8-1: Wind measurement mast and pyranometer stand - items and quantities

<table>
<thead>
<tr>
<th>pos.</th>
<th>description</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>wind measurement mast 30m including foundations, guy anchors and cables and lightning rod as described in chapter 8.2</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>upper cross arm for 2 sensors as described in chapter 8.3</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>lower cross arm for 1 sensor chapter 8.4</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>pyranometer stand including foundation as described in chapter 8.5</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>cross arm for pyranometer as described in chapter 8.6</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>shadow roof for data logger as described in chapter 8.7</td>
<td>8</td>
</tr>
</tbody>
</table>

All parts made from steel have to be painted with corrosion protective paint. The paint should be a tone of red similar to that in the flag of The Gambia. The finish should be matt.

Orientation of mast and relative position of Pyranometer have to be as described in section 8.2.2.

8.2 Wind measurement mast

8.2.1 Overall design
In the following, the main specification for the masts is mentioned:
- Triangular guyed steel lattice mast
- Side length 30 cm, cross-bracing in “zig-zag” design with vertical distance ≤ 40 cm
- Preferable constructed of single flanged elements, length 3 – 4 m
- Main vertical elements: tube diameter > 3 cm or angle profile 80 x 80 mm, thickness 8 – 12 mm
- Guyed with steel cables at least in three height levels and from three anchor points (in a radius of 20m around the mast and at 0°, 120° and 240°)
- Foundation of mast: concrete cube (min. 1x1x1 m)
- Foundation of anchor point (see section 8.2.3)
- Including lightning arrester on the top of the mast
- Masts and foundations shall be designed to withstand wind speeds of 180 km/hour and other applicable loads in accordance with the approved codes and standards

The overall design of the mast is shown in the following Figure 8-1.

![Figure 8-1: General design of the lattice mast](image)

For orientation of the wind measurement mast and the pyranometer stand (see details chapter 8.5) please refer to the following Figure 8-2.
8.2.2 Orientation and relative location of mast and stand

The following Figure 8-2 shows the location of the stand relative to the wind measurement mast and orientation of the ensemble. The installation has to follow precisely the design.

![Figure 8-2: Orientation and relative location of mast and stand](image-url)
8.2.3 Anchor design and guying rope

The anchor to fix the guying cable should be attached to the ground according the following Figure 8-3. The steel anchor has to be rammed into the ground before the concrete is poured into the excavation for the foundation. The details of the top to the anchor are given in Figure 8-4. An angle iron welded to the anchor and equipped with 3 drilled holes will allow easy fixation of the 3 guy cables.
8.3 Upper cross arm

The upper cross arm will be equipped with a wind direction vane and wind speed sensor. Elevation for this cross arm is exactly 30 m above ground. The distance between the sensors and the centre of mast/tower has to be 1.5 m. That means that the cross arm must have a length of 3 m (see Figure 8-5).

The arms has to be tight fixed to the mast at least at two connecting points, in order to avoid any vibration of the cross arms. The cross arm has to be mounted exactly horizontally. It has to be fixed on that of the tree sides, which shows to the western direction (see following Figure 8-6 seen from above).

To fix the anemometers and wind vane, tubes or round bars have to be welded to the cross arm. After installing the cross arm to the mast the tubes have to be exactly perpendicular (max. deviation only +/- 1°). (see Figure 8-5 and Figure 8-6)

**view from the front**

![Diagram](image)

**view from the side**

![Diagram](image)

*Figure 8-5: Upper cross arm layout*
Lattice tower

view from the top (mounted to tower)

Lattice tower

bend welded to the tower.
Cross arm fixed with nut.

Direction WEST

view from the side (mounted to tower)

Lattice tower

Cross arm

bar exactly perpendicular!!

Angle: 90° +/- 1°

Angle: 90° +/- 1°

Angle: 90° +/- 1°

Bar exactly perpendicular!!

300 mm (side length of mast)

tube welded to the L-bar: rectangular!!

3.0 m

300 mm (side length of tower)

0.1 m

1.5 m

centre of tower

Up / skyward

Figure 8-6: Position of the upper cross arm mounted to the mast
8.4 Lower cross arm

The lower cross arm will be equipped with a wind speed sensor only. Elevation for this cross arm is exactly 10 m above ground. The distance between the sensors and the centre of mast/mast has to be 1.5 m. That means that the cross arm must have a length of 1.5 m + 0.5 x side length of the mast, i.e. 1.65m (see Figure 8-5).

The cross arm has to be fixed to the mast at least at two connecting points, in order to avoid any vibration of the cross arms. The cross arm has to be mounted exactly horizontally. It has to be fixed on that of the three sides, which shows to the western direction (see following Figure 8-6 seen from above). The arm has to show to the north (see Figure 8-2)

To fix the anemometer, one tubes or round bar has to be welded to the cross arm. After installing the cross arm to the mast the tube/bar has to be exactly perpendicular (max. deviation only +/- 1°). (see Figure 8-5 and Figure 8-6)

![Diagram of lower cross arm layout](image)

**Figure 8-7: Lower cross arm layout**
**Figure 8-8: Position of the lower cross arm mounted to the mast**
8.5 Stand for pyranometers

For the installation of the pyranometers a separate stand is required. The basic design is similar to the mast. It is also a lattice construction done with tubes and bars, but quadrangular.

The steel plate on top has to be exactly flat and horizontal. The holes specified in the following sketch (Figure 8-9) have to be drilled with high precision.

---

**Figure 8-9: Design of pyranometer stand**
8.6 Cross arm for pyranometer stand

The cross arm with the following design (Figure 8-10) has to be added to two of the pyranometer stands.

The holes specified in the following Figure 8-10 have to be drilled with high precision. The holes at the open end of the arm have to fit properly to the drills in the steel plate of the pyranometer stand. The required bolts and nuts (M6) have to be supplied.

cross section at end

drilled holes: 6mm diameter

drilled holes to fit to the holes on the stand

Figure 8-10: Design of pyranometer cross arm
8.7 Shadow roof for data logger

To protect the data logger in the case of high temperatures, the mast has to be equipped with a so called "shadow roof". As the roof will carry the solar module it is very important that it faces south. The precise orientation is south east and given in Figure 8-2 (location of shadow roof and data logger)!

The width of the shadow roof has to be 60 cm. The roof overhang is at least 40 cm with an angel of approximately 80°. See details next Figure 8-11.

![Shadow roof design](image)

The shadow roof should be welded or bolted on the mast or fixed with a clamp at approximately 2 m height above ground.

For mounting of the data logger and the solar module to the shadow roof, drilled holes are required. The positions are shown in the next Figure 8-12 and Figure 8-13.
Figure 8-12: Position of drilled holes for logger mounting

Figure 8-13: Position of drilled holes for solar nodule mounting