# Chapter 8

# Micro-Hydropower Generation Planning

# Chapter 8. Micro-Hydropower Generation Planning

## 8.1. Current Status of Micro-Hydropower Development

In Zambia, there already exist some micro-hydropower plants (hereinafter referred to as "Mc-HPs") as shown in Chapter 3. These Mc-HPs, located in a remote area far from ZESCO's distribution lines, are operated by local cooperatives for supplying electricity to local hospitals, clinics, schools, farm, and so on. In the Rural Electrification Master Plan Study, development of Mc-HPs like that is considered to be an option to enhance rural electrification in some remote areas in Zambia.

According to the estimate of some preceding studies, Zambia has a potential of hydropower generation of more than 6,000 MW and only 1,700MW out of that has been developed so far. However, not many Mc-HP projects to serve rural electrification have been discussed so far, with some exceptions like "Chitokoloki Mission" and "Zengamene" projects that REA selected for REF release in 2006 (refer to Table 3-2). This modest approach toward Mc-HPs shows a clear contrast with the case of large hydropower development to be connected to the national grid, where many projects have come up for consideration in these days, and some of them will possibly be realized, for improving the country's supply-demand balance that has become seriously tight due to the rapid growth of domestic electricity consumption such as the recovery of mining sector.

## 8.2. Data Collection

### 8.2.1. Rainfall Data

Table 8-1 shows the annual rainfall data at 39 meteorological stations that are monitored by Zambia Meteorological Department (ZMD). The locations of these stations are plotted in Figure 8-1. "Rainfall" in this table indicates the average of past 30 years (1963-1992), and these data are extracted from GIS database that REA obtained from ZMD. This database shall be incorporated into the Rural Electrification GIS database in this REMP Study.

**Table 8-1 Rainfall Data (1963-1992 average)**

| Station | Longitude (E) | Latitude (S) | Rainfall (mm) | Station | Longitude (E) | Latitude (S) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| Chipata | 32.58 | 13.57 | 980.4 | Mansa | 28.85 | 11.10 | 1179.2 |
| Chipepo | 27.88 | 16.80 | 776.5 | Mbala | 31.33 | 8.85 | 1202.4 |
| Choma | 27.07 | 16.85 | 770.7 | Mfuwe | 31.93 | 13.27 | 810.8 |
| Isoka | 32.63 | 10.17 | 1086.2 | Misamfu | 31.22 | 10.18 | 1330.7 |
| Kabompo | 24.20 | 13.60 | 1040.6 | Mkushi | 29.80 | 13.60 | 1178.4 |
| Kabwe Met | 28.48 | 14.42 | 901.4 | Mongu | 23.17 | 15.25 | 914.4 |
| Kabwe Agro | 28.50 | 14.40 | 878.2 | Mpika | 31.43 | 11.90 | 993.6 |
| Kafironda | 28.17 | 12.63 | 1274.8 | Msekera | 32.57 | 13.65 | 1010.3 |
| Kafue | 27.92 | 15.77 | 746.3 | Mtmakulu | 28.32 | 15.55 | 878.2 |
| Kalabo | 22.70 | 14.95 | 807.8 | Mumbwa | 27.07 | 14.98 | 820.6 |
| Kaoma | 24.80 | 14.80 | 904.5 | Mwinilunga | 24.43 | 11.75 | 1390.4 |
| Kasama | 31.13 | 10.22 | 1309.5 | Ndola | 28.66 | 13.00 | 1185 |
| Kasempa | 25.83 | 13.47 | 1155.4 | Petauke | 31.28 | 14.25 | 967.8 |
| Kawambwa | 29.25 | 9.80 | 1361.9 | Samfya | 29.32 | 11.21 | 1478.7 |
| Livingstone | 25.82 | 17.82 | 637.1 | Senanga | 23.27 | 16.12 | 727 |
| Lundazi | 33.20 | 12.28 | 874.2 | Serenje | 30.22 | 13.23 | 1058.7 |
| Lusaka Hq | 28.32 | 15.42 | 821.5 | Sesheke | 24.30 | 17.47 | 627.7 |
| Lusaka Airport | 28.43 | 15.32 | 934 | Solwezi | 26.38 | 12.18 | 1341.9 |
| Lusitu | 28.82 | 16.18 | 534.7 | Zambezi | 23.12 | 13.53 | 1022.3 |
| Magoye | 27.63 | 16.13 | 715.1 | | | | |

Source: ZMD

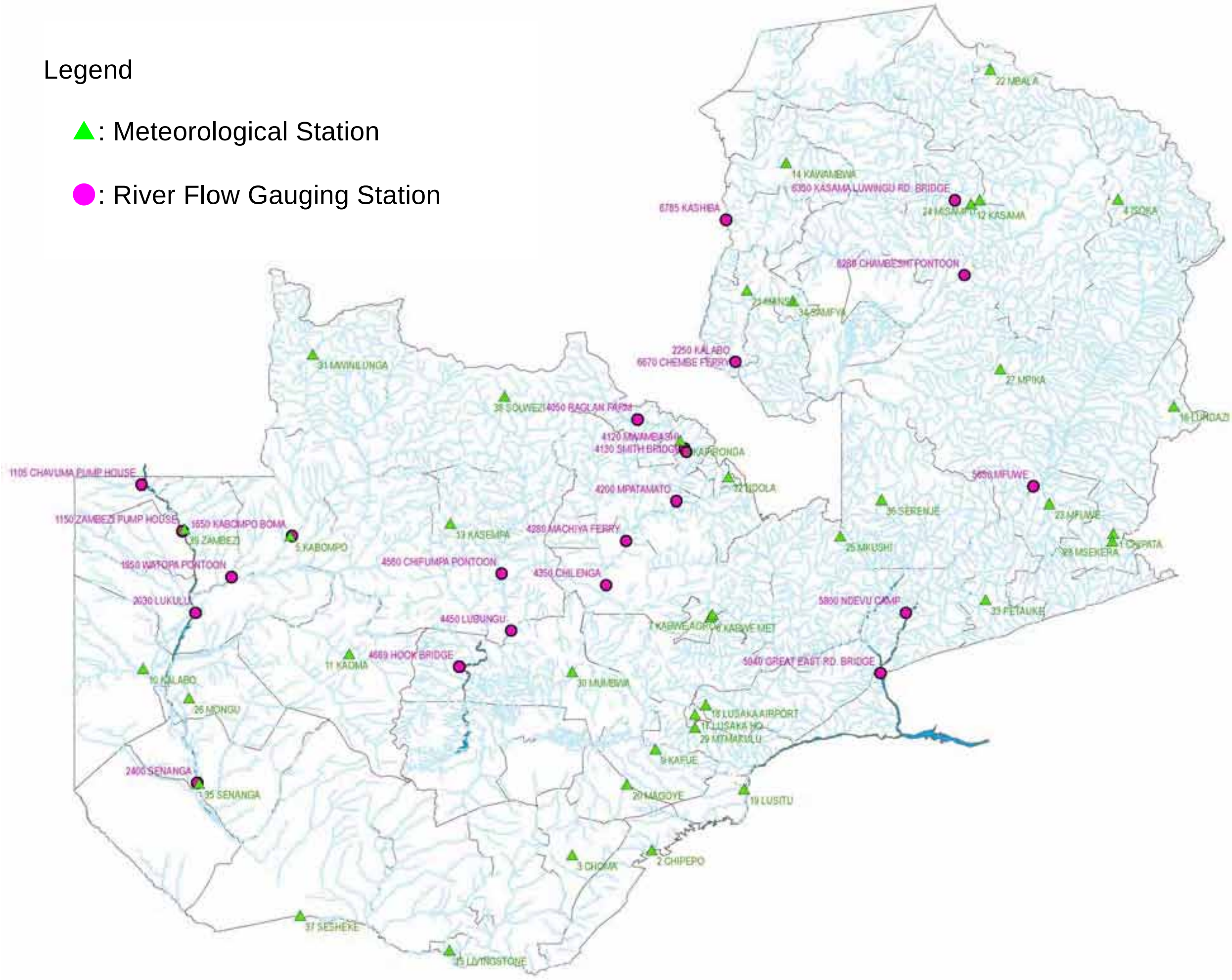



**Figure 8-1 Location of Meteorological Stations and River Flow Gauging Stations**

### 8.2.2. River Flow Data

Table 8-2 shows the river flow data at 24 measuring stations, monitored by the Department of Water Affairs (DWA) of MEWD. These data are in principal the average of past 10 years (Oct. 1996-Sep. 2006), though many measuring stations have missing periods more or less. 4 stations (marked with * in the table) have no data at all during this period, thus they are substituted by the river flow data during 1963- 1992, which are found in the study report of the National Water Resources Master Plan in the Republic of Zambia, 1995, by JICA. The locations of these stations are plotted in Figure 8-1.

**Table 8-2 River Flow Data (Oct.1996 – Sep.2006)**

| Station Number | Name of Station | East Longitude | South Latitude | Catchment Area [km²] | Monthly Mean discharge [m³/s] | | | | | | | | | | | | Flow Regime [m³/s] | | | Anunual Runoff [mil m³] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Max. | Min. | Ave. | |
| **ZAMBEZI RIVER** | | | | | | | | | | | | | | | | | | | | |
| 1105 | Chavuma Pump House | 13: 5 | 22:41 | 75,967 | 434 | 439 | 463 | 538 | 652 | 720 | 729 | 577 | 505 | 476 | 455 | 442 | 974 | 423 | 530 | 16,729 |
| 1150 | Zambezi Pump House | 13:33 | 23: 6 | 87,275 | 46 | 50 | 91 | 290 | 658 | 1818 | 1762 | 538 | 322 | 174 | 91 | 61 | 2976 | 35 | 726 | 22,910 |
| 1650 | Kabompo Boma | 13:36 | 24:13 | 42,740 | 141 | 152 | 198 | 286 | 350 | 394 | 401 | 252 | 204 | 182 | 168 | 154 | 518 | 108 | 216 | 6,814 |
| 1950 | Watopa Pontoon | 14: 1 | 23:36 | 67,261 | 62 | 65 | 110 | 257 | 351 | 510 | 412 | 167 | 122 | 104 | 87 | 69 | 882 | 42 | 195 | 6,162 |
| 2030 | Lukulu | 14:23 | 23:14 | 206,531 | 183 | 190 | 310 | 717 | 1569 | 1943 | 1915 | 982 | 479 | 348 | 277 | 222 | 2727 | 134 | 829 | 26,157 |
| 2250 | Kalabo | 11:50 | 28:44 | 123,072 | 10 | 7.5 | 7.5 | 11 | 30 | 88 | 95 | 98 | 77 | 46 | 33 | 17 | 165 | 5.1 | 38 | 1,205 |
| 2400 | Senanga | 16: 7 | 23:15 | 284,538 | 236 | 245 | 341 | 583 | 1029 | 1822 | 2293 | 2123 | 1177 | 608 | 404 | 300 | 2941 | 163 | 902 | 28,441 |
| **KAFUE RIVER** | | | | | | | | | | | | | | | | | | | | |
| 4050 | Raglan Farm | 12:25 | 27:44 | 5,775 | 3.1 | 2.8 | 9.4 | 41 | 79 | 112 | 98 | 25 | 15 | 10 | 6.5 | 3.9 | 474 | 0.5 | 34 | 1,085 |
| 4120 | Mwambashi | 12:43 | 28:13 | 827 | 3.1 | 1.3 | 4.2 | 16 | 19 | 21 | 13 | 4.6 | 2.8 | 2.2 | 1.5 | 1.1 | 48 | 0.1 | 8.3 | 262 |
| 4130 | Smith Bridge | 12:45 | 28:14 | 8,914 | 14 | 14 | 41 | 95 | 166 | 171 | 129 | 77 | 34 | 26 | 21 | 15 | 284 | 6.8 | 81 | 2,553 |
| 4200 | Mpatamato | 13:15 | 28: 8 | 12,001 | 9.4 | 14 | 60 | 174 | 261 | 253 | 163 | 66 | 41 | 31 | 22 | 15 | 430 | 5.8 | 91 | 2,862 |
| 4280 | Machiya Ferry | 13:39 | 27:37 | 23,065 | 16 | 17 | 53 | 159 | 233 | 248 | 195 | 97 | 58 | 60 | 50 | 22 | 485 | 11 | 90 | 2,851 |
| 4350 | * Chilenga | 14: 6 | 27:25 | 34,451 | 29 | 32 | 77 | 199 | 347 | 479 | 445 | 260 | 121 | 77 | 56 | 39 | 571 | 92 | 179 | 5,650 |
| 4450 | Lubungu | 14:34 | 26:27 | 55,962 | 23 | 23 | 72 | 206 | 338 | 444 | 327 | 275 | 105 | 63 | 46 | 34 | 790 | 5.8 | 160 | 5,043 |
| 4560 | Chifumpa Pontoon | 13:59 | 26:21 | 20,999 | 29 | 28 | 44 | 112 | 129 | 189 | 159 | 71 | 50 | 47 | 40 | 34 | 417 | 17 | 83 | 2,632 |
| 4669 | Hook Bridge | 14:56 | 25:55 | 96,239 | 32 | 28 | 64 | 238 | 442 | 651 | 528 | 290 | 131 | 90 | 71 | 53 | 1614 | 12 | 219 | 6,922 |
| **LUANGWA RIVER** | | | | | | | | | | | | | | | | | | | | |
| 5650 | * Mfuwe | 13: 6 | 31:46 | 73,422 | 55 | 56 | 185 | 487 | 813 | 800 | 469 | 212 | 133 | 100 | 80 | 64 | 1610 | 34 | 181 | 8,894 |
| 5800 | * Ndevu Camp | 14:23 | 30:28 | 55,488 | 21 | 31 | 208 | 638 | 1232 | 888 | 446 | 165 | 83 | 56 | 37 | 24 | 3329 | 11 | 327 | 10,270 |
| 5940 | Great East Rd. Bridge | *15:00* | *30:12* | 140,922 | 43 | 42 | 200 | 1098 | 784 | 1084 | 768 | 266 | 154 | 107 | 76 | 55 | 3240 | 12 | 471 | 14,864 |
| **CHAMBESHI RIVER** | | | | | | | | | | | | | | | | | | | | |
| 6289 | Chambeshi Pontoon | 10:57 | 31: 4 | 34,745 | 20 | 18 | 46 | 118 | 207 | 268 | 253 | 178 | 109 | 65 | 43 | 30 | 847 | 4.6 | 113 | 3,549 |
| 6350 | Kasama Luwingu Rd. Bridge | 10:11 | 30:58 | 6,504 | 22 | 26 | 50 | 87 | 98 | 110 | 110 | 59 | 42 | 36 | 29 | 27 | 310 | 10 | 59 | 1,860 |
| 6670 | Chembe Ferry | 11:50 | 28:44 | 123,072 | 257 | 241 | 366 | 410 | 537 | 598 | 665 | 667 | 604 | 471 | 431 | 331 | 1660 | 9.5 | 466 | 14,699 |
| 6785 | * Kashiba | 10:23 | 28:38 | 161,275 | 237 | 195 | 265 | 536 | 1068 | 1758 | 1741 | 1295 | 931 | 712 | 488 | 323 | 2012 | 174 | 741 | 26,044 |

Source: DWA

Note: Data of the stations with asterisk (*) during the said period was not available thus was substituted with 1963-1992 data from the Study Report on the National Water Resources Master Plan in the Republic of Zambia (JICA, 1995)

### 8.2.3. Hydropower Potential for Electrification

Table 8-3 shows the list of unelectrified RGCs in the priority list that may have a waterfall in the neighbourhood, and the distance to the waterfall. This information was obtained from District Planners through the Rural Electrification Workshop held in each Provincial centre. There are two main conditions to determine the existence of hydropower potential, namely the certain volume of water flow and the effective elevation gain of waterfall thus the information regarding the existence of waterfall around the unelectrified RGCs indicates the possibility of electrification through micro-hydropower. This table suggests that North-western, Northern, and Luapula Province may have a lot of Micro-hydropower potential sites.

**Table 8-3 Distance from Unelectrified RGCs to the Nearest Waterfall**

| Province | District | Name of RGC | Distance [km] | Province | District | Name of RGC | Distance [km] |
|---|---|---|---|---|---|---|---|
| North-western | Chavuma | Chivombo | 30 | North-western | Zambezi | Liyovu | 0.5 |
| | | Sanjongo | 3 | | | Chinyingi | 0.4 |
| | | Lukolwe | 11 | | | Muyembe | 1 |
| | | Chinwandumba | 17 | | | Kashona | 1 |
| | | Kalombo | 15 | Northern | Isoka | Kafwimbi | 30 |
| | | Kakhoma | 9 | | Kasama | Lukulu North | 5 |
| | | Kamisamba | 19 | | | Namakwi | 1 |
| | | Kambuya | 18 | | | Chilubula | 1.7 |
| | | Mandalo | 1 | | | Chishimba | 0.05 |
| | | Chambi | 2 | | Mporokoso | Mukupakaoma | 1 |
| | | Mukelangombe | 28 | | | Chiwala | 10 |
| | Mwinilunga | Ntambu | 7 | | | Chishamwamba | 6 |
| | | Ikelenge | 0 | | Mungwi | Kayambi | 2 |
| | | Nyakaseya | 7 | | | Kalulu | 2 |
| | | Kanyama | 15 | | | Nsampa | 2 |
| | | Chisengi | 20 | | | Chisau | 2 |
| | | Kanongesha | 7 | | | C/Weyaya | 2 |
| | | Jimbe | 24 | | Nakonde | Chilolwa | 0.5 |
| | | Saluj | 27 | Luapula | Kawambwa | Chibote | 20 |
| | | Samteba | 10 | | | Mukuma | 10 |
| | | Kafweku | 15 | | | Kalamba | 11.2 |
| | | Lwakela | 5 | | | Township | 18.2 |
| | | Kawiku | 20 | | Milenge | Musolo | 5 |
| | Zambezi | Chitokoloki | 26 | | Mwense | Chama | 20 |
| | | Mpidi | 15 | | | Mubamba | 2 |
| | | Dipalata | 5 | Lusaka | Kafue | Tukunka | 0 |
| | | Ishima | 2 | Southern | Choma | Kanchomba | 2 |
| | | Katontu | 5 | | Livingstone | Mulala | 8 |
| | | Lukunyi | 5 | | | Majeledi | 7 |
| | | Kayenge | 0.5 | | | Simwizi | 9 |
| | | Milomboyi | 4 | | | Sakurita | 4 |
| | | Mwange | 10 | Western | Kaoma | Mangango | 1 |
| | | Matondo | 3 | | Shang'ombo | Sioma | 10 |
| | | Likungu | 2 | | | | |

Source: Information obtained from District Planners through Provincial Workshop, November 2006

## 8.3. Review of Existing Hydropower Development Plans

### 8.3.1. On-grid Hydropower Development Plans

Existing plans of on-grid HPP projects are listed in Table 8-4 and the location of these sites is plotted in Figure 8-2. The numbering in the table corresponds to that in the map.

**Table 8-4 Planned On-grid HPP Projects**

| No. | Name of Site | Province | Output [MW] | Estimated Cost [million US$] | Expected Construction Period |
|---|---|---|---|---|---|
| 1 | Kabompo Gorge | North-western | 34 | 78 | 2009-2012 |
| 2 | Itezhi-Tezhi | Southern | 120 | 150 | 2009-2013 |
| 3 | Batoka Gorge | Southern | 1600 | 3,000 | |
| 4 | Devil's Gorge | Southern | 1600 | 3,000 | |
| 5 | Kariba North (Extension) | Southern | 1080(+360) | 255 | 2008-2010 |
| 6 | Kafue Gorge Lower | Southern | 750 | 740 | 2010-2014 |
| 7 | Mumbotuta Falls | Luapula | 301 | 483 | |
| 8 | Mambilima Falls | Luapula | 326 | 674 | |
| 9 | Kalungwishi | Northern | 218 | 570 | 2009-2013 |
| 10 | Lusiwasi (Extension) | Central | 62(+50) | 80 | |
| 11 | Musonda Falls (Extension) | Luapula | 7.5(+2.5) | 10 | |
| 12 | Chishimba Falls (Extension) | Northern | 9.6(+3.6) | 15 | |
| 13 | Lunzua Falls (Extension) | Northern | 10(+9.25) | 23 | |

Source: ZESCO

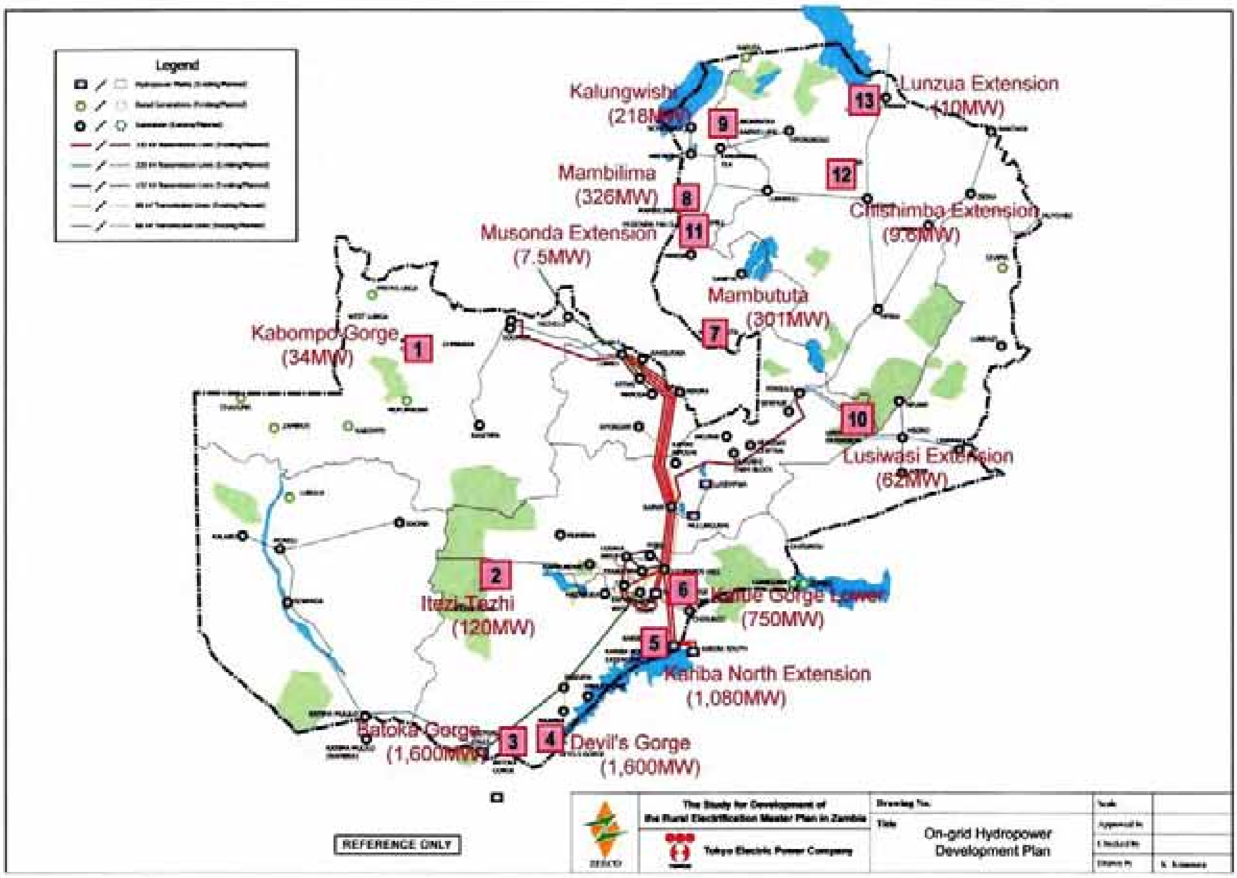



**Figure 8-2 Location of On-grid HPP Project Sites**

The outline of projects in the list is as follows:

### (1) Kabompo Gorge Project

Kabompo Gorge site is located in south of Mwinilunga District, North-western Province, and the project is a development of 34MW hydropower plant on Kabompo River. NORPLAN, a Norwegian consultant, implemented pre-feasibility study in 2000 in collaboration with ZESCO. OPPPI wants to finish the bid for feasibility study and construction works up to end of November 2007. Then it is expected to complete the feasibility study in 2008, to implement the construction works from 2009 to 2012.

### (2) Itezi-Tezhi Project

The existing Itezhi-Tezhi dam is located on the Kafue River, about 350 km west of Lusaka. The project consists of installing 2 units of 60MW generators, and the estimated cost is about 150 million US$. This Hydropower plant will be connected to the national grid at Muzuma substation in Southern Province via 330 kV transmission lines. To carry out this development, ZESCO and TATA Africa Holdings signed on a Memorandum of Understanding on Nov. 2006 and they will form a special purpose vehicle company called Itezhi-Tezhi Power Corporation Limited. This new plant was originally planed to supply electricity from the end of 2009, but the project has not made great progress yet, and now it is still on the detail design and financing stage. Based on the latest information from OPPPI, the construction works will be implemented from 2009 to 2013.

### (3) Batoka Gorge Project

Batoka Gorge site is located on the border with Zimbabwe, Southern Province, and the project is 1,600MW hydropower plant scheme using the rich water of Zambezi River. Feasibility study was executed in 1993 by ZESCO and ZESA, power utility of Zimbabwe. Because of the site location on the international border, both Zambian and Zimbabwean Government plans to develop this potential in collaboration, and the 1,600MW of generation capacity will be shared in halves by them, which gives additional 800MW generation capacity to Zambian national grid. Zambezi River Authority possesses the right for the development of this site, but the there is no remarkable progress after the feasibility study.

### (4) Devil's Gorge Project

Devil's Gorge site on Zambezi River is located about 100km downstream of Batoka Gorge site. The site also has 1,600MW of generation capacity, which will be shared in halves by Zambian and Zimbabwean Government. Zambezi River Authority also possesses the right for the development of this site, but any study has not been done, and the schedule of the development has been left vacant.

### (5) Kariba North Bank Project

ZESCO plans to expand existing 600MW Kariba North Bank hydropower plant (the total capacity after ongoing rehabilitation would be 720MW). The scope of the project is to add two more turbine-generator units with 180MW each. Then KNB-HP will have six unit of 180MW and its total capacity will be 1,080MW. This construction works are expected to start 2008, and to be finished by 2010 funded by Chinese Government.

### (6) Kafue Gorge Lower Project

The site of Kafue Gorge Lower project is located on 65 km upstream of the confluence of Kafue River and Zambezi River, and 2 km away from the existing KG-PS. The feasibility study of this project was completed in 1995 by Harza Engineering Company. This study report suggested the installation of 4 units of 150MW turbine-generators, but ZESCO later upgraded this to 5 units of 150MW. Now the candidate site of the development has been changed from the site reported in the feasibility study, OPPPI plans to hire a consultant and to start feasibility study for the new site in early 2008 supported by IFC, International Finance Cooperation.

### (7) Mumbotuta Falls Project

Mumbotuta Falls site is located in the south end of Luapula Province on the border with Republic of Congo. This is the project to develop 301MW hydropower plant on Luapla River. HARZA implemented pre-feasibility study in 2001, but there is no progress after the study. Figure 8-3 shows a picture of Mumbotuta Falls.

**Figure 8-3 Picture of Mumbotuta Falls**

### (8) Mambilima Falls Project

Mambilima Falls site on Luapula River is located at about 110km northwest of Mansa District centre, the capital of Luapula Province, on the border with Republic of Congo. Along with Mumbotuta Falls Project, HARZA implemented pre-feasibility study in 2001, but there is no progress after the study. Two sites are introduced in this study report. Their potentials of power generation are evaluated at 124MW and 202MW, and the costs for developments are estimated at 174 million US$ and 500 million US$ respectively. The total potential and project cost of these two sites are indicated on Table 8-4.

### (9) Kalungwishi Project

Kalungwishi project consists of 135MW Kundabwika Falls site and 83MW Kabwelume Falls site, which are located on Kalungwishi River in northwest of Mporokoso District, and the total potential of hydropower generation is 218MW. Feasibility study was conducted by HARZA in 2000, which reported that total potential of these two sites was 163MW. OPPPI revised the study recently and upgraded the potential up to 218MW with 570 million US$ of project cost including 170 million US$ of transmission line cost. Now the project is getting forward by Luzua Power Authority, Zambian private company. They are planning to start the construction works from 2009 and to complete the works by 2013.

### (10) Upgrade of ZESCO's Four Small Hydropower Plants

ZESCO owns four small hydropower plants, which are described in Chapter 3.3.1(2), and ZESCO has plans to upgrade all of them. Pre-investment study for these extension/renovation projects was implemented in 1997 by Knight Piesold, and ZESCO is planning to update this study in early 2008. In this study report, some options for each hydropower plant are indicated, and Table 8-5 shows the summery of these options.

**Table 8-5 Existing Plan of Extension/Renovation of Four Small Hydropower Plants**

| Name | Lusiwasi | Musonda | Chishimba | Lunzua |
|---|---|---|---|---|
| Existing Capacity | 12MW | 5MW | 6MW | 0.75MW |
| Number of Unit | 3MW x 4 | 1MW x 5 | A: 1.2MW x 4<br>B: 0.3MW x 4 | 0.25MW x 3 |
| Option 1 | Installation of 20MW x 2 units to existing plant | Upgrade of existing units up to 1.25MW x 5 units, and installation of additional 1.25MW x 1 unit | Installation of 0.3MW x 1 unit to B station | Installation of 0.25MW x 1 unit to existing plant |
| Cost [million US$] | 60.5 | 10.1 | 3.9 | 1.3 |
| Option 2 | Development of upper site, installing 5MW x 2units | | Replacing 0.3MW x 4units of A station with 0.75MW x 2 units, plus existing B station | Replacing existing 0.25MW x 3 units with 1MW x 1 unit |
| Cost [million US$] | 19.5 | | 4.7 | 1.6 |
| Option 3 | | | Abolition of A station and reconstruction with 2.4MW x 2 units, plus existing B station | Abolition of existing plant and reconstruction with 5MW x 2 units |
| Cost [million US$] | | | 15.0 | 23.0 |
| Upgraded Capacity (Maximum Case) | 62MW<br>(Option 1+2) | 7.5MW<br>(Option 1) | 9.6MW<br>(Option 3) | 10MW<br>(Option 3) |

Source: ZESCO

### 8.3.2. Off-grid Hydropower Development Plans

Existing plans of off-grid HPP projects are listed in Table 8-6, and the location of these sites is plotted in Figure 8-4. The numbering in the table corresponds to that in the map.

**Table 8-6 Planned Off-grid HPP Projects**

| No. | Name of Site | Province | District | Output [MW] | Estimated Cost [million US$] |
|---|---|---|---|---|---|
| 1 | Chavuma Falls | North-western | Chavuma | 15 | 20.0 |
| 2 | Chikata Falls | Northwestern | Kabompo | 3.5 | 13.1 |
| 3 | West Lunga | Northwestern | Mwinilunga | 2.0 | 5.8 |
| | | | | 2.5 | 7.2 |
| 4 | Mwinilunga | Northwestern | Mwinilunga | 1.5 | Site1: 7.0<br>Site2: 4.5 |
| 5 | Chitokoloki Mission | Northwestern | Zambezi | 0.15 | 0.3 |
| 6 | Shiwang'andu | Northern | Chinsali | 1.0 | 1.4 |

Source: DoE, ZESCO, and Mwinilunga Ventures Ltd.

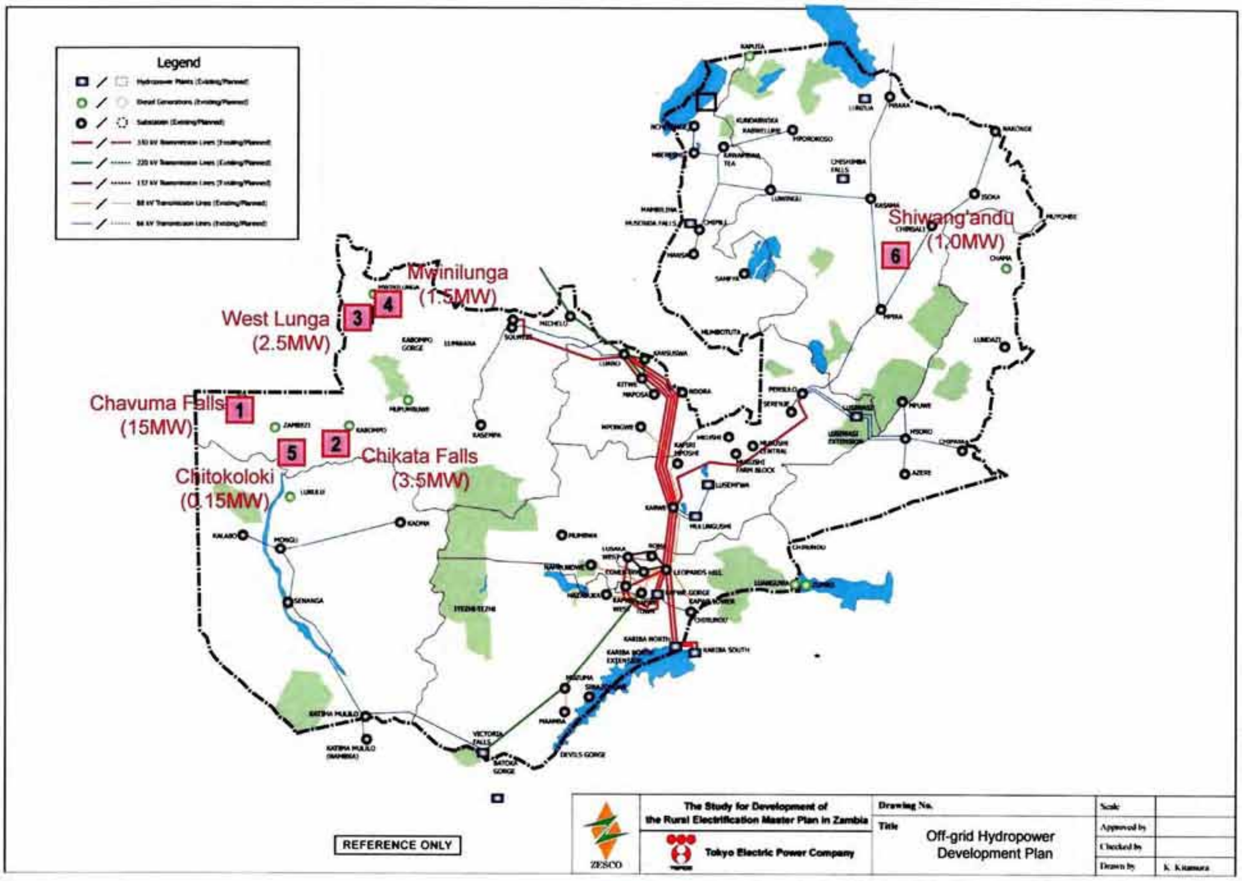



**Figure 8-4 Locations of Off-grid HPP Project Sites**

The outline of some projects in the list is as follows:

#### (1) Chavuma Falls Project

The potential generation capacity and the cost on Table 8-6 were provided by ZESCO, but no further information was not given. Yet, this project site was visited in October 2007 by Mr. Charles Rea who is an independent consultant in Mwinilunga hired by the Study Team for hydropower potential survey and also a developer of existing Zengamina Hydropower Plant. The following information was provided by him.

There are two possible sites, namely Chanda Falls and Chavuma Falls. Chanda Falls has a head of 13.5m, which gives 2 to 3MW in the wet season with rich river flow of 10 to 20 $m^3$/s. The existing diesel generator could supplement the shortage of output in the dry season. Additional development of Chavuma Falls site has a possibility to be an alternative to this backup diesel generator. Chavuma Falls site has a river flow of about 50$m^3$/s even in the dry season, and the head of 7m is available with 5m-height weir, which gives 3MW in the dry season. But the length of the weir would be about 200m and it cost about 2.5 million US$, which would raise the total project cost. The problem is that the tail water level rises leaving only about 2m net head during 2 month in the wet season. Therefore, both two sites should be developed and supplement each other during each low generation period. Figure 8-5 shows a picture of Chavuma Falls.

**Figure 8-5 Picture of Chavuma Falls**

(2) Chikata Falls Project

Chikata Falls is located on Kabompo River about 5km north of Kabompo District centre. NORPLAN, a Norwegian consultant, implemented pre-investment study in 2000 in collaboration with ZESCO, and SMEC, Australia's consulting engineering firms, carried out pre-feasibility study in 2007. This is a 3.5MW run-of-river type hydropower project, and the project cost was reported 12 million US$. This project is expected to be the alternative to the existing diesel power plant in Kabompo District centre. Figure 8-6 shows a picture of the site.

**Figure 8-6 Picture of Chikata Falls**

### (3) West Lunga Project

West Lunga Project is considered as the best alternative to existing diesel power plant supplying electricity to Mwinilunga District centre. The site is located about 7.5km downstream from the Mwinilunga Road Bridge on West Lunga River. NORPLAN also implemented pre-investment study in 2000 for low-head run-of-river scheme in collaboration with ZESCO. Two alternatives with separate dam site are reported in this study: one has 2.0MW of generation capacity with 5.8 million US$ of construction cost, and the other has 2.5MW with 7.2 million US$.

### (4) Mwinilunga Project

This is a 1.5 MW hydropower scheme near the Mwinilunga Boma, and is expected to help reducing the area's dependence on diesel generation. Enprima Ltd., Finnish consultant, conducted the feasibility study in 2004. There are 2 possible sites for this project, one is Kanyikomboshi and the other is Kakobakani, which are respectively at the distance of 6.5km and 15 km downstream from the road bridge in Mwinilunga town. The estimated project costs of Kanyikomboshi and Kakibakani are 7.2 million US$ and 4.5 million US$ respectively.

### (5) Chitokoloki Mission Project

Chitokiloki Mission Hospital is situated on the east bank of Zambezi River, 40km south of Zambezi. Since ZESCO's distribution lines have not reached this Mission Hospital yet, the hospital is operating its own 105kW diesel generator only in the limited time, from 11:00 to12:00 and from 18:00 to 21:30, for pumping up water and working medical device such as X-ray. The hospital plans to install 2 units of water turbines (100-150kW) by UEK Corporation, USA, in order to reduce the fuel cost and make electricity available 24 hours. Chitokoloki Mission and UEK Corporation prepared the proposal of this project and submitted to DoE, which was taken over to REA and was selected as one of REF release projects (K100 million) in 2006.

### (6) Shiwang'andu Project

Shiwang'andu is located 120km north of Mpika. The plan of installing mini-hydro pilot plant is a part of the project named "Renewable Energy Based Electricity Generation for Isolated Mini-Grids", which is implemented by United Nations Industrial Development Organization (UNIDO) and Global Environment Facility (GEF) and consists of 3 pilot plants powered by mini-hydro, solar and biomass. The total cost is estimated at 7.5 million US$ (out of which 1.4 million US$ is budgeted for the hydropower plant). For financing this cost, however, 2.75 million US$ of co-financing from private investors is requested, which might be the highest barrier to actualise the project. The generation capacity of the hydropower plant is designed as 1,000 kW, considering the water flow of 11m$^3$/sec and the gross elevation gain of 12m. Figure 8-7 shows pictures of Shiwang'andu Project site.

**Figure 8-7 Pictures of Shiwang'andu Project Site**

## 8.4. Hydropower Potential Survey

The purpose of the Hydropower Potential Survey is to estimate the amount of hydropower generation potential and the development cost. Hydropower potential surveys were mainly implemented in North-western, Northern and Luapla Provinces, where the national grid has not been developed enough and also where is relatively rich difference of elevation. Since Western Provincial Planner submitted the information of some small falls, the Study Team conducted the additional survey in Western Province following the information.

The surveys were implemented separately in two phases; the first survey was for North-western and Western Provinces, and the second survey was for Northern and Luapula Provinces. The targets of potential site are determined based on the information from Counterparts, Local Government and Local Consultants in addition to the map study on the 1:50,000 scale topographic map.

### 8.4.1. Method of Hydropower Potential Estimation

#### (1) Water Head Measurement

Hydropower potential is in proportion of the water head, therefore, measuring the gross water head is one of the main issue of this survey. The study team decide the place of intake and tailrace, and measure the elevation along the river with total station to estimate the gross head of the site. Here, effective head, which is used to hydropower potential calculation, is set at 90% of gross head.

#### (2) Design Discharge Estimation

Water discharge is another component of hydropower potential. To design the generation capacity, it is quite essential to figure out the average water flow amount in the dry season. However, the site does not have any flow gauging equipment. Therefore, the study team estimates the river flow of the site by the following method.

i) Obtain the river flow data at the nearest gauging station located downstream of the site [River flow A].

ii) Acquire the catchment area of the gauging station [Catchment area A], which are usually included by the database of gauging station itself.

iii) Figure out the catchment area of the actual site [Catchment area B] using 1:50,000 topographic maps.

iv) Calculate the waterflow at the site [River flow B] by the following equation;

*[River flow A]: [River flow B]= [Catchment area A]: [Catchment area B],*

*Therefore, [River flow B]= [River flow A]* [Catchment area B]/ [Catchment area A]*

After conversion of the existing river flow data into the discharge of the actual site, the study team draws a duration curve for each site, figures water flow of 80% availability (more than 80% days in a year, water flow is more than this amount), and makes it the design discharge for the site.

#### (3) Hydropower Potential Estimation

Hydropower potential can be calculated by the following equation;

$$P=9.8*Q*H*\eta_T*\eta_G$$

Here, $P$: Generating Power [kW]

$Q$: Water Discharge [$m^3/s$]

$H$: Effective Head [m]

$\eta_T$: Turbine Efficiency

$\eta_G$: Generator Efficiency

In this potential estimation, the study team fixes the turbine efficiency and generator efficiency at 85% and 95% respectively, which are considered as a reasonable figure given the present technical circumstances.

### (4) Construction Cost Estimation

The study them roughly designs the general layout for good hydropower potential sites and estimates the length of weir, channel, penstock, tailrace, spillway and distribution line. Based on this basic design, the construction cost is calculated. Design conditions are as follows:

- Civil facilities are mainly structured by stone masonry
- Ratios of common excavation and rock excavation are 20% and 80%, respectively
- Turbine and generator are Cross-flow turbine manufactured in Europe, which are frequently adopted to existing small hydropower plant in Zambia
- Voltage of distribution line is thirty-three (33) kV

Table 8-7 shows the unit price of each item, which is based on the actual price in the Zengamina Mini-hydropower Project in Mwinilunga, and information from ZESCO and REA. The costs of 33kV distribution line and 33kV/400V Transformer are following the costs determined in Table 7-3, Chapter 7.

**Table 8-7 Unit Price**

| Item | Unit Price |
|---|---|
| Access Road | US$ 30,000 /km |
| Road maintenance | US$ 3,000 |
| Masonry | US$ 150 /$m^3$ |
| Concrete | US$ 600 /$m^3$ |
| Rebar | US$ 1,400 /t |
| Tunnel boring | US$ 1,000 /m |
| Common Excavation | US$ 10 /$m^3$ |
| Rock Excavation | US$ 60 /$m^3$ |
| Steel structure | US$ 2,800 /t |
| 33kV distribution line | US$ 36,000 /km |
| 33kV/400V Transformer (100MVA) | US$ 13,700 /unit |

After calculation of direct cost for construction, engineering service cost, overhead cost and Profit margin are tacked on the direct cost at 8%, 25% and 20% of direct cost respectively. These percentages are decided following the discussion with REA.

## 8.4.2. Results of Hydropower Potential Survey

### (1) North-western Province

The hydropower potential survey in North-western Province was carried out from 24th May to 30th May. The study team found out nine (9) hydropower potential sites. The locations of the surveyed hydropower potential sites are shown in Figure 8-8. The results of the survey are described as follows.

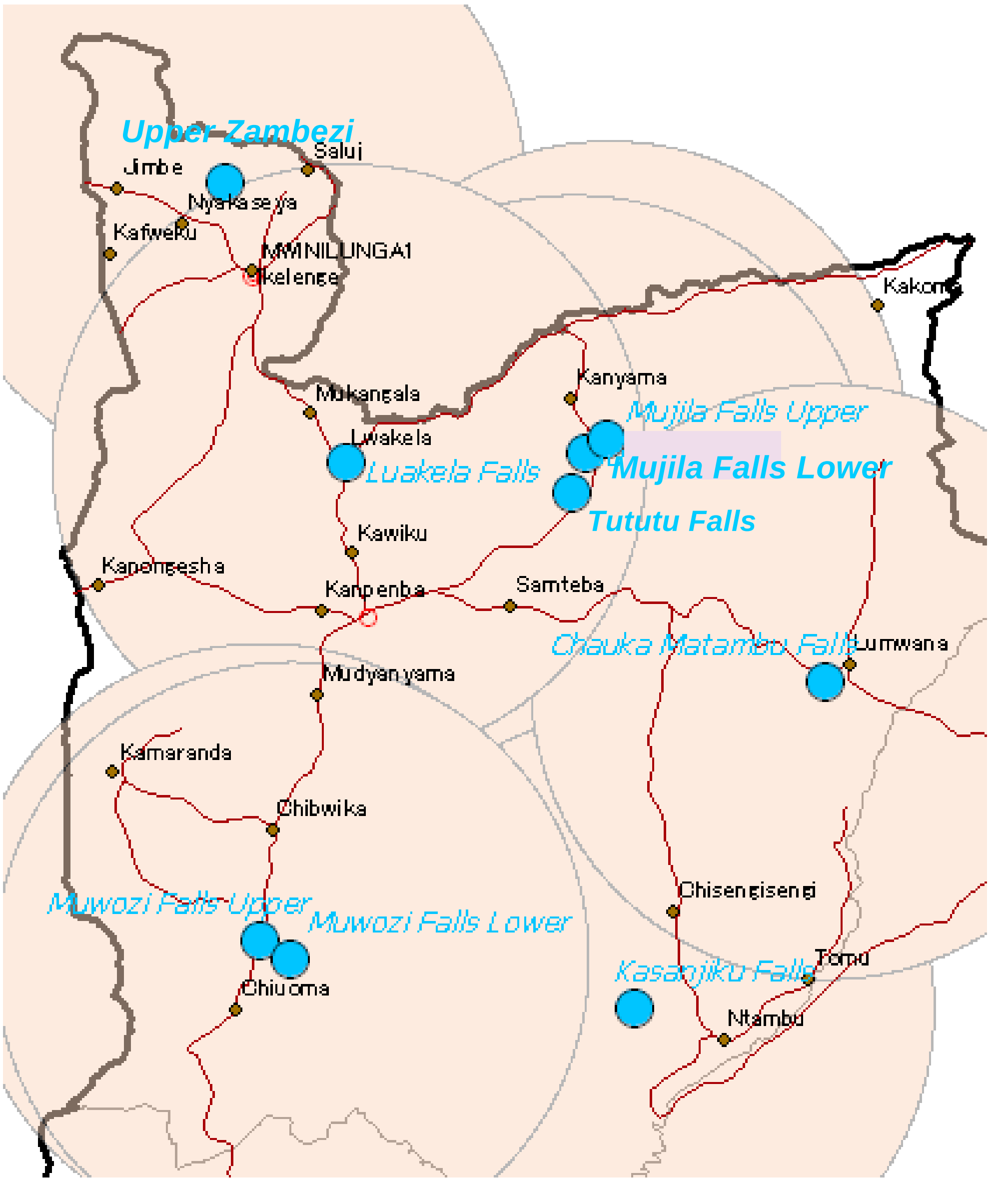



**Figure 8-8 Location of Hydropower Potential Site in Northwestern Province**

(a) Upper Zambezi Site

Upper Zambezi Site is located about 75 km north of the centre of Mwinilunga District, on the uppermost stream of Zambezi River. There is Zengamina Hydropower Plant (700kW, here after Zengamina HP) at only 4.5km downstream of this site. The survey was implemented on 24th May 2007, and the water flow was about 10m$^3$/s with 9m gross head. Since the water flow at 80% availability is 6.44m$^3$/s on the flow duration curve (Figure 8-9), which was edited by the Study Team, the designed discharge should be 6.0m$^3$/s and then the potential generation capacity is estimated at 380kW. Figure 8-10 shows pictures of this site.

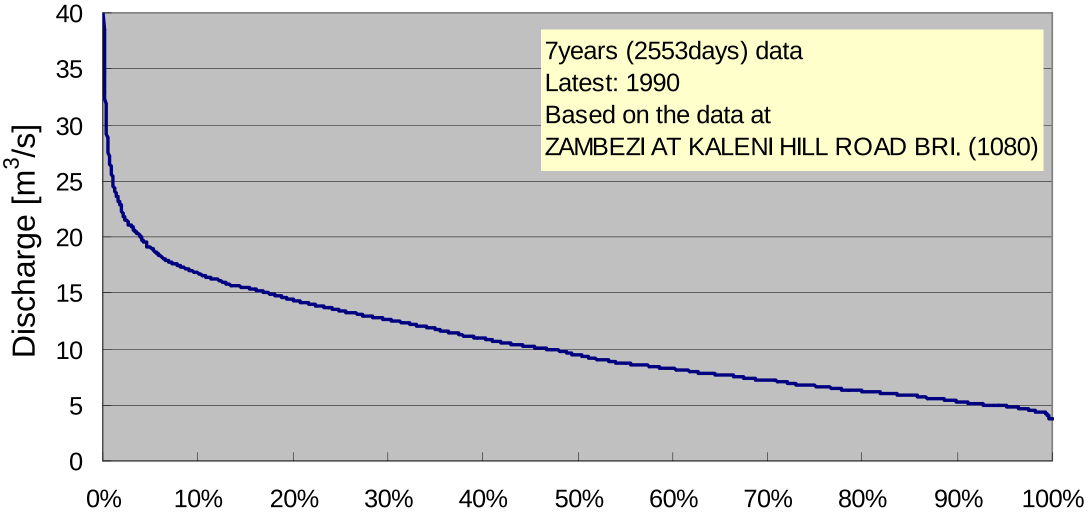



**Figure 8-9 Flow Duration Curve at Upper Zambezi Site**

a) Main falls


b) Water channel on the right bank


c) View from head tank to powerhouse

**Figure 8-10 Pictures of Upper Zambezi Site**

Zengamina Power Company, which owns the Zengamina HP, has already been planning to develop this site with a dam of 10m height. Thanks to this additional height of dam, they estimated that the potential generation capacity of this site is 1,000kW with 18m effective head and 8.0m$^3$/s designed discharge and the project cost is about USD 3.0 million. Furthermore, since they will be able to use water more effectively due to this planned dam, they also want to install another 700 kW unit to existing Zengamina HP and to expand its total capacity up to 1,400kW.

Existing Zengamina HP supplies electricity to Ikelenge RGC (potential demand: 1,995kW), which is located 4.5km south of Zengamina HP and Nyakaseya RGC (potential demand: 483kW), which is located 14km northwest of Ikelenge RGC via 33kV distribution line. However, due to the large potential demand of these areas, it is quite possible that electricity consumption there exceeds the 700kW capacity of Zengamina HP in the near future. Therefore, it is really effective option to develop Upper Zambezi Site and to connect to Zengamina HP. There is no household and firms in influenced area by construction works, so the environmental issue would not be a barrier of the development. The Study Team estimated development cost of this potential as a run-of-river type, 380kW hydropower plant. Table 8-8 shows the summery of this site.

**Table 8-8 Project Summery of Upper Zambezi Site**

**[Design Result]**

| | |
|---|---|
| Province | Northwestern |
| District | Mwinilunga |
| Name of the Site | Upper Zambezi |
| Name of the River | Zambezi River |
| Latitude | S11:06:18 |
| Longitude | E24:13:41 |
| Catchment Area | 698 $km^2$ |
| 80% available discharge | 6.44 $m^3/s$ |
| Design Discharge | 6.0 $m^3/s$ |
| Gross Head | 9.0 m |
| Effective Head | 8.0 m |
| Generation Capacity | 380 kW |
| Volume of Powerhouse | 362 $m^3$ |
| Volume of Weir | 216 $m^3$ |
| Length of Channel | 142 m |
| Length of Penstock | 47 m |
| Length of Tailrace | 30 m |
| Length of Spillway | 60 m |
| Length of Distribution Line | 4.5 km |

**[Electrified Area]**

| | |
|---|---|
| Ikelenge RGC | 1995 kW |
| Nyakaseya RGC | 483 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 1,496,720 US$ |
| i) Temporary Works | 224,360 US$ |
| ii) Civil Engineering | 677,860 US$ |
| iii) Turbine, Gen and Main Transformer | 364,000 US$ |
| iv) Distribution Line & Transformer | 230,500 US$ |
| II. Engineering Service Cost | 119,738 US$ |
| III. Overhead Cost | 374,180 US$ |
| IV. Profit Margine | 299,344 US$ |
| Grand Total | 2,289,982 US$ |

(b) Mujila Falls Lower Site

Mujila Falls Lower (hereafter MFL) Site is on Mujila River, which is a tributary to West Lunga River and is located 45km northeast of Mwinilunga District centre. The water flow as of 25th May 2007 was about 15$m^3$/s. The river has several falls within a span of 400m stream, therefore 18m gross head will be available including the height of 5m weir. The upstream of the planned weir is depression contour, so this could be a natural reservoir after the construction of the weir. Therefore, though its water flow at 80% availability at the site is 9.21$m^3$/s from the flow duration curve (Figure 8-11), designed discharge can be set at 10.0$m^3$/s. Due to this head and discharge, maximum generation capacity of 1,400kW will be achieved.

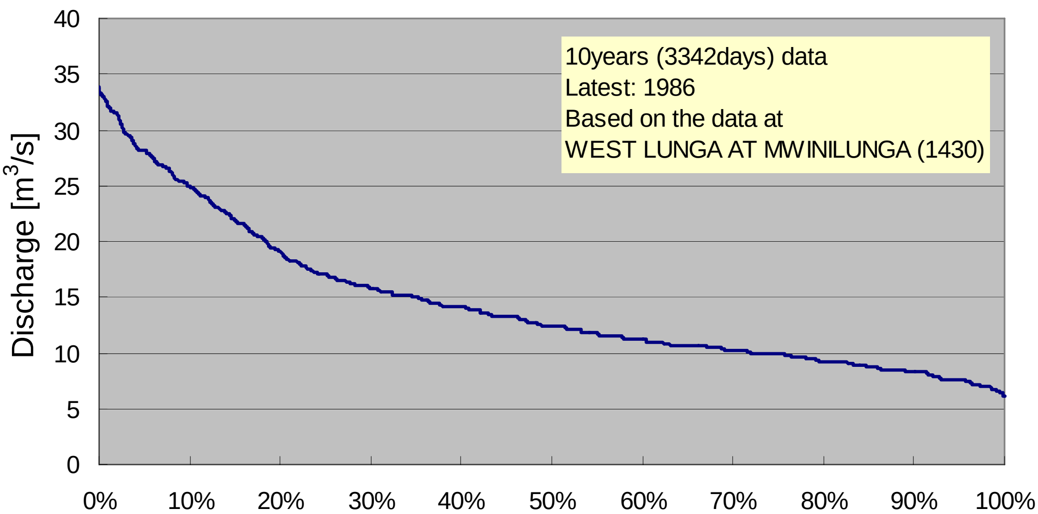



**Figure 8-11 Flow Duration Curve at Mujila Falls Lower Site**

Figure 8-12 shows pictures of MFL site. As Mujila River is bending to the left toward downstream after the weir, so direct distance from the weir to the end of the rapids on the left bank is only about 270m. However, since the left bank of the river is a steep hill, it is recommended to make a non-pressure tunnel conduit from intake to head tank. Due to this effort, the length of penstock will become shorter and the project cost will be smaller.

a) Mujila falls lower

b) Overview of the site

c) Depression contour for natural reservoir

**Figure 8-12 Pictures of Mujila Falls Lower Site**

Possible demand sites are Kanyama RGC (potential demand: 598kW) at about 10km north of MFL site and Kakoma RGC (potential demand: 350kW), located near the border with Congo, 60km east from Kanyama RGC. The potential of MFL site is too much for only these two RGCs. But there are two important villages along the main road within catchment area of Kanyama RGC. One is Mujila Village, located on the way from the falls to Kanyama RGC. This village has about 200 households and the Mujila Falls Agriculture Centre, whose potential demand is 234kW. The other is Kapundu Village, located about 10km south from the falls. This village also have 200 households, an elementary school, and a clinic, whose potential demand is 233kW. The total demand of these two RGCs and two villages is 1,415kW, which is nearly equal to the potential of generation capacity. Therefore, to maximize the benefit of MFL site development, these two villages should be included in the electrified area.

The site is located in the valley, and there is no household and firms to be influenced by the development. The left bank of the river would be opened up to create water tunnel and a powerhouse, so the trees in the hill of left bank must be cut off. Nevertheless, the environmental issue would not be a barrier of the development. The Study Team estimated development cost of this potential. Table 8-9 shows the summery of this site.

**Table 8-9 Project Summery of Mujila Falls Lower Site**

**[Design Result]**

| | |
|---|---|
| Province | Northwestern |
| District | Mwinilunga |
| Name of the Site | Mujila Falls Lower |
| Name of the River | Mujila River |
| Latitude | S11:30:52 |
| Longitude | E24:46:24 |
| Catchment Area | 1,146 $km^2$ |
| 80% available discharge | 9.21 $m^3/s$ |
| Design Discharge | 10.0 $m^3/s$ |
| Gross Head | 18.0 m |
| Effective Head | 17.1 m |
| Generation Capacity | 1,400 kW |
| Volume of Powerhouse | 596 $m^3$ |
| Volume of Weir | 450 $m^3$ |
| Length of Channel | 210 m |
| Length of Penstock | 23 m |
| Length of Tailrace | 20 m |
| Length of Spillway | 36 m |
| Length of Distribution Line | 98 km |

**[Electrified Area]**

| | |
|---|---|
| Kanyama RGC | 598 kW |
| Kakoma RGC | 350 kW |
| Mujila Village | 234 kW |
| Kapundu Village | 233 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 6,393,200 US$ |
| i) Temporary Works | 404,070 US$ |
| ii) Civil Engineering | 1,070,230 US$ |
| iii) Turbine, Gen and Main Transformer | 1,158,000 US$ |
| iv) Distribution Line & Transformer | 3,760,900 US$ |
| II. Engineering Service Cost | 511,456 US$ |
| III. Overhead Cost | 1,598,300 US$ |
| IV. Profit Margine | 1,278,640 US$ |
| Grand Total | 9,781,596 US$ |

(c) Mujila Falls Upper Site

Mujila Falls Upper (hereafter MFU) Site is located 4.4km upstream of MFL site (shown above) on Mujila River. The water flow as of 25th May 2007 was about 8$m^3/s$. There are several falls within a span of 100m stream, which gives in total 14m gross head including steep downstream and the weir to be installed. The flow duration curve at this site (Figure 8-13) indicates that its water flow at 80% availability is 4.14$m^3/s$, and the potential generation capacity of this site is estimated at 420kW assuming that the designed discharge is 4.0$m^3/s$. Figure 8-14 shows pictures of MFU site.

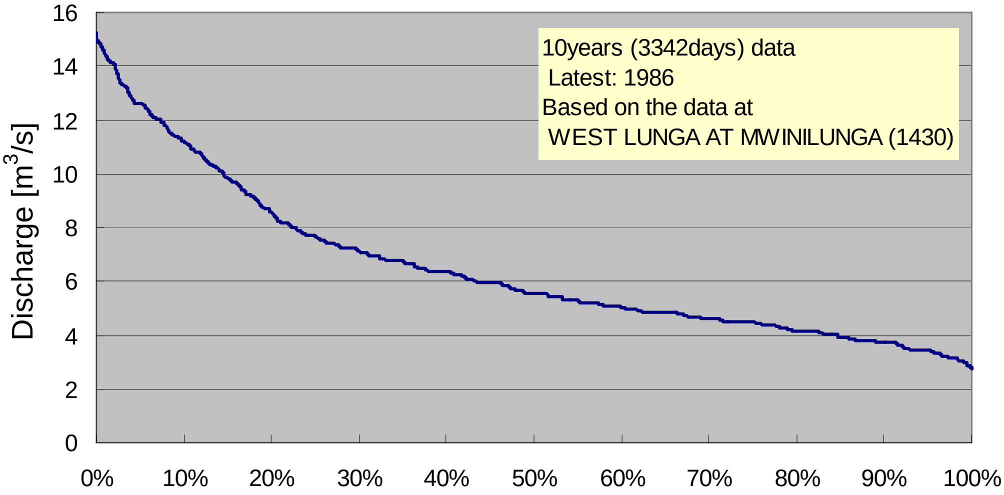



**Figure 8-13 Flow Duration Curve at Mujila Falls Upper Site**

a) Mujila falls upper

b) Upstream of the falls

**Figure 8-14 Pictres of Mujila Falls Upper Site**

MFU site, with its rich hydropower potential and ease of construction, appears to be highly suitable for hydropower development. However, possible demand sites to be electrified with MFU site, which will be Kanyama and Kakoma RGCs, will overlap with those for MFL site.

Furthermore, since the potential generation capacity of MFL site is much more than that of MFU site and only developing MFL site is enough to supply electricity to these two RGCs, the development of MFU site is less prioritized than MFL site. The development of MFU site might be considered in case the total power demand of this area exceeds the generation capacity of MFL site in the future.

There are five households and their livestock farm beside the site. The structures of hydropower plant will not affect their lives but the access road and the noise of construction work will influence them. But these issues will not discourage against the development because they are ambitious of using electricity to enhance the efficiency of their firm management. The Study Team estimated development cost of this potential. Table 8-10 shows the summery of this site.

**Table 8-10 Project Summery of Mujila Falls Upper Site**

**[Design Result]**

| | |
|---|---|
| Province | Northwestern |
| District | Mwinilunga |
| Name of the Site | Mujila Falls Upper |
| Name of the River | Mujila River |
| Latitude | S11:29:32 |
| Longitude | E24:48:25 |
| Catchment Area | 515 $km^2$ |
| 80% available discharge | 4.14 $m^3/s$ |
| Design Discharge | 4.0 $m^3/s$ |
| Gross Head | 14.0 m |
| Effective Head | 13.2 m |
| Generation Capacity | 420 kW |
| Volume of Powerhouse | 393 $m^3$ |
| Volume of Weir | 180 $m^3$ |
| Length of Channel | 78 m |
| Length of Penstock | 36 m |
| Length of Tailrace | 19 m |
| Length of Spillway | 47 m |
| Length of Distribution Line | 11 km |

**[Electrified Area]**

| | |
|---|---|
| Kanyama RGC | 598 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 1,479,720 US$ |
| i) Temporary Works | 157,900 US$ |
| ii) Civil Engineering | 466,320 US$ |
| iii) Turbine, Gen and Main Transformer | 391,000 US$ |
| iv) Distribution Line & Transformer | 464,500 US$ |
| II. Engineering Service Cost | 118,378 US$ |
| III. Overhead Cost | 369,930 US$ |
| IV. Profit Margine | 295,944 US$ |
| Grand Total | 2,263,972 US$ |

(d) Tututu Falls Site

Tututu Falls Site is located at 7km south of MFL site on Kapundu River that is a tributary to Mujila River. The water flow as of 25th May 2007 was only about 1.5$m^3/s$, so designed discharge should be 1.0$m^3/s$ at most. And as gross head there is 4.0m, potential generation capacity would be only 30kW. Figure 8-15 shows a picture of this site.

Kapundu village, which is one of surrounding villages of Kanyama RGC, exists beside Tututu Falls Site. These villages are out of the scope of this Rural Electrification Master Plan, but to electrify Kapundu village would be significant because it has about 200 households, an elementary school and a clinic. However, it is unnecessary to develop this site because the potential demand of this village can be easily covered by the potential generation capacity of MFL site

**Figure 8-15 Picture of Tututu Falls Site**

(e) Kasanjiku Falls Site

Kasanjiku Falls Site is located about 80km southeast of Mwinilunga District centre on Kasanjiku River, which is a tributary to Kabompo River. The water flow as of 26th May 2007 was $10m^3/s$ and its gross head is 10m including 4m height of weir to be installed. The flow duration curve at this site (Figure 8-16) indicates that its water flow at 80% availability is $4.63m^3/s$. Therefore, the potential generation capacity of this site is estimated at 320kW assuming that the designed discharge is $4.5m^3/s$. Figure 8-17 shows pictures of Kasanjiku Falls Site. The banks of the river are covered by bushes, which must be cut off in construction stage. But there are no household and firms to be influenced by the development of the site.

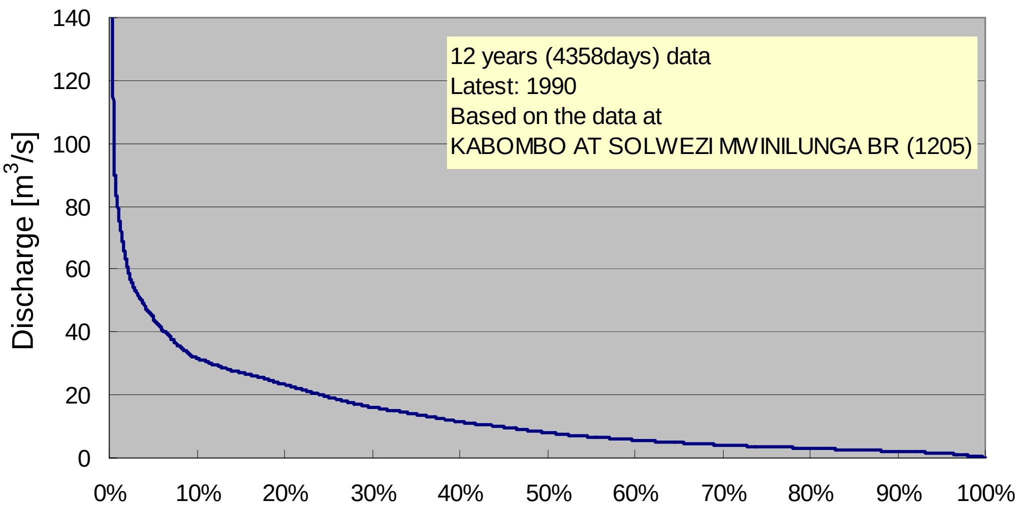



**Figure 8-16 Flow Duration Curve at Kasanjiku Falls Site**

a) Kasanjiku falls

b) Upstream of the falls

c) Downstream of the falls

**Figure 8-17 Pictures of Kasanjiku Falls Site**

Possible demand site to be electrified is Ntanbu RGC (potential demand: 532kW), which is located at 15km southeast from this site. Ntanbu RGC has the new Luwi Hospital, which was funded by Korean government, and was ranked as the first priority on the Mwinilunga RGC list for the willingness to be electrified. The potential generation capacity of Kasanjiku Falls Site will not fully satisfy the potential demand of Ntanbu RGC, but it is enough to satisfy the present potential demand. Additionally, Ntanbu RGC is located quite far from District centre where 66kV transmission line will be extended by ZESCO in the future. Those are the reason why the hydropower potential of Kasanjiku Falls Site is still attractive to be developed. The Study Team estimated the construction cost and Table 8-11 shows the summery of the project.

**Table 8-11 Project Summery of Kasanjiku Falls Site**

**[Design Result]**

| | |
|---|---|
| Province | Northwestern |
| District | Mwinilunga |
| Name of the Site | Kasanjiku Falls |
| Name of the River | Kasanjiku River |
| Latitude | S12:21:10 |
| Longitude | E24:50:55 |
| Catchment Area | 1,605 $km^2$ |
| 80% available discharge | 4.63 $m^3/s$ |
| Design Discharge | 4.5 $m^3/s$ |
| Gross Head | 10.0 m |
| Effective Head | 9.0 m |
| Generation Capacity | 320 kW |
| Volume of Powerhouse | 314 $m^3$ |
| Volume of Weir | 180 $m^3$ |
| Length of Channel | 231 m |
| Length of Penstock | 44 m |
| Length of Tailrace | 10 m |
| Length of Spillway | 69 m |
| Length of Distribution Line | 22 km |

**[Electrified Area]**

| | |
|---|---|
| Ntambu RGC | 532 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 2,301,150 US$ |
| i) Temporary Works | 470,850 US$ |
| ii) Civil Engineering | 659,500 US$ |
| iii) Turbine, Gen and Main Transformer | 324,000 US$ |
| iv) Distribution Line & Transformer | 846,800 US$ |
| II. Engineering Service Cost | 184,092 US$ |
| III. Overhead Cost | 575,288 US$ |
| IV. Profit Margine | 460,230 US$ |
| Grand Total | 3,520,760 US$ |

(f) Chauka Matambu Falls Site

Chauka Matambu Falls Site is located 80km east of Mwinilunga District centre on West Lumuwana River, which is a tributary to Kabompo River. The accessibility of the site is very good because the site is situated only 3km south from Solwezi-Mwinilunga main road. The main falls has 6m drop and another fall on 200m downstream has 3m drop, which gives 11m of gross head including the height of low weir. The water flow as of 28th May 2007 was $4m^3/s$, and the flow duration curve at this site (Figure 8-18) indicates that its water flow at 80% availability is $2.64m^3/s$. Therefore, the potential generation capacity would be estimated at 180kW assuming $2.5m^3/s$ of designed discharge. Figure 8-19 shows pictures of Chauka Matambu Falls Site. The bushes on the left bank must be opened due to the construction works, and there is a Filicales firm on the left bank near the proposed place for powerhouse. In addition, access road for the site will cross the Lumuwana RGC. Therefore, the environmental impact of the development should be discussed before the site is developed.

Possible potential site is Lumuwana RGC (potential demand: 370kW), which is situated just beside the main road and has greatly grown recently due to pineapple plantations. Though its potential demand in 2030 will exceed the potential generation capacity, the potential of Chauka Matambu Falls Site can satisfy the current potential demand and is situated close to the demand site. Therefore, to develop this hydropower potential and to electrify only the plantations and public facilities can accelerate the further growth of this area. The Study Team estimated the project cost and Table 8-12 shows the summery of the project.

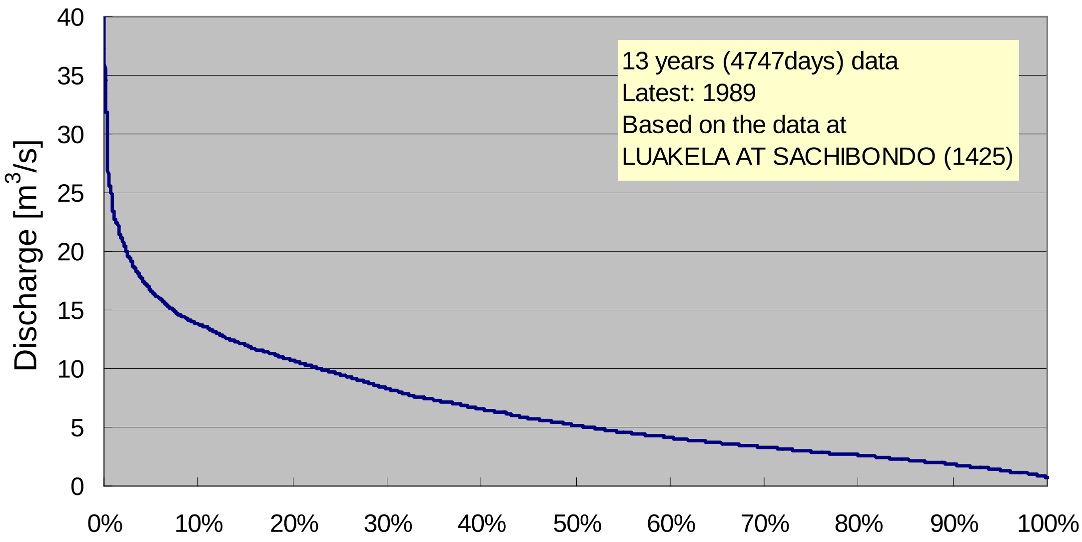



**Figure 8-18 Flow Duration Curve at Chauka Matambu Falls Site**

a) Main falls

b) Lower falls

**Figure 8-19 Pictures of Chauka Matambu Falls Site**

### Table 8-12 Project Summery of Chauka Matambu Falls Site

**[Design Result]**

| | |
|---|---|
| Province | Northwestern |
| District | Mwinilunga |
| Name of the Site | Chauka Matambu Falls |
| Name of the River | West Lumuwana River |
| Latitude | S11:51:34 |
| Longitude | E25:08:13 |
| Catchment Area | 537 km$^2$ |
| 80% available discharge | 2.64 m$^3$/s |
| Design Discharge | 2.5 m$^3$/s |
| Gross Head | 11.0 m |
| Effective Head | 9.1 m |
| Generation Capacity | 180 kW |
| Volume of Powerhouse | 197 m$^3$ |
| Volume of Weir | 600 m$^3$ |
| Length of Channel | 175 m |
| Length of Penstock | 235 m |
| Length of Tailrace | 25 m |
| Length of Spillway | 40 m |
| Length of Distribution Line | 6 km |

**[Electrified Area]**

| | |
|---|---|
| Lumwana RGC | 371 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 1,306,780 US$ |
| i) Temporary Works | 269,930 US$ |
| ii) Civil Engineering | 549,750 US$ |
| iii) Turbine, Gen and Main Transformer | 230,000 US$ |
| iv) Distribution Line & Transformer | 257,100 US$ |
| II. Engineering Service Cost | 104,543 US$ |
| III. Overhead Cost | 326,695 US$ |
| IV. Profit Margine | 261,356 US$ |
| Grand Total | 1,999,374 US$ |

(g) Lwakela Falls Site

Luakela Falls Site is located about 25km north of Mwinilunga District centre on Luakela River, which is a tributary to West Lunga River. The water flow as of 28th May 2007 was 5m$^3$/s and the gross head is 7m with a simple low weir. The flow duration curve at this site (Figure 8-20) indicates that its water flow at 80% availability is 2.14m$^3$/s. Therefore, the potential generation capacity of this site is estimated at 100kW assuming that the designed discharge is 2.0m$^3$/s. Figure 8-21 shows a picture of Lwakela Falls Site.

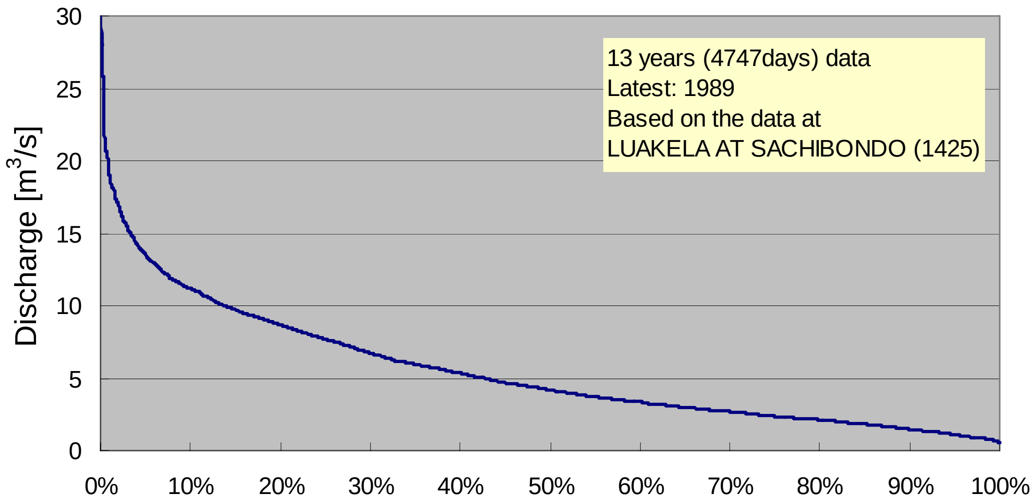



**Figure 8-20 Flow Duration Curve at Luakela Falls Site**

**Figure 8-21 Picture of Lwakela Falls Site**

There is Lwakela RGC (potential demand: 257kW) only 0.5km northwest of this site. The potential generation capacity is much less than the potential demand, and this RGC can be cheaply connected to the national grid after ZESCO realize the plan of transmission line extension to Mwinilunga District centre. Therefore, there is no necessity to develop this site.

(h) Muwozi Falls Upper Site

Muwozi Falls Upper Site is located about 60km south of Mwinilunga District centre on Muwozi River that is a tributary to West Lunga River. Its gross head is 4m and the discharge as of 29th May 2007 was only $1.5m^3/s$. The discharge would be designed at most $1.0m^3/s$ considering the low flow in the dry season, and the potential generation discharge would be estimated at 30kW. Figure 8-22 shows a picture of Muwozi Falls Upper Site.

Chiwoma RGC (potential demand: 418kW) is located 6km south of the falls. The potential generation capacity is much less than the demand and the effectiveness of the hydropower development is extremely low.

**Figure 8-22 Picture of Muwozi Falls Upper Site**

(i) Muwozi Falls Lower Site

Muwozi Falls Lower Site is located about 6km downstream of Muwozi Falls Upper Site. Its gross head is 5m and the discharge as of 29th May 2007 was only 1.5$m^3$/s. The discharge would be designed at most 1.0$m^3$/s considering the low flow in the dry season, and the potential generation discharge would be estimated at 35kW. Figure 8-23 shows a picture of Muwozi Falls Lower Site.

Nearest demand site is also Chiwoma RGC (potential demand: 418kW). The potential generation capacity is too small compared with the demand and there is no reason to develop this site.

**Figure 8-23 Picture of Muwozi Falls Lower Site**

(2) Northern and Luapula Provinces

The hydropower potential survey in Northern and Luapula Provinces was carried out from 4th August to 11th August 2007. The study team found out eleven hydropower potential sites during this period. The locations of the surveyed hydropower potential sites are shown in Figure 8-24. The results of the survey for each site are described as follows.

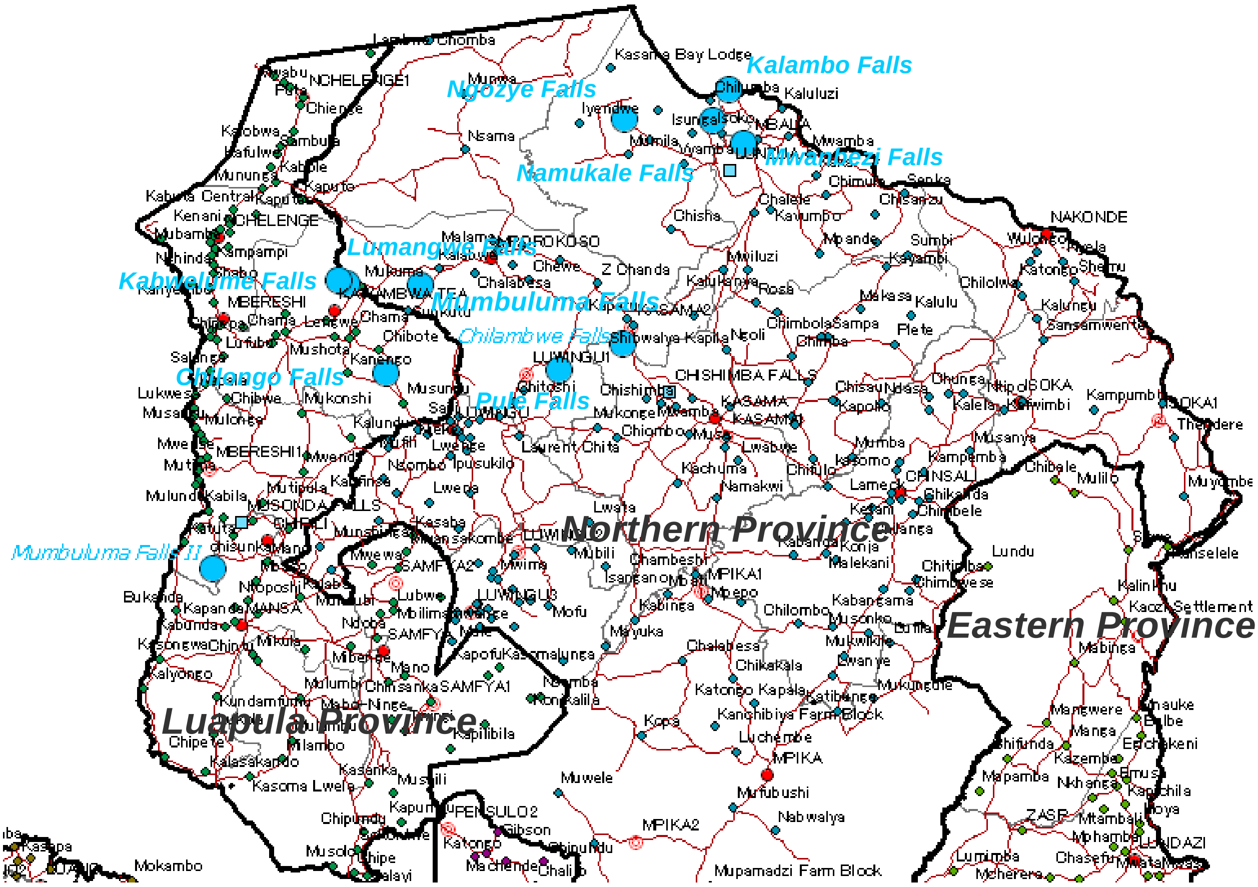
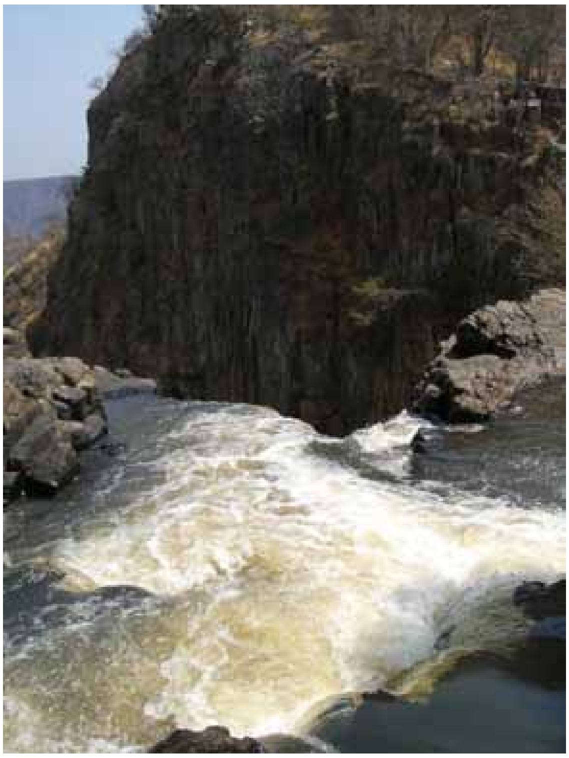



**Figure 8-24 Location of Hydropower Potential Site in Northern and Luapula Provinces**

(a) Kalambo Falls Site (Northern Province)

Kalambo Falls Site is located at the north end of Mbala District on Kalambo River running along the border with Tanzania and into the Lake Tanganyika. The fall has the second highest drop in the nation and is certified as a national monument. The water flow as of 4th August 2007 was 1.5m$^3$/s, and it will decrease around 1m$^3$/s in the dry season. The water is falling plumb down and topographic survey could not be executed owing to the safety aspect. The potential generation capacity is estimated at 1,650kW assuming 1.0m$^3$/s of designed discharge and 231m of gross head which is said in the official guidance. Figure 8-25 shows pictures of the site.

a) Kalambo falls (side view)



b) Kalambo falls (from top of a waterfall)

c) Landscape from the top of a waterfall

**Figure 8-25 Pictures of Kalambo Falls Site**

Possible demand site for this hydropower potential will Mbala District centre, which is located about 35km south of the falls. Mbala District centre is out of the scope of rural electrification because Mbala District centre has already been electrified by the national grid via 66kV transmission line from Kasama substation, but as Mbala is branched at very end of the grid and has problem of quality of electricity, to settle a power plant here will be quite effective to enhance the stability of electricity. Nearest RGC from the falls is Kaluluzi (potential demand: 53kW), but since the distance from Kaluluzi to Mbala substation is only 22km. Therefore, this RGC can easily connected to the grid from Mbala substation and this is much more cost-effective than developing Kalambo Falls Site.

The falls can be accessed by car from the left bank without any difficulties. However, it is required to dig the bedrock more than depth of 200m perpendicularly, which is costly and works with a lot of difficulty. In addition, there must be several problems to be solved because the falls are located on the national border and are registered as a national monument. As stated above, Kalambo Falls Site is not attractive for the purpose of rural electrification in spite of its rich hydropower potential.

(b) Mwanbezi Falls Site (Northern Province)

Mwanbezi Falls Site is located about 8km southwest of Mbala District centre on Mwanbezi River. The water flow as of 4th August 2007 was about 1.0m$^3$/s, which would decrease at about 0.7m$^3$/s in the dry season, and the gross head is 3m. Figure 8-26 shows the picture of the site. The land condition around the site is smooth and the construction works of 10kW micro hydropower plant will be simple, however, the potential generation capacity is too small and there is no necessity of development.

**Figure 8-26 Picture of Mwanbezi Falls Site**

(c) Namukale Falls Site (Northern Province)

Namukale Falls Site is located about 6km east of Mpulungu District centre on Lunzua River. The distance from the falls to Lake Tanganyika is about 1.5km and Lunzua Falls HP, owned by ZESCO, exists on upstream. The water flow as of 5th August 2007 was 4m$^3$/s. Since flow duration curve at this site (Figure 8-27) indicates that the water flow at 80% availability is 2.37m$^3$/s, designed discharge should be settled at 2.3m$^3$/s. This site has two falls with 4m drop and 10m drop in a row, and 16m gross head in total is available including the drop of steep flow on up the first fall and the low weir to be installed, hence the potential generation capacity is estimated at 270kW. Figure 8-28 shows pictures of this site.

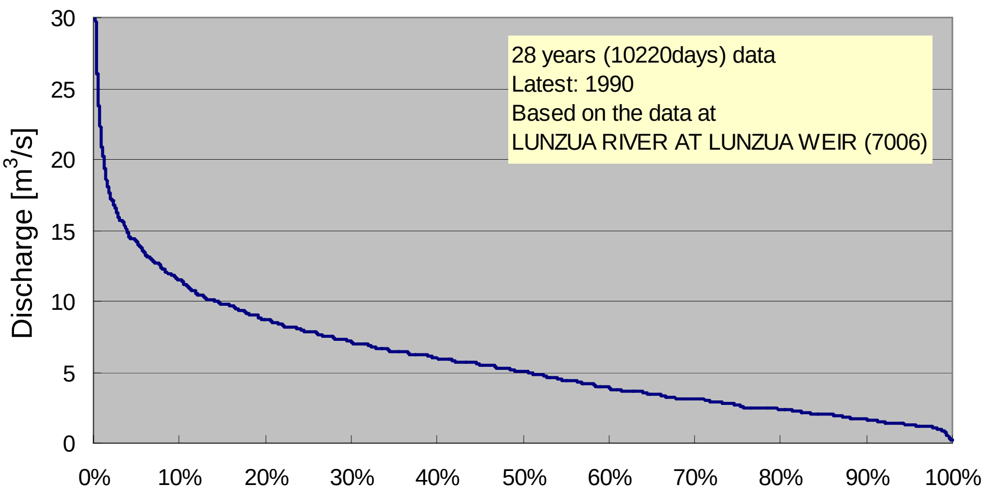



**Figure 8-27 Flow Duration Curve at Namukale Falls Site**

a) Lakeside village of Lake Tanganyika near Namukale Falls

b) Namukale Falls

c) Overview of the site

**Figure 8-28 Pictures of Namukale Falls Site**

Possible demand site is Mpulungu Central RGC (potential demand: 2,201kW), which is ranked first on our priority list of 1,217 unelectrified RGCs. The problems are the lack of the potential generation capacity for the large potential demand and poor accessibility. There was no road approaching this falls, so the Study Team had to travel by boat on Lake Tanganyika and walk to the falls from the right bank of the river. Nevertheless, the development of this hydropower potential is considerable. As preparations of the development, construction of a land route approaching the falls and also a bridge to the left bank, which arrows to develop a hydropower plant on the left bank and makes the works easier, are required. The left bank is completely covered with bushes, and it seems that there is no living area within the influenced area by the proposed hydropower plant. The Study Team estimated the project cost and Table 8-13 shows the summery of the site.

**Table 8-13 Project Summery of Namukale Falls Site**

**[Design Result]**

| | |
|---|---|
| Province | Northern |
| District | Mpulungu |
| Name of the Site | Namukale Falls |
| Name of the River | Lunzua River |
| Latitude | S8:45:02 |
| Longitude | E31:09:47 |
| Catchment Area | 791 km$^2$ |
| 80% available discharge | 2.37 m$^3$/s |
| Design Discharge | 2.3 m$^3$/s |
| Gross Head | 16.0 m |
| Effective Head | 15.0 m |
| Generation Capacity | 270 kW |
| Volume of Powerhouse | 274 m$^3$ |
| Volume of Weir | 90 m$^3$ |
| Length of Channel | 200 m |
| Length of Penstock | 45 m |
| Length of Tailrace | 15 m |
| Length of Spillway | 70 m |
| Length of Distribution Line | 6 km |

**[Electrified Area]**

| | |
|---|---|
| Mpulungu Central RGC | 2201 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 1,351,220 US$ |
| i) Temporary Works | 338,560 US$ |
| ii) Civil Engineering | 451,860 US$ |
| iii) Turbine, Gen and Main Transformer | 290,000 US$ |
| iv) Distribution Line & Transformer | 270,800 US$ |
| II. Engineering Service Cost | 108,098 US$ |
| III. Overhead Cost | 337,805 US$ |
| IV. Profit Margine | 270,244 US$ |
| Grand Total | 2,067,367 US$ |

(d) Ngozye Falls Site (Northern Province)

Ngozye Falls Site is located about 70km west of Mbala District centre on Ngozye River. The water flow as of 6th August 2007 was only 0.1m$^3$/s, so it can hardly be expected to get stable water to produce certain amount of electricity in dry season. In spite of its rich head drop of 100m, the potential generation capacity is estimated at only 35kW assuming 0.05m$^3$/s of designed discharge. Figure 8-29 shows the picture of the site. Because the falls is situated on the cliff, it is expected that the construction works of civil facilities are quite difficult. Due to the small potential and difficulty of the development, the necessity of this potential development is extremely low.

**Figure 8-29　Picture of Ngozye Falls Site**

(e) Chilambwe Falls Site (Northern Province)

Chilambwe Falls Site is located about 70km northeast of Kasama, Capital of Northern Province, on Kafubu River, which is a tributary to Luombe River. The water flow as of 7th August 2007 was 1.5$m^3$/s and its gross head was 40m. Since flow duration curve at this site (Figure 8-30) indicates that the water flow at 80% availability is 0.85$m^3$/s. Figure 8-31 shows pictures of this site.

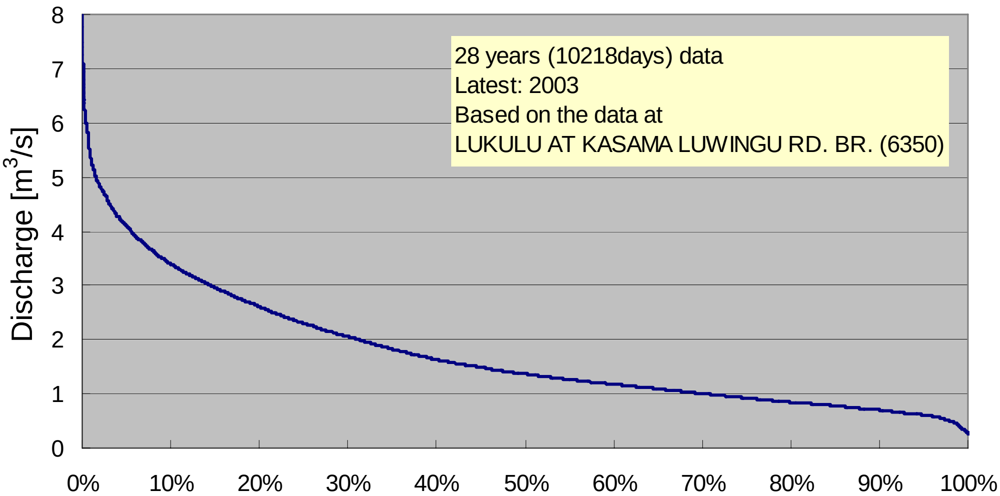



**Figure 8-30　Flow Duration Curve at Chilambwe Falls Site**

a) Chilambwe Falls

b) Upstream of the falls

c) Downstream of the falls

**Figure 8-31 Pictures of Chilambwe Falls Site**

The upstream of the falls is very flat with potential for a long low weir to take off the water to the canal. Head tank should be installed on the upper edge of the steep fall via water canal of which length will be about 150m. Short penstock should be installed to lead the water to turbine on the steep slope of the left bank. Down the falls, there is a wide flat for powerhouse to be built. There are no firm and household, hence the environmental issue would not be a barrier for the development.

This falls is about 3km off the Kasama-Mporokoso main road and it is easy to access the site by vehicle. Possible demand site would be Kapatu RGC (potential demand: 610kW) or Sibwalya Kapila RGC (potential demand: 4,013kW), which are both 16km apart from the falls. The potential generation capacity cannot fulfil huge demands of these RGCs. Each RGC has clinic, schools, large firms, etc. so the requirement of electrification is strong. However, this Kasama-Mporokoso road is situated in the pocket of well-developed 66kV transmission line in Northern Province because Kasama has been connected from south and Mporokoso has been connected from west. Therefore, it is highly beneficial to develop this hydropower potential to supply electricity only to these public facilities and business entities. In order to fulfil the current potential demand of Kapatu RGC, or potential demand of public facilities and business entities in Kapatu and Sibwalya Kapila RGCs, it is necessary for the site to be developed with 300kW generation capacity, which requires 1.0m$^3$/s of designed discharge. This discharge is a bit more than the water flow at 80% availability, but the Study Team decided the designed discharge at 1.0m$^3$/s and estimated the project cost of Chilambwe Falls development as a 300kW hydropower plant. Table 8-14 shows the summery of the project.

**Table 8-14 Project Summery of Chilambwe Falls Site**

**[Design Result]**

| | |
|---|---|
| Province | Northern |
| District | Moporokoso |
| Name of the Site | Chilambwe Falls |
| Name of the River | Kafubu River |
| Latitude | S9:49:58 |
| Longitude | E30:43:26 |
| Catchment Area | 175 $km^2$ |
| 80% available discharge | 0.85 $m^3/s$ |
| Design Discharge | 1.0 $m^3/s$ |
| Gross Head | 39.5 m |
| Effective Head | 37.8 m |
| Generation Capacity | 300 kW |
| Volume of Powerhouse | 298 $m^3$ |
| Volume of Weir | 48 $m^3$ |
| Length of Channel | 138 m |
| Length of Penstock | 192 m |
| Length of Tailrace | 50 m |
| Length of Spillway | 30 m |
| Length of Distribution Line | 41 km |

**[Electrified Area]**

| | |
|---|---|
| Kapatu RGC | 610 kW |
| Sibwalya Kapila RGC | 4013 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 2,355,510 US$ |
| i) Temporary Works | 190,320 US$ |
| ii) Civil Engineering | 324,390 US$ |
| iii) Turbine, Gen and Main Transformer | 310,000 US$ |
| iv) Distribution Line & Transformer | 1,530,800 US$ |
| II. Engineering Service Cost | 188,441 US$ |
| III. Overhead Cost | 588,878 US$ |
| IV. Profit Margine | 471,102 US$ |
| Grand Total | 3,603,931 US$ |

(f) Mumbuluma Falls Site (Northern Province)

Mumbuluma Falls Site is located about 47km west of Mporokoso District centre on Luangwa River that is a tributary to Kalungwishi River. The head drop of the falls is 6m and there are steep rapids upstream for about 400m and downstream for about 200m, which gives a total gross head measured at 18m. Its water flow as of 8th August 2007 was about 30$m^3$/s, and the flow duration curve at the site (Figure 8-32) gives 14.35$m^3$/s of the water flow at 80% availability. Then the maximum potential generation capacity is estimated at 1,630kW assuming designed flow at 13.5$m^3$/s. Figure 8-33 shows a picture of the site. The right bank to be developed is covered with shrubs, and there is no household and firm within the area to be opened up due to the construction works of the hydropower plant.

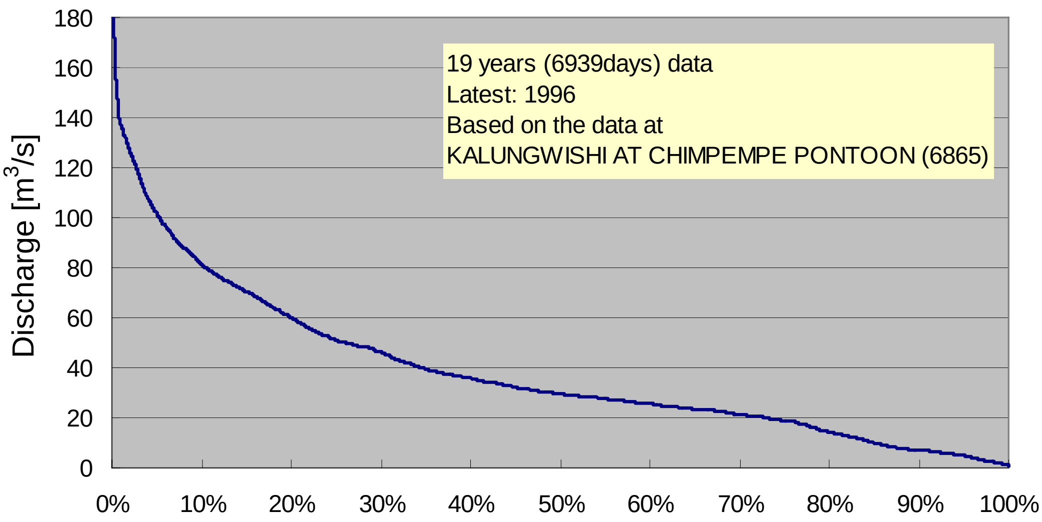



**Figure 8-32 Flow Duration Curve at Mumbuluma Falls Site**

**Figure 8-33 Picture of Mumbuluma Falls Site**

Possible demand sites would be Sunkutu RGC (potential demand: 386kW) located 15km south of the site and Kalabwe RGC (potential demand: 472kW) located 13km north of the site. The potential generation capacity is much bigger than the total potential demand of these two RGCs. So there is another option to develop at suitable capacity to for these two RGCs. The Study Team designed the plant at 930kW with lower gross head of 14m and discharge of 9.0m$^3$/s, which reduce the length of water channel, and estimated the project cost, shown in Table 8-15.

**Table 8-15 Project Summery of Mambuluma Falls Site**

**[Design Result]**

| | |
|---|---|
| Province | Northern |
| District | Moporokoso |
| Name of the Site | Mambuluma Falls |
| Name of the River | Luanguwa River |
| Latitude | S9:32:53 |
| Longitude | E29:44:47 |
| Catchment Area | 4,848 km$^2$ |
| 80% available discharge | 14.35 m$^3$/s |
| Design Discharge | 9.0 m$^3$/s |
| Gross Head | 14.0 m |
| Effective Head | 13.0 m |
| Generation Capacity | 930 kW |
| Volume of Powerhouse | 751 m$^3$ |
| Volume of Weir | 576 m$^3$ |
| Length of Channel | 140 m |
| Length of Penstock | 65 m |
| Length of Tailrace | 25 m |
| Length of Spillway | 88 m |
| Length of Distribution Line | 32 km |

**[Electrified Area]**

| | |
|---|---|
| Kalabwe RGC | 471 kW |
| Sunkutu RGC | 386 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 3,597,360 US$ |
| i) Temporary Works | 454,770 US$ |
| ii) Civil Engineering | 1,105,890 US$ |
| iii) Turbine, Gen and Main Transformer | 734,000 US$ |
| iv) Distribution Line & Transformer | 1,302,700 US$ |
| II. Engineering Service Cost | 287,789 US$ |
| III. Overhead Cost | 899,340 US$ |
| IV. Profit Margine | 719,472 US$ |
| Grand Total | 5,503,961 US$ |

(g) Lumangwe Falls Site (Northern Province)

Lumangwe Falls Site is located 80km west of Mporokoso District centre and 46km northeast of Kawambwa District centre of Luapula Province. It is identified as a national monument and a popular scenic site. Figure 8-34 shows a picture of the falls. The falls, which has 30m head drop, are situated on Kalungwishi River and its water flow as of 8th August was estimated more than 100m$^3$/s. These figure gives about 15,000kW of potential generation capacity assuming 70m$^3$/s designed discharge if it is developed as run-of –river type hydropower station without high dam.

This site has already been studied and well known as a Kalungwishi Project (listed on Table 8-4) with 218MW potential generation capacity including Kabwelme Falls Site, which will be mentioned next. Therefore, this site is described here just as a record of our survey and should not be handled on this Rural Electrification Master Plan.

**Figure 8-34 Picture of Lumangwe Falls Site**

(h) Kabwelme Falls Site (Northern Province)

Kabwelme Falls Site, which is also identified as a National Monument, is located only 4km downstream of Lumangwe Falls Site described above. Figure 8-35 shows a picture of the falls. The falls, which has 20m head drop, has more than 100m$^3$/s water flow on 8th August 2007, and its potential generation capacity can be estimated at about 10,000kW assuming 70m$^3$/s designed discharge if it is developed as run-of –river type hydropower station without high dam. But this potential has also been registered on large hydro development list as Kalungwishi Project and should not be handled here in this Master Plan.

**Figure 8-35 Picture of Kabwelme Falls Site**

(i) Pule Falls Site (Northern Province)

Pule Falls Site on Kasanshi River, which is a tributary to Lukulu River, is located about 50km north off Chitoshi RGC on the midmost of Kasama-Luwing main road. The falls have 35m head drop and the steep rapids give some addition, then in total 48m gross head can be expected. The water flow as of 10th August 2007 was only $0.3m^3/s$, and the flow duration curve (Figure 8-36) indicates that the water flow at 80% availability is only $0.14m^3/s$. This low discharge gives only 50kW of potential generation capacity. Figure 8-37 shows pictures of the site.

Mukupa Kaoma RGC (potential demand: 2,177kW) is situated only 1.5km apart from the falls. Because this large RGC has more than 100km distance from existing substation, dispersed power source with isolated grid exactly suits. Nevertheless, the potential generation capacity of Pule Falls Site would be too much smaller than the potential demand.

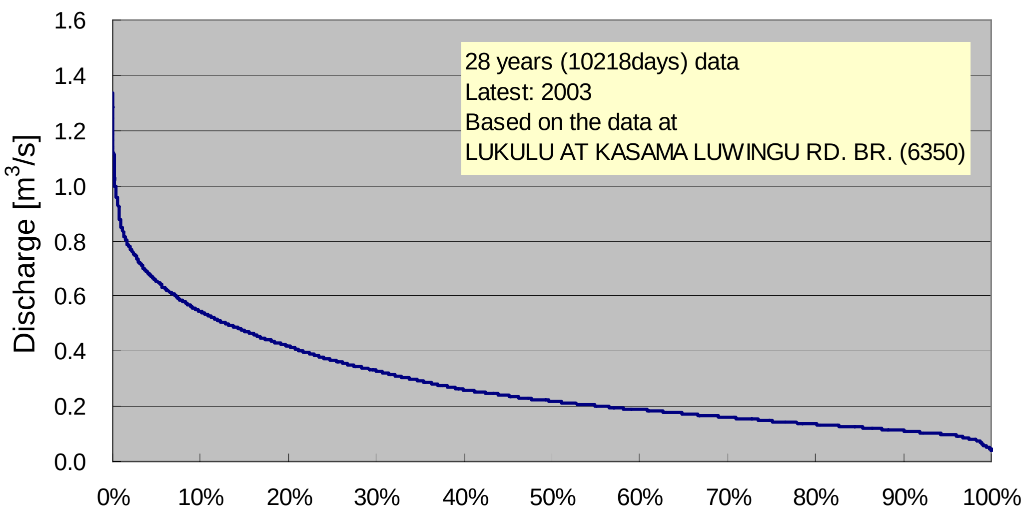



**Figure 8-36 Flow Duration Curve at Pule Falls Site**

a) Pule Falls

b) Downstream of the falls

**Figure 8-37 Pictures of Pule Falls Site**

(j) Chilongo Falls Site (Luapula Province)

Chilongo Falls Site on Lufubu River, which is a tributary to Kalungwishi River, is located about 60km southeast of Kawambwa District centre. The rich drop of the falls gives 40m of gross head, and the water flow as of 9th August 2007 was $3.6m^3/s$. The flow duration curve (Figure 8-38) shows $1.83m^3/s$ for its water flow at 80% availability, so the potential generation capacity is estimated at 500kW assuming that the designed discharge is $1.7m^3/s$. Figure 8-39 shows pictures of the site.

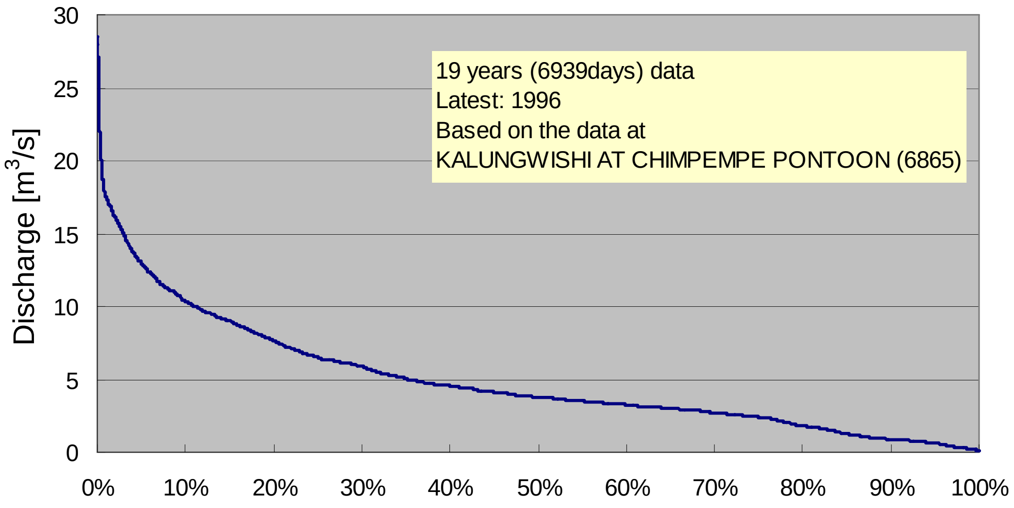



**Figure 8-38 Flow Duration Curve at Chilongo Falls Site**

a) Chilongo Falls

b) Upstream of the falls

c) Downstream of the falls

**Figure 8-39 Pictures of Chilongo Falls Site**

There are some firms and small community around the path to the falls though it is not very close to the falls. But the access road for the proposed power plant should be designed not to disturb their live activities.

The possible demand site would be Kanengo RGC (potential demand: 79kW) located 29km west of the falls and Chibote RGC (potential demand: 133kW) located 18km north of the falls. The total demand of 212kW is about 300kW less than the potential generation capacity. There are three more RGCs, Chama (potential demand: 355kW), Mushota (potential demand: 588kW), and Lengwe (potential demand: 178kW), which are located very closely one another in the middle of the falls and existing Kawambwa Tea substation. The length of 33kV distribution line to be extended from Chilongo Falls Siteis to these 3RGCs is about 33km, which 11km shorter than that from Kawambwa Tea substation. If the hydropower potential were large enough to supply 1,333kW of electricity in total of all these five RGCs, the development of this hydropower potential could be the most effective. Actually the potential generation capacity of the site is less than half of the total demand, so these three RGCs should be connected to the national grid in the end. Here, the Study Team estimated the project cost at 500kW generation capacity, and Table 8-16 shows the summery of the project.

**Table 8-16  Project Summery of Chilongo Falls Site**

**[Design Result]**

| | |
|---|---|
| Province | Luapula |
| District | Kawambwa |
| Name of the Site | Chilongo Falls |
| Name of the River | Lufubu River |
| Latitude | S9:58:25 |
| Longitude | E29:34:41 |
| Catchment Area | 618 $km^2$ |
| 80% available discharge | 1.83 $m^3/s$ |
| Design Discharge | 1.7 $m^3/s$ |
| Gross Head | 40.0 m |
| Effective Head | 37.2 m |
| Generation Capacity | 500 kW |
| Volume of Powerhouse | 453 $m^3$ |
| Volume of Weir | 105 $m^3$ |
| Length of Channel | 300 m |
| Length of Penstock | 390 m |
| Length of Tailrace | 50 m |
| Length of Spillway | 250 m |
| Length of Distribution Line | 49 km |

**[Electrified Area]**

| | |
|---|---|
| Kanengo RGC | 79 kW |
| Chibote RGC | 133 kW |

**[Project Cost Estimation]**

| | |
|---|---|
| I. Construction Cost | 3,766,250 US$ |
| i) Temporary Works | 619,630 US$ |
| ii) Civil Engineering | 855,420 US$ |
| iii) Turbine, Gen and Main Transformer | 445,000 US$ |
| iv) Distribution Line & Transformer | 1,846,200 US$ |
| II. Engineering Service Cost | 301,300 US$ |
| III. Overhead Cost | 941,563 US$ |
| IV. Profit Margine | 753,250 US$ |
| Grand Total | 5,762,363 US$ |

(l) Mumbuluma Falls II Site (Luapula Province)

Mumbuluma Falls II Site is located about 34km northwest of Mansa District centre on Luamfumu River, that is a tributary to Luapula River. Since the name of the falls is as same as Mumbuluma falls in Northern Province, the Study Team renamed this falls ‘Mumbuluma Falls II’ on this report. Figure 8-40 shows the picture of the site. Existing two small falls in a row gives 12m gross head. The water flow as of 10th August 2007 was about 1.5$m^3/s$, then its potential generation capacity will be 70kW with 0.8$m^3/s$ designed discharge considering the low water flow in dry season. This falls could be regarded as a quite suitable hydropower potential site if it is evaluated from the view of ease of construction and accessibility, but the potential generation capacity is too low to be invested.

a) Upper Falls

b) Lower Falls

**Figure 8-40 Pictures of Mumbuluma Falls II Site**

### (3) Western Province

The hydropower potential survey in Western Province was carried out from 4th June to 6th June 2007. At first, the survey would be carried out only in North-western, Northern and Luapula Provinces, but Western Provincial Planner reported the existence of some falls for small hydropower development to DoE, so the Study Team additionally implemented the survey at the recommended falls. Figure 8-41 shows the location of surveyed sites.

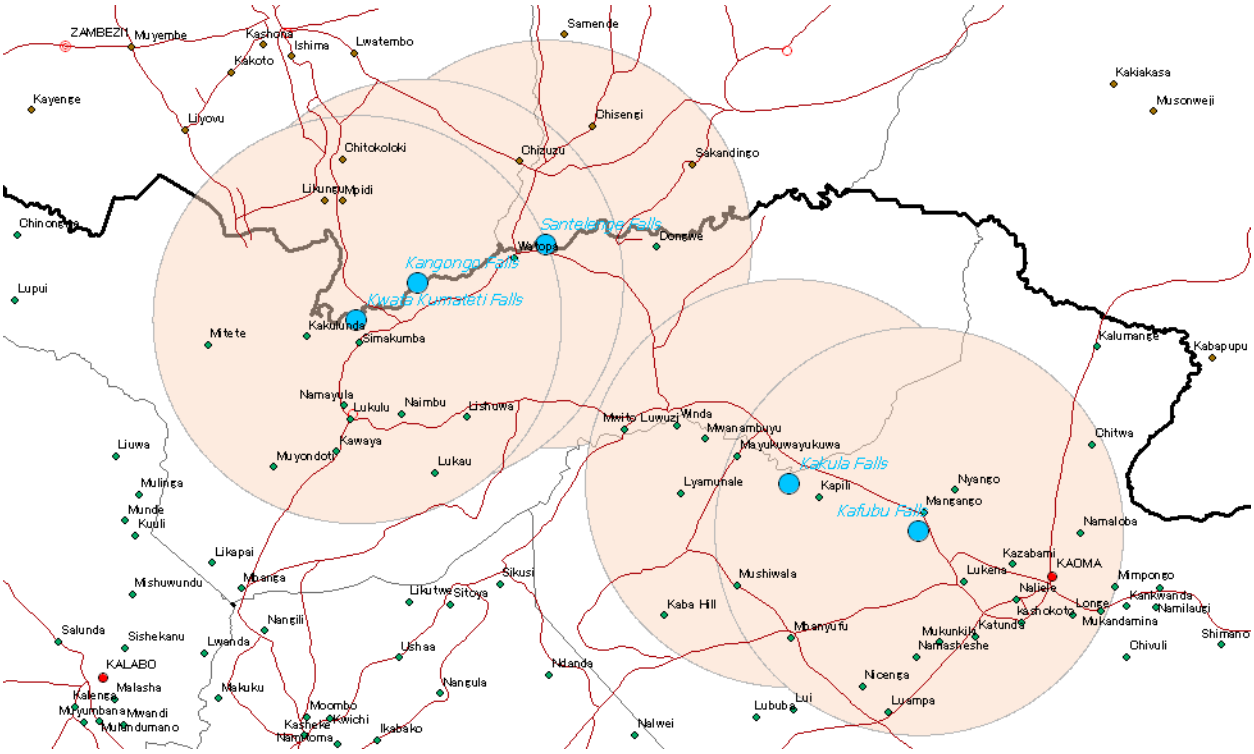



**Figure 8-41 Location of the Hydropower Potential Site in Western Province**

Table 8-17 indicates the summery of five surveyed sites, and Figure 8-42 shows the pictures of them. It is clear on the pictures that these five sites have rich amount of water flow but are located on quite flat land, therefore, it is difficult to earn high head drop without high-dam or quite long water channel, which are not suitable for rural electrification by small hydropower plant. Hence these sites are introduced here as our survey records, but the hydropower potentials are not discussed.

**Table 8-17 Summery of Surveyed Site in Western Province**

| Name of Site | District | Latitude | Longitude | Name of River | Date of Visit |
|---|---|---|---|---|---|
| Santelenge Falls | Lukulu | S14:01:29 | E23:41:44 | Kabompo | 04-June-2007 |
| Kangongo Falls | Lukulu | S14:06:38 | E23:24:47 | Kabompo | 04-June-2007 |
| Kwata Kumateti Falls | Kaoma | S14:11:27 | E23:16:38 | Luena | 05-June-2007 |
| Kakula Falls | Kaoma | S14:33:06 | E24:13:45 | Luena | 06-June-2007 |
| Kafubu Falls | Kaoma | S14:39:28 | E24:30:51 | Luena | 07-June-2007 |


a) Santelenge Falls on Kabompo River


b) Kangongo Falls on Kabompo River


c) Kwata Kumateti Falls on Luena River

d) Kakula Falls on Luena River

e) Kafubu Falls on Luena River

**Figure 8-42 Pictures of Surveyed Sites in Western Province**

### (4) Summery of Hydropower Potential Survey

The Study Team visited twenty-five hydropower potential sites, nine sites in North-western Province, nine sites in Northern Province, two sites in Luapula Province, and five sites in Western Province.

In North-western Province, there are lot of District centres, which have not been electrified by national grid, so small hydropower generation with isolated grid is a significant method of rural electrification. Five hydropower potential sites, Upper Zambezi, Mujila Falls Lower, Mujila Falls Upper, Kasanjiku Falls, and Chauka Matambu Falls, were evaluated to be reasonable site for Rural Electrification. Table 8-18 shows the summery table of the hydropower potential site in North-western Province.

The falls in Northern and Luapula Province have relatively high head drops, and four hydropower potential sites out of eleven sites, Namukale Falls, Chilambwe Falls, Mambuluma Falls, and Chilongo Falls, have a suitable potential to be discussed in the Master Plan. Table 8-19 shows the summery table of the hydropower potential site in Northern and Luapula Provinces.

Additionally, the national grid has been already extended to almost all the District centres in Northern and Luapula Provinces, then the necessity of small hydropower plant with micro-grid is not so high.

However, as this area is located quite far from Zambian power source in Southern Province, the stability of electricity is low. Therefore, it is important to develop large hydropower plants such as Kalungwishi Site, which will help to enhance the quality of electricity on the national grid.

**Table 8-18 Summery of the Hydropower Potential Survey in Northwestern Province**

| **Name of the Site** | Upper Zambezi | Mujila Falls Lower | Mujila Falls Upper | Tututu Falls | Kasanjiku Falls | Chauka Matambu Falls | Luakela Falls | Muwozi Falls Upper | Muwozi Falls Lower |
|---|---|---|---|---|---|---|---|---|---|
| Date of Survey | 24-May-07 | 25-May-07 | 25-May-07 | 25-May-07 | 26-May-07 | 28-May-07 | 28-May-07 | 29-May-07 | 29-May-07 |
| Province | Northwestern | Northwestern | Northwestern | Northwestern | Northwestern | Northwestern | Northwestern | Northwestern | Northwestern |
| District | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga | Mwinilunga |
| Latitude | S11:06:18 | S11:30:52 | S11:29:32 | S11:34:27 | S12:21:10 | S11:51:34 | S11:31:38 | S12:15:04 | S12:16:45 |
| Longitude | E24:13:41 | E24:46:24 | E24:48:25 | E24:45:14 | E24:50:55 | E25:08:13 | E24:24:44 | E24:16:54 | E24:19:33 |
| Name of the River | Zambezi | Mujila | Mujila | Kapunda | Kasanjiku | West Lumuwana | Luakela | Muwozi | Muwozi |
| Effective Head [m] | 8.0 | 17.1 | 13.2 | 3.6 | 9.0 | 9.1 | 6.3 | 3.6 | 4.5 |
| Designed Dischirge [$m^3/s$] | 6.0 | 10.0 | 4.0 | 1.0 | 4.5 | 2.5 | 2.0 | 1.0 | 1.0 |
| Potential [kW] | 380 | 1400 | 420 | 30 | 320 | 180 | 100 | 30 | 35 |
| **Electrified RGC 1** | Ikelenge | Kanyama (incl. 2 villages) | Kanyama | Kanyama | Ntambu | Lumuwana | Luakela | Chiwoma | Chiwoma |
| Length of the Power Line [km] | Existing | 13 | 10.5 | 19 | 21 | 4 | 0.5 | 6.5 | 7.5 |
| Connected from | Zengamina HP | Mujila Falls Lower | Mujila Falls Upper | Tututu Falls | Kasanjiku Falls | Chauka Matambu Falls | Luakela Falls | Muwozi Falls Upper | Muwozi Falls Upper |
| Number of Households in 2006 | 1763 | 921 | 521 | 521 | 416 | 310 | 216 | 361 | 361 |
| Potential Demand in 2030 [kW] | 1995 | 1065 | 598 | 598 | 532 | 371 | 257 | 418 | 418 |
| Priority Order | 57 | 671 | 671 | 671 | 322 | 526 | 660 | 497 | 497 |
| Priority in the District | 2 | 4 | 4 | 4 | 1 | 5 | 18 | 14 | 14 |
| **Electrified RGC 2** | Nyakaseya | Kakoma | | | | | | | |
| Length of the Power Line [km] | Existing | 60 | | | | | | | |
| Connected from | Ikelenge RGC | Kanyama RGC | | | | | | | |
| Number of Households in 2006 | 400 | 301 | | | | | | | |
| Potential Demand in 2030 [kW] | 483 | 350 | | | | | | | |
| Priority Order | 445 | 551 | | | | | | | |
| Priority in the District | 3 | 17 | | | | | | | |
| **Cost Estimation [thousand US$]** | 2,290 | 9,782 | 2,264 | - | 3,521 | 2,000 | - | - | - |

## Table 8-19 Summery of the Hydropower Potential Survey in Northern and Luapula Provinces

| **Name of the Site** | Kalambo Falls | Mwanbezi Falls | Namukale Falls | Ngozye Falls | Chilambwe Falls | Mumbuluma Falls | Lumangwe Falls | Kabwelume Falls | Pule Falls | Chilongo Falls | Mumbuluma Falls II |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of Survey | 04-Aug-07 | 04-Aug-07 | 05-Aug-07 | 06-Aug-07 | 07-Aug-07 | 08-Aug-07 | 08-Aug-07 | 08-Aug-07 | 10-Aug-07 | 09-Aug-07 | 10-Aug-07 |
| Province | Northern | Northern | Northern | Northern | Northern | Northern | Northern | Northern | Northern | Luapula | Luapula |
| District | Mbala | Mbala | Mpulungu | Mpulungu | Mporokoso | Mporokoso | Mporokoso | Mporokoso | Mporokoso | Kawambwa | Mwense |
| Latitude | S8:35:40 | S8:51:41 | S8:45:02 | S8:44:14 | S9:49:58 | S9:32:53 | S9:32:24 | S9:31:22 | S9:57:47 | S9:58:25 | S10:55:42 |
| Longitude | E31:14:22 | E31:18:31 | E31:09:47 | E30:44:09 | E30:43:26 | E29:44:47 | E29:23:16 | E29:21:06 | E30:25:08 | E29:34:41 | E28:44:09 |
| Name of the River | Kalambo | Mwanbezi | Lunzua | Ngozye River | Kafubu | Luangwa | Kalungwish | Kalungwish | Kasanshi | Lufubu | Luamfumu |
| Effective Head [m] | 207.9 | 2.7 | 15.0 | 90.0 | 37.8 | 13.0 | - | - | 43.2 | 37.2 | 10.8 |
| Designed Dischirge [$m^3/s$] | 1.0 | 0.7 | 2.3 | 0.05 | 1.0 | 9.0 | - | - | 0.14 | 1.7 | 0.8 |
| Potential [kW] | 1650 | 10 | 270 | 35 | 300 | 930 | - | - | 50 | 500 | 70 |
| **Electrified RGC 1** | Mbala BOMA | - | Mpulungu Central | Iyendwe | Kapatu | Kalabwe | - | - | Mukupa Kaoma | Kanengo | Chibondo |
| Length of the Power Line [km] | 34 | | 6 | 22 | 17 | 16.5 | | | 1.5 | 29 | 24 |
| Connected from | Kalambo Falls | | Namukale Falls | Ngozye Falls | Chilambwe Falls | Mumbuluma Falls | | | Pule Falls | Chilongo Falls | Mumbuluma Falls II |
| Number of Households in 2006 | - | | 2000 | 200 | 512 | 425 | | | 1974 | 60 | 286 |
| Potential Demand in 2030 [kW] | - | | 2201 | 231 | 610 | 471 | | | 2177 | 79 | 331 |
| Priority Order | Electrified | | 1 | 728 | 95 | 453 | | | 50 | 1029 | 567 |
| Priority in the District | - | | 4 | 7 | 14 | 10 | | | 1 | 3 | 6 |
| **Electrified RGC 2** | | | | | Sibwalya Kapila | Sunkutu | | | | Chibote | |
| Length of the Power Line [km] | | | | | 6 | 15.5 | | | | 17 | |
| Connected from | | | | | Kapatu | Mumbuluma Falls | | | | Chilongo Falls | |
| Number of Households in 2006 | | | | | 3646 | 350 | | | | 90 | |
| Potential Demand in 2030 [kW] | | | | | 4013 | 386 | | | | 133 | |
| Priority Order | | | | | 13 | 512 | | | | 907 | |
| Priority in the District | | | | | 2 | 8 | | | | 4 | |
| **Cost Estimation [thousand US$]** | - | - | 2,068 | - | 3,604 | 5,504 | - | - | - | 5,763 | - |

# Chapter 9

# Solar Power Planning

# Chapter 9. Solar Power Planning

## 9.1. Current Status of Solar Power

### 9.1.1. Renewable Energy Possibilities for Rural Electrification in Zambia

The most favourable way of electrifying villages is to extend the existing national distribution network all over the country. Grid extension has an advantage that it highly satisfies demand-side needs from the aspects not only of quantity (24-hour available) but also of quality (voltage and frequency stability). However, from the geographic and demographic points of view, such as location and population density, grid extension to some areas that are too remote from the existing lines, which requires high construction cost for limited potential power, may not be economically viable. In short, grid extension may not always be the panacea for enhancing rural electrification.

Utilization of renewable energy to create onsite electricity supply system is considered to be realistically the most effective mode of electrifying the above mentioned remote areas even if it would be inferior to national grid extension in quantity and quality. Another problem regarding onsite electrification using renewable energy is that in many countries there's no specific policy, regulation or official guideline regarding the selection of sites and electrification mode, and even technical standards are not necessarily specified systematically.

The 1944 National Energy Policy (NEP), which among other goals was to accelerate rural electrification through the formulation of guidelines regarding renewable energy and the establishment of Rural Electrification Fund (REF) was expected to support the promotion of renewable energy. In 2003, the Zambian Government passed the Rural Electrification Act establishing the Rural Electrification Authority (REA) with the intention of expanding electrification-related services targeting impoverished rural areas. With the arrangements regarding policies and organizations gradually completed, we consider that the spread of rural electrification using renewable energy will be widely promoted, once the government proceeds with a concrete implementation plan.

### 9.1.2. Current Status of Solar Power Electrification

At the moment, the solar energy's contribution to improving the electrification rate in Zambia is quite minor since the pilot projects regarding solar power have only just begun a few years ago.

Presently pilot projects are funded by SIDA and are operated by private companies called Energy Service Companies (ESCOs). ZAMSIF has also provided solar system for schools and health centres for the Ministries of Education and Health. Recently, several distributors have been set up in Lusaka that are responsible for designing, installing and maintaining solar power facilities. Their business is not just limited to supplying equipment and services, but also extending to the sales of solar panels and their accessories to end-users.

### (1) Solar Power Projects through ESCO

ESCOs, the first commercial energy suppliers using solar home system (SHS), started their business with the financial support from Swedish International Development Agency (SIDA), which is inline with the Zambian Government's policy to reduce poverty in rural areas through electricity supply by making use of resources of private sector.

The first pilot project for rural electrification began in 1998, and a total of 400 systems were targeted for installation in ordinary homes in three towns (Nyimba, Chipata and Lundazi) in Eastern Province. NESCO was established in Nyimba in 2000, and until early 2001, and CHESCO in Chipata and LESCO in Lundazi were also established. Taking into consideration the current situation of insufficient skills of business operations, their office is located in each District Centre, not onsite, respectively, and daily maintenance and servicing of facilities are carried out by four or five employees consisting of a supervisor, a manager, a reporter and two experts. Table 9-1 shows the number of houses that these 3 ESCOs supply electricity with SHS and Figure 9-1 shows the organization chart of CHESCO.

Each service company is responsible for leasing SHS to customers. The service company also maintains the equipment and collects monthly electricity tariff from customers. Table 9-2 shows the standard equipment supplied by ESCOs. The basic facilities for ordinary household consist of four fluorescent lights and a 12v socket. These are used for lighting, TV/Video and radio and rarely used for refrigerator to keep medicine for livestock. The consumers are upper-middle class people such as schoolteachers, police officers and government employees and farmers who account for only 12 to 17%. Figure 9-2 shows the typical daily load curve. Figure 9-3 and Figure 9-4 present the examples of houses using SHS in Chipata.

The needs for solar power generation in remote area are increasing, and in Nyimba district for example, 350 households are waiting for installation of SHS. It is necessary to improve the technical criteria, operation and maintenance, operation of organization and market development.

**Table 9-1 SIDA-funded ESCOs**

| Company Name | Installations | Site Location |
|---|---|---|
| NESCO (Nyimba Energy Service Company) | 100 | Nyimba |
| CHESCO (Chipata Energy Service Company) | 150 | Chipata |
| LESCO (Lundazi Energy Service Company) | 150 | Lundazi |

**Table 9-2 Standard Equipment of SIDA-Funded SHS**

| Equipment | Specifications | Notes |
|---|---|---|
| PV Panel | 55Wp (rating) 20A | In some cases, such as clinics, two panels are installed. |
| Battery | 12V, 105Ah | Normal Capacity of 4 days |
| Regulator | Pre-Paid Meter | Electricity charges are pre-paid on a monthly basis. |

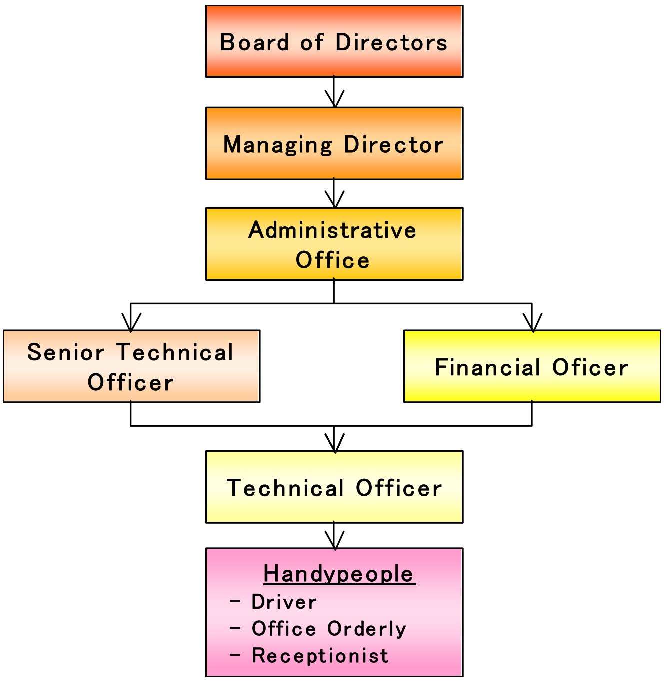



**Figure 9-1　Organaization Structure of Chesco**

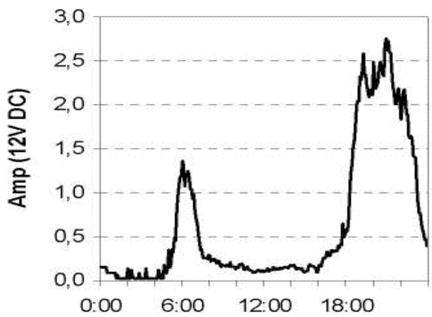



**Figure 9-2　Average Daily Load Curve over 21 Days**

**Figure 9-3　A House Equipped with a Solar Home System in Chipata**

**Figure 9-4　A House Equipped with a Solar Home System in Chipata**

### (2) Solar Power Projects by the Government

(a) ZAMSIF-funded Projects

Zambia Social Investment Fund (ZAMSIF) was established and started its business operation in 1993 using funds from the World Bank. The projects started from facilities such as schools and hospitals in un-electrified areas of Northern Province, and SHSs with various scales were installed in a total of 750 sites by 2001.

Before 2006, SHS installation sites funded by ZAMSIF were mainly in places such as schools, health centre, and staff houses for teachers and health workers. Table 9-3 lists the standard equipment used by ZAMSIF for the installation of SHS. A rough estimate of the number and capacity of ZAMSIF-installed SHS by area is shown in XXTable 9-4.

**Table 9-3 Standard Equipment of ZAMSIF-funded SHS**

| Equipment | Specifications | Notes |
|---|---|---|
| PV Panel | 75Wp | |
| Battery | 12V, 96-300Ah | Normal capacity of 4 days |
| Controller | 12V, 15A | Charge controller |
| Lighting Fixtures | 11W×4, 9W×4 | Lighting in 8 places |
| Switch | | Supplied with 5 switches |

**Table 9-4 ZAMSIF-installed SHS**

| | Town/Village | Capacity (Wp) | | Town/Village | (Wp) |
|---|---|---|---|---|---|
| Central Province | Chibombo | 6,640 | Northern Province | Chilubi | 960 |
| | Kabwe | (N.A.) | | Chinsali | 5,520 |
| | Kapiri–Mposhi | 3,680 | | Isoka | 5,200 |
| | Mkushi | 1,680 | | Kaputa | 1440 |
| | Mumbwa | 4,640 | | Kasama | 5,040 |
| | Serenje | 8,160 | | Luwingu | 3,920 |
| | | **24,800** | | Mbala | 4,240 |
| Copperbelt Province | Chililabombwe | (N.A.) | | Mpika | 10,000 |
| | Chingola | (N.A.) | | Mporokoso | 6,080 |
| | Kalulushi | (N.A.) | | Mpulungu | 2,000 |
| | Kitwe | 4320 | | | **44,400** |
| | Luanshya | (N.A.) | North-Western Province | Chavuma | 1,200 |
| | Lumfwanya | 2560 | | Kabompo | 2,320 |
| | Mufulira | 1440 | | Kasempa | 3,200 |
| | Ndola | 1520 | | Mufumbwe | 1,680 |
| | | **9,840** | | Mwinilunga | 6,640 |
| Eastern Province | Chadiza | 4,480 | | Solwezi | 4,880 |
| | Chama | 4,480 | | Zambezi | 1,200 |
| | Chipata | 12,800 | | | **21,120** |
| | Katete | 8,480 | Southern Province | Choma | 6,640 |
| | Lundazi | 15,040 | | Gwembe | 2,800 |
| | Mambwe | 2,320 | | Itezhi-tezhi | 1,440 |
| | Nyimba | 5,200 | | Kalomo | 11,280 |
| | Petauke | 9,920 | | Kazungula | 3,520 |
| | | **62,720** | | Livingstone | 2,160 |
| Luapula Province | Chiengi | 9,440 | | Mazabuka | 3,040 |
| | Kawambwa | 960 | | Monze | 6,240 |
| | Mansa | 3,280 | | Namwala | 720 |
| | Milenge | 1,360 | | Siavonga | (N.A.) |
| | Mwense | 1,920 | | Sinazongwe | 3,920 |
| | Nchelenge | 1,680 | | | **41,760** |
| | Samfya | 11,600 | Western Province | Kalabo | 9,440 |
| | | 30,240 | | Kaoma | 10,480 |
| Lusaka Province | Chongwe | 4,720 | | Lukulu | 4,320 |
| | Kafue | 1,200 | | Mongu | 5, 520 |
| | Luangwa | 1,920 | | Senanga | 13,680 |
| | Lusaka | (N.A.) | | Sesheke | 4,560 |
| | | | | Shang'ombo | 4,000 |
| | | **7,840** | | | **52,000** |
| **T o t a l** | | | | | **294,720** |

Source: ZAMSIF, as of June 2007

(b) GRZ-funded Projects

In 2005 the Zambian Government carried out the installation of 75/80Wp SHS in 207 locations, which include 165 residences of local leaders and 42 schools, using Rural Electricity Fund (REF) and solar-funds from the Department of Energy. In May 2005, 8 schools in Senanga and Mongu in Western Province were targeted. The funds were used to cover the cost of solar power generation equipment and installation. However, funds that were required to carry out operation and maintenance, and capacity building were not included. Table 9-5 is the specifications that GRZ (DoE) set when procuring SHS equipment to be installed on chief's palace.

**Figure 9-5 A house equipped with a Solar Home System in Lundazi**

**Table 9-5 Specifications of SHS Equipment procured by GRZ (Residential Use)**

| **Technical Specification** | |
|---|---|
| **1.0** | **Components for Solar Home Systems to be Supplied** |
| 1.1 | Providing 75 Wp Solar Panel |
| 1.2 | 96-300 Ah 12V DC Battery |
| 1.3 | 12 – 15A Charge/Discharge Controller |
| 1.4 | 8 Light Units (4 X 11W & 4 X 9W) |
| 1.5 | Provision of 5 Switches |
| **2.0** | **Standards for Components and Workmanship** |
| 2.1 | Crystalline Silicon Photovoltaic Module |
| 2.2 | Batteries, with minimum 300 cycles to 80% depth of discharge at $25^{0}$C |
| 2.3 | Battery Charge regulators capable of disconnecting load at full charge |
| 2.4 | Minimum Warranties of 2 years on all Components |
| 2.5 | Photovoltaic Modules covered by warranty of 10 Years |
| 2.6 | Batteries covered by warranty of 2 Years against defects or degradation |
| 2.7 | Provision of Lockable Box for Battery and Charge Controller |

Source: DoE "Evaluation Report on the Tender for the Supply, Delivery and Installation of Solar Home Systems to Chief's Palaces", January 2005

(c) GRZ/UNIDO/GEF Projects

The program for renewable energy supported by GRZ/UNIDO/GEF was initially aimed at biomass energy, and then the solar power system program was built onto the project.

Site location and evaluation of the solar power system programme in Chinsanka in Samfa District, Luapula Province, were completed in 2002, and presently arrangement of coordination between agencies concerned and fund procurement were in progress. Chinsanka was the largest commercial centre in the area consisting of 875 houses and 70 stores in an area of about 2km radius.

Expansion of the grid is difficult in Zambia due to the low population density. Off-grid diesel electric power generation is very costly because the fuel is imported from abroad. To solve the issues, GRZ/UNIDO/GEF is promoting the use of renewable energy and projects to support solar power is expected to expand in the future.

## 9.2. Data Collection

### 9.2.1. Solar Power Generation Potential

#### (1) Climatic Overview

Zambia is located at longitude of 8°S - 17°S and latitude of 23°E - 34°E and has an area of 752,600 $km^2$. The most of the county is highland plateau of 1,000 – 1,350m and has a tropical climate.

A cool, dry season lasts from May to August during which the morning and evening temperatures in May and June range from 4°C to 5°C. A hot, dry season lasts from September to November and a hot, rainy season from December to April.

Regarding the characteristics of annual rainfall observed in Lusaka, the rainy season usually begins from mid-November and lasts until March, whereas there is virtually no rainfall from August to October. The average annual rainfall in northern part of the country is relatively high (about1400mm p.a.), compared to that in southern part (about 500mm p.a.).

#### (2) Solar radiation and the potential for solar energy

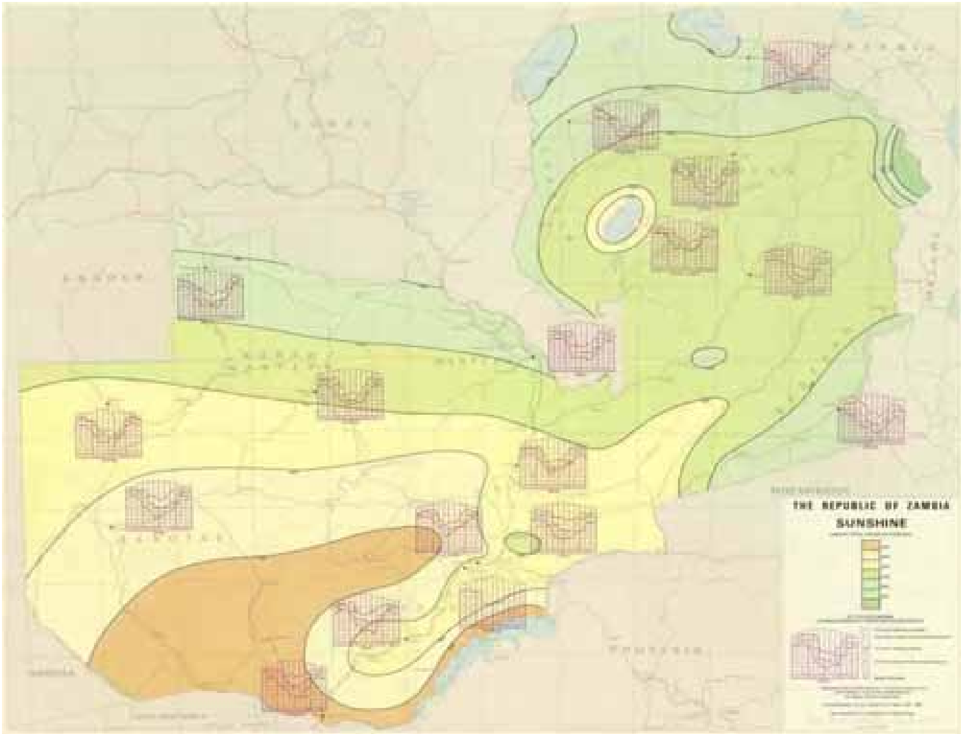
According to data from Zambia Meteorological Department (ZMD), which is under the Ministry of Communication and Transport, the average annual solar radiation in Zambia is 15.66MJ/$m^2$/day (or 4.35kWh/m2/day in electricity conversion). Zambia's average annual solar radiation is 1.3 times higher than that of Japan (Tokyo)'s 12MJ/$m^2$/day (or 3.34 kWh/$m^2$/day). Figure 9-6 shows the solar radiation map of Zambia, and Table 9-6 shows the annual average global solar radiation by region. There is not much inequality among regions in annual solar radiation, which is recorded relatively high and stable between 6,600 and 7,700MJ/$m^2$ p.a., which means that Zambia has potential for the solar energy all over the country. Table 9-7 shows the average daily solar generation in each region, which is 4.35kWh/$m^2$/day.

The potential solar generation can be estimated as follows. First, we assume that 1$m^2$ solar panel (approximately L=1.2m x B=0.8m) is installed on all of households in rural area (1,288,064 households in rural area as of 2004, source: CSO). An area of 1.3$km^2$ is used for solar generation in total, which is equivalent to 0.00017% of Zambia's national land area (752,610 $km^2$). And when we assume that the conversion efficiency of solar panels is 0.1, about 200GWh can be generated in a year. This generation is also equivalent to 30MW scale power plant with 80% operating rate.

The electricity generation and capacity scale are equal to about 6% of Zambia's electricity consumption (3,516GWh in 2006, excluding bulk sales to mining industry and export) and about 1.6% of total installed capacity of power plants in Zambia (about 1,800MW) respectively. As these figures indicate, utilization of highly potential solar generation is one of effective measures for rural electrification in Zambia.

Potential Electricity Generation from Solar Power (kWh/year)
= Average Solar Radiation (kWh/ $m^2$/day) × Land Area ($km^2$) ×365 (day/year) × $10^6$
× Conversion Efficiency

- Average Solar Radiation: 4.35 kWh/$m^2$/day
- Land Area: 1.3$km^2$
- Conversion Efficiency: 0.1
- Unit Measurement: 1MJ/$m^2$ =23.89cal/$cm^2$=238.9kcal/$m^2$=0.2778kWh/$m^2$




Note: STANDARDIZED to 20years July1945-Jun1965
Source: Department of Meteorology

**Figure 9-6 Solar Radiation Map of Zambia**

**Table 9-6 Annual Global Solar Radiation by Region**

(MJ/m²・Year)

| | |
|---|---|
| Lusaka | 6,832 |
| Livingstone | 7,677 |
| Ndola | 6,646 |
| Mansa | 7,422 |
| Mongu | 7,187 |
| Kawambwa | 6,999 |
| Mwinilunga | 7,093 |
| Kasama | 7,571 |
| Mpika | 7,613 |
| Zambezi | 6,868 |
| Kasempa | 6,756 |
| Kabompo | 6,743 |
| Solwezi | 7,318 |
| Kafironda | 6,981 |
| Chipata | 6,941 |
| Kafue Polder | 7,701 |
| Kabwe | 7,002 |
| Mount Makulu | 6,795 |
| Choma | 6,981 |

**Table 9-7 Average Daily Solar Power Generation (2002-2005)**

(kWh/m²/day)

| | |
|---|---|
| Chipep | 4.12 |
| Kabwe | 3.32 |
| Livingstone | 3.69 |
| Lundazi | 3.89 |
| Lusaka01 | 8.37 |
| Lusaka02 | 8.51 |
| Magoye | 3.84 |
| Mbala | 3.75 |
| Mfuwe | 2.45 |
| 'Misamf | 4.43 |
| Mongu | 6.31 |
| Mumbwa | 3.53 |
| Petauke | 3.68 |
| Solwezi | 2.87 |
| Zambezi | 2.56 |
| **Average** | **4.35** |

Source: Zambia Meteorological Department

## 9.3. Review of Existing Solar Power Development Plans

### 9.3.1. Possibilities and Challenges of the Solar Power Development

The average population density in Zambia is 13.1 people/km$^2$, and the population density is relatively high in urban area such as Lusaka (63.5 people /km$^2$) and Copperbelt (50.5 people/km$^2$), while it is very low in rural areas such as North-Western Province (4.6 people/km$^2$), Western Province (6.1 people/km$^2$) and Northern Province (8.5 people/km$^2$).

Taking into account the low population density and the limited power demand in rural areas, extending the national grid throughout the country may be inefficient in some remote areas in that the expected revenue may not be enough to cover the initial investment and the operation/maintenance costs. Installation of SHS on each premise as a kind of distributed onsite energy resources can be expected for increasing and improving electrification rate in remote areas for contributing to poverty reduction and for correcting the gap in economic levels among regions. However, it also has a number of issues to be tackled for practically using renewable energy such as a high initial investment, the necessity of securing a stable and long-term revenue source to sustain its business, and technical follow-up.

The challenges found so far in the course of implementation of solar power generation pilot projects are as follows:

- Lack of knowledge and consciousness regarding solar power generation technology,
- High equipment and operational costs against low ability to pay of households in rural area,
- Lack of guidelines for promoting solar energy as a substitute of electrification through the national grid,
- Lack of customers' understanding of their obligation to pay electricity tariff, which causes gradually worsening tariff collection
- Lack of customers' understanding of appropriate use of equipment, which causes its frequent breakdown that could have been prevented
- Chronic shortage of technical experts and lack of organizations and training for the development of technical experts, and
- Establishment of equipment and material supply systems and maintenance techniques.

### 9.3.2. Lessons Learned from ESCO Projects

Since ESCO solar power generation projects were first introduced in Zambia they have been limited to the Eastern Province. However, the demand for the services in unelectrified households and commercial sector has increased in other parts of the country.

However, installation costs of the ESCO projects depends on how much subsidy would be offered, and the electricity tariff only covers the running costs (staff costs and maintenance costs), i.e. it is not enough to cover the initial investment. Therefore the current ESCOs cannot afford reinvesting in new solar panels to expand their business. In addition, there is no other prominent candidate to start the same kind of ESCO business without subsidy though the potential demand for this kind of project electrification may also exist in other areas.

Main issues to be solved are as follows:

- Lowering costs of operation and maintenance through the improvement of management
- Formulation of technical standard, and
- Enlightenment of customers for their obligation to pay and the correct use of equipment.

It is recommended that ESCOs shall develop manuals regarding the operations of its organization, the operation and maintenance of equipment and the collection of electricity tariff, so that they can improve the sustainability of its business and can expand the size of business in the future without subsidies.

### 9.3.3. Lessons Learned from GRZ Projects

Installation of SHS funded by REF is implemented as the Government initiated project mostly for schools and public facilities as well as for individual users a relatively high income; individuals such as traditional leaders and middle-income earners in rural areas.

Based on the knowledge gained from the projects being implemented, the future measures and policies can be summarized as stated below.

- Formulation of off-grid solar electrification programme with a view to long term planning
- Setting guidelines for selecting target areas, demand estimation and standardization of solar electrification and equipment
- Formulation of manuals and implementation of training programme in operation and maintenance to enhance sustainability
- Taking efficiency and rationalization into consideration, securing stable income by setting payment and collection methods of electricity tariff, and expansion of the business by increased investment by controlling costs
- Development of markets for the SHS

## 9.4. Local In-country Survey and Assessment of Existing Solar Power Generation Systems

### 9.4.1. Solar Energy Resource and Current Status in Zambia

The purpose of rural electrification using solar power generation in Zambia is to reduce the dependency to charcoal, kerosene and other resources which are generally procured and used in that country, and to increase access to electricity services by applying solar power generation technology, in order to contribute to poverty reduction by improving productivity and quality of life. The average annual amount of global solar radiation in Zambia is 6,600-7,700MJ/M2 per year, and especially Central Province, Southern Province, Eastern Province, Western Province, Northern Province and North-Western Province are rich in this energy with each of their average annual amount of global solar radiation is more than 7,000MJ/M2 per year, where it is expected that even a 50Wp solar power generation system (household system) can generate about 70kWh electricity annually. However, currently solar power generation systems have been introduced only in small part of the country by the support of foreign donors and the government, and the approach to increase the number of electrified houses is in its early stages to be encouraged in the future.

### 9.4.2. Assessment of Previous Solar Power Generation Projects

In Zambia several organizations have completed pilot projects for the use of solar power generation systems. Electrification projects using solar power generation were implemented as ESCO projects, including fund raising and operation, establishment of a framework, and administration of projects for electrification. Electricity supply by solar power generation in unelectrified areas is welcomed by users / potential users because of the positive results of previous projects, and the increased number of applicants for installation of these systems, which realize electrification relatively easily, indicates the large expectation for electrification. However, as the nature of electrification using solar power generation, (1) The capacity is smaller than the case of electrification using grids, (2) There are limitations to facility usage, (3) It is difficult to expect the same benefit as the case of electrification using grids which can leverage motors, (4) Significant productivity improvement has not yet achieved. In addition, there are several issues in technical business skills to ensure the sustainability, and in the coordination among donors, and because of their disparities in electrification purposes, individual organizations and government authorities, although they are organized as the ESCO project framework.

In general households, solar power generation is used for lights, TVs, DVD players and CD players with radio. Among them electricity supply to lights and TVs are most appreciated, and recently the electricity use for media such as battery charge is added to them, reflecting the popularization of mobile phones. In future rural electrification, increased aspirations for accesses to information can not be ignored.

School buildings and other related facilities in this country use adobe bricks for their walls, and they have only a few windows because of their structure. Inside these buildings it is dark even during daytime hours, and darker in rainy seasons and cloudy days. Even in fine days similar phenomenon occurs in evenings. Learning efficiency, which remains low in such circumstances, will significantly be improved by lightening after electrification. The results of previous projects prove that learning hours and motivation for learning have been increased by lightning in classrooms, raising the expectation to introduce electrification to more schools.

The benefit of lightening in clinics is that since they can use microscopes, for example, in sample test of malaria, the consultation quality of doctors has been improved. In addition, since medicines can be stored in refrigerators, various kinds / larger quantity of officinal drugs can be stocked there. Before electrification, it was dark inside clinics even during daytime hours, which gave a negative image to patients and clinics were not places where patients were willing to go. These benefits show that electrification has significantly changed and contributed to the improvement of medical technologies.

### 9.4.3. Current Local Procurement Status of Solar Power Generation Systems

In Zambia solar power generation systems for general households are procured from several agents (suppliers) in Lusaka, the capital of the country, and systems for ESCO projects of each donor and for government projects are supplied via bidding among these suppliers, but the criteria are not clearly defined. Existing facilities except for those in ESCO projects were sold as maintenance-free systems, and buyers should bear the responsibility for operation maintenance including the case when any trouble occurs, however, these systems have issues in technological sustainability. According the market survey in 2007 in Lusaka, the procurement of solar power generation facilities fully relies on imports. Major suppliers of facilities in previous projects are described below, and these facilities are imported mainly via South Africa.

**Table 9-8 Results of Market Survey on Solar Power Generation Facilities in Zambia**

| Company | **Supply Country** | **Item** |
|---|---|---|
| Kyosera | Japan | Solar Modules |
| Xantrex | USA | Inverter |
| Edwards | Australia | Solar Hot System |
| Steca | Germany | Charge regulators |
| Deltec | France | High Deep Cycle Batteries |
| Surrette | Canada | Deep Cycle Batteries |
| Mingle | Germany | Torches, Telephone Chargers |
| Sollatek | UK | Glowstar Protection<br>Power promotion |
| Logic Electronics | Netherlands | Solar lantern |

Source; JICA Study team

### 9.4.4. Essential Agendas for Systematic and Rational Implementation of Solar Power Generation Projects

Considering the rural electrification rate (3% in 2007), and because electrification promotion is a long term project, it is important to develop an off-grid electrification program using solar power, including a long term plan based on electrification policies of the government. Government authorities should lead the initiative while reflecting opinions of each province, to develop selection criteria of subject areas, expect demands, and standardize electrification methods using solar power. Also a framework should be established that defines responsibilities and alignment in logistics, construction, materials / equipment ownership, maintenance, education / training, fund collection and other related tasks.

### 9.4.5. Standardization of Implementation Plans, Applied Technologies and Equipment Specifications, and Development of Technical Manuals

Unification of technical standards, standardization of solar power generation technologies which align with local characteristics regarding design and installation items, etc., and technical manuals are needed for installation, implementation and operation maintenance. Currently the procurement of solar power generation facilities mainly relies on imports, but in order to promote the future utilization of parts manufactured in the country, costs and quality of these products should achieve an international level, requiring the establishment of technical standards, quality improvement, and technological advancement for cost reduction, of solar power generation facilities.

### 9.4.6. Establishment of a System and Framework for Operation, Maintenance and Management of Facilities / Services

In previous ESCO projects using solar power generation in Zambia, systems are not purchased by users, but they are installed in users' houses. The electricity generated from these systems is supplied to users and the electricity charge is collected from the users. Facilities are owned by the government and maintained by operating organizations. However, with limited supply quantity and similarly limited revenue of these projects, these organizations can not afford activities other than ongoing administration of themselves, nor to start an economic cycle of initial investment - revenue increase - productivity increase (electricity rate increase). In these ESCO projects, a mechanism to transfer the ownership from the government should be defined. Solar power generation facilities in Zambia are not purchased by users, but they are installed in users' houses. The electricity generated from these systems is supplied to users and then the electricity charge is collected from the users. Previous experiences in ESCO projects indicate that it is difficult to collect invested funds within a short period, and operating organizations need stable management foundation. Based on these insights, it is recommended that organizations which can obtain supports from central authorities while being located in rural areas should be established and operated by themselves. Especially if future rural electrification by solar power generation expands across the country, it may be difficult for traditional ESCO projects to sustain operations because of regional characteristics and gaps, requiring a single organization to administer electrification projects in the future.

It is recommended to develop engineers and standardize operation maintenance method under a maintenance system which can reflect opinions from the government and stakeholders. In order to focus on sustainability and regional characteristics, projects need (1) Low cost operation and maintenance, (2) Establishment a framework to realize them, (3) Development of a market for solar power generation facilities, (4) Formulation of technical standards including selection criteria.

### 9.4.7. Policy for Rural Electrification Framework Using Solar Power Generation

(1) The Rural Electrification Authority (REA), the relevant government authority, should unify organizations, because this system uses the Rural Electrification Fund (REF).

(2) A framework for capacity building of REA, provinces, districts and rural residents should be established.

(3) Since rural electrification extends to a broad range of areas, initiatives and independence of individual provinces and residents should be reinforced to promote responsibilities of residents

to share facility costs and participation in O&M.

(4) Participation of private sectors should be encouraged to strengthen alignment between the government and private sectors.

**Table 9-9 Stakeholders of Electrification by Solar Power Generation and Their Roles / Responsibilities**

| Level | Role |
|---|---|
| Government | ・Plays a leading role in rural electrification and is responsible for planning, expansion and decision making.<br>・Engages in the upstream of rural electrification including fund raising, planning, defining technical standards, and capacity building of government - province - district - organization related to electrification projects. |
| Province<br>District | ・Working with REA, develops annual targets for the electrification plan, approves projects, and verifies their quality when completed, etc.<br>・Regularly monitors projects, and reports their status to REA.<br>・Gives instructions and advices regarding operation maintenance to resolve regional technical gaps. |
| Organization | ・RGC or each household is responsible for the management and operation of their systems.<br>・Develops engineers for each area after implementing systems.<br>・Transfers technologies to enable users to manage their systems. |

### 9.4.8. Human Resource Development

Issues for human resources and technologies based on the insights from the experiences in previous electrification projects using solar power generation in Zambia are listed below.

(1) Lack of knowledge and low awareness of solar power generation technologies.

(2) Damages to facilities caused by low understanding of end users on how to use the facilities.

(3) Chronic shortage of professional engineers.

(4) Lack of organizations and trainings to develop engineers.

(5) Establishment of a system to supply materials / equipment, and maintenance methods for them.

For the sustainability of the framework, resolution of these issues is the most prioritized critical agenda. If these issues are not resolved, low understanding of end users on their responsibility to pay their bills may deteriorate the bill collection rate, resulting in a risk to the organizational sustainability. Therefore developing manuals for operation and maintenance, and providing trainings are critical for the sustainability of the framework. It is recommended that a system for this framework which can start working at the implementation of facilities should be established.

### 9.4.9. Technical Training Plan

(1) Establishing technical standards and developing standard O&M curriculum.

(2) Founding a centralized training centre to develop technical instructors using the defined technical standards and standard O&M curriculum.

(3) Developing technical instructors at each province or district level to maintain solar power generation facilities on regional basis.

### 9.4.10. Significance of Solar Power Generation and Conclusion

Electrification by solar power generation will significantly contribute to poverty reduction and resolution of economic gaps which are major issues in Zambia, because it will create social benefits, and develop regional areas and even peripheral areas.

Economically, electrification still needs public financial assistance, although the project will request users to share the cost as much as possible. It may be difficult to quantify most of the expected benefits from rural electrification in low income areas, but it will contribute to the infrastructure building which achieves rural electrification, social and economical stability, and benefits. Solar power generation is sure to play a major role in the increase of electrification rate in remote areas, where there are limited sources for power supply and distribution lines.

## 9.5. Design and Specification of Solar Power Generation Systems

### 9.5.1. Design of Solar Power Generation Facilities

The subjects of electrification are RGCs which are centers for rural economical activities. Systems are installed in (1) public facilities (schools, clinics and community halls), (2) other public facilities (markets), and (3) private houses.

Major components of solar power generation facilities are solar power modules, mountings, controllers, inverters, fuses, batteries, switches, fluorescent lights and plugs. In Zambia solar panels available in the market have a capacity of about 20Wp to 125Wp, and the selection will be made among them. The output power capacity for a private house is designed to be about 100W, a capacity of one to three about 8-10W lights plus two or three hours use of a radio or TV depending on each of the output power capacity, and this capacity is defined as the standard specification. For schools, it is important to define the number of classrooms and teachers' rooms to be electrified for lighting and other purposes, and the standard electrification will be implemented to equipment including lights, TVs and communication devices in three classrooms and two teachers' rooms. For clinics standard electrification will be implemented to equipment including lights, TVs, communication devices, refrigerators and sterilizers in consultation rooms.

### 9.5.2. Standard Specification of Solar Power Generation Systems

Based on results of pilot projects for solar power generation facilities in Zambia and availability of procurement, the specifications are defined as follows.

**Table 9-10　Specification of Solar Power Generation Systems (Schools)**

| *[School]* | | | |
|---|---|---|---|
| Solar Equipment | Specification | Unit | Amount |
| Solar Modules | 85Wp | Piece | 1 |
| Battery | 105Ah | Unit | 1 |
| Charge controller | 12A | 〃 | 1 |
| Solar fluorescent. | c/w switch 8W | 〃 | 10 |
| Rip cord | $4.0mm^2$ | m | 8 |
| Cable | 2.5mm | m | 50 |
| Roof model frame | | rack | 1 |

**Table 9-11　Specification of Solar Power Generation Systems (Private Houses)**

| *[Private House]* | | | |
|---|---|---|---|
| Solar Equipment | Specification | Unit | Amount |
| Solar Modules | 60Wp | Piece | 1 |
| Battery | 105Ah | Unit | 1 |
| Charge controller | 6.6A | 〃 | 1 |
| Solar fluorescent. | c/w switch 10W | 〃 | 6 |
| Rip cord | $4.0mm^2$ | m | 8 |
| Cable | 2.5mm | m | 30 |
| Roof model frame | | rack | 1 |

**Table 9-12　Specification of Solar Power Generation Systems (Markets)**

| *[Market]* | | | |
|---|---|---|---|
| Solar Equipment | Specification | Unit | Amount |
| Solar Modules | 70Wp | Piece | 1 |
| Battery | 105Ah | Unit | 1 |
| Charge controller | 8.8A | 〃 | 1 |
| Solar fluorescent. | c/w switch 10W | 〃 | 7 |
| Rip cord | $4.0mm^2$ | m | 8 |
| Cable | 2.5mm | m | 35 |
| Roof model frame | | rack | 1 |

## 9.6. Cost Assessment Method for Solar Power Generation System

The cost assessment of Solar power generation facilities is made based on the relation between the total cost including hardware and installation costs at the implementation, and operation maintenance cost, and their lifetime. The hardware cost should be minimized or reduced by deciding standard specifications based on the defined technical standards, and by introducing biddings or other arrangements for lot purchases of a certain expected quantity. The installation cost of facilities should be unified using technical standards and installation manuals while ensuring the quality by skilled engineers. For installation local companies are employed in the early stages, but in the future it is recommended that a system in which users install the facilities by themselves should be established. To maintain and enhance projects in unelectrified areas while sustainably controlling cost, it is also recommended to develop manuals for organizational management and operation maintenance of facilities, as well as for bill collection, to improve operational quality. In addition, government-led fund raising plans and cost assessments which cover whole fund flow including cost sharing by users, are required. It will be critical to enhance projects by investment increase, control costs including hardware and operation costs, and maintain users' ability to pay, by ensuring stable revenue through setting electricity tariffs, establishing bill collecting system and other arrangements, and reducing expenditures through improving efficiency and encouraging rationalization.

# Chapter 10

# Other Renewable Energies Planning

# Chapter 10. Other Renewable Energies Planning

## 10.1. Current Status of Other Renewable Energies

### 10.1.1. Renewable Energy in Zambia

There are various kinds of alternative renewable energy sources that could be used besides micro-hydro and solar power, namely biomass, geothermal, and wind-power. Zambia is said to have some potential of the said renewable energy sources, and the Zambian Government has been keen to expand the use of renewable energy, which is considered to be effective in addressing the following concerns, (though, in fact, the current utilization of renewable energy still contributes very little to the nation's energy supply).

- Diversifying energy sources,
- Increasing the electrification rate in rural areas since renewable energy is an on-site energy source and it is generally available in rural areas, and
- Improving the living standards of residents in impoverished rural areas, improving their health and educational level, and reducing endemic diseases such as HIV/AIDS.

Table 10-1 shows the availability and potential for the use of renewable energy in Zambia.

**Table 10-1 Availability and Potential for Utilization of Renewable of Energy Resources and Technologies in Zambia**

| Renewable Energy | Opportunities/Use | Resource Availability | Potential Energy Output |
|---|---|---|---|
| **PV** | Thermal (water heating), Electricity (water pumping, lighting, refrigeration) | 6-8 sunshine hours | 5.5 kWh/m$^2$/day (modest potential especially for limited irrigation) |
| **Wind** | Electricity<br>Mechanical (water pumping) | Average 3m/s | Good potential, especially for irrigation |
| **Micro-hydro** | Small grids for electricity supply | Reasonably extensive | Requires elaboration and quantification |
| **Biomass** (Combustion and Gasification) | Electricity generation | Agro wastes Forest wastes Sawmill wastes | Requires elaboration and quantification |
| **Biomass** (biomethanation) | Electricity generation<br>Heating and cooking | Animal waste<br>Agro- and industrial waste<br>Waste water | Potential requires elaboration |
| **Biomass** (extraction, processing for transport) | Ethanol for blending with gasoline to replace lead as octane enhancer<br>Biodiesel for stationary engines | Sugarcane<br>Sweet sorghum<br>Jatropha | 15,000 ha to meet current demand |
| **Biomass** (for household energy) | Improved charcoal production<br>Improved biomass stove | Sawmill wastes and indigenous trees from sustainable forest management | Reasonably extensive |

Source: Centre for Energy, Environment, and Engineering (Z) Limited, 2004 National Energy Policy (MEWD), 2006

However, many issues remain to be solved to expand the use of renewable energy, such as:

- Support from Government/donors for subsidising private sector investment to cover very high initial investment,
- Improvement of technical capacity to operate and maintain photovoltaic systems,

- Development of organization and management for sustainable business enterprises;
- Promoting the establishment of the market for equipment and materials.

At the time of writing, the Government provided only policy guidelines regarding the utilization of renewable energies and there was no specific program.

## 10.2. Data Collection

### 10.2.1. Wind-power Potential

Wind-power has the characteristic that it is strongly affected by the climate, land features and surrounding environment. Zambia is a landlocked country surrounded by 8 countries. The distance from the eastern border to the Indian Ocean is 700km and the western border to Atlantic Ocean 1,000km. The elevation of the country ranges between 1,000m and 1,350m. Gently sloped plateau is savanna, which is covered with grass and shrubs.

The Zambia Meteorological Department (ZMD) has 18 observatories in the country (limited to the sites where reliable data are available), which are record wind velocities at a height of 10m from the ground. Table 10-2 shows the annual average wind velocity in Zambia.

The data reported by the Zambia Meteorological Department show the monthly average wind velocity from 2002 to 2005 at each observatory. The country's annual average wind velocity is about 3.2m/second.

**Table 10-2 Annual Average Wind Velocity in Zambia (2002-2005)**

| | | | | |
|---|---|---|---|---|
| Chipep | Kabwe | Livingstone | Lundaz | *Lusaka01* |
| 4.1 | 3.3 | 3.7 | 3.9 | *N.A.* |
| *Lusaka02* | Magoye | Mbala | Mfuwe | 'Misamf |
| *N.A.* | 3.84 | 4.1 | 2.6 | 4.4 |
| Mongu | Mumbwa | Petauke | Solwezi | Zambezi |
| 6.3 | 3.5 | 3.7 | 2.9 | 2.6 |
| Kafiro | Mwinil | Mumbwa | Kaoma | Kabomp |
| 1.7 | 1.6 | 3.5 | 1.14 | 1.1 |
| Average | **3.2**（m/s） | | | |

Source: Zambia Meteorological Department

### 10.2.2. Biomass Potential

Promotion of biomass energy development in Zambia is in line with the Government policy to promote fair share of sustainable renewable resources in the energy supply. The Government has been developing the guidelines to improve institutional and legal frameworks for the promotion of biomass energy development in the future.

In Zambia, wood fuel as forest resource has been consumed as firewood and charcoal. Forests are estimated to cover an area of 50million ha, or 66% of the national land. Most households use firewood and charcoal for cooking and heating, and this accounts for over 70% of the energy consumption in Zambia (2004). This type of energy consumption is projected to continue in the future, as the statistics show that the percentage of using firewood for cooking is 60.9%, using charcoal 24.3%, while electricity accounts for only 13.8% (Draft National Energy Policy, October 2006). Meanwhile, as the population grows and the demand for energy increases the cutting of timber exceeds the rate of reforestation, forests are destroyed and the consequential negative environmental effects such as desertification become serious concerns.

Zambian Government has a strong interest in the utilization of bio-fuels. Use of bio-fuels in the transport sector has been discussed. In general, bio-fuel is classified into bio-ethanol and bio-diesel. The bio-ethanol is produced by fermentation of residue of agricultural products such as oats, rice and sugarcane. The fuel is used by mixing ethanol of with 3 to 10%. Actually the history of automobiles shows that initially bio-ethanol was used as the fuel; but it was gradually replaced by gasoline because of the lower costs. Bio-diesel is produced from crop material such as casaba, jatropha curcas, canola oil and soybeans. Methanol is added to the bio-diesel to initiate a chemical reaction to lower the viscosity for practical use.

Although the expansion of renewable energies utilization is called for, there are no examples of electrification projects using biomass in Zambia.

Table 10-3 shows residue of major crops for biomass energy in Zambia.

**Table 10-3 Residue of Some Major Crops Grown in Zambia**

| Crop | Type of residue | Average Annual crop production $10^3$t (1987-1999) | Average Residue Annual availability $10^3$t |
|---|---|---|---|
| Maize | Stalk+cobs | 1,143.0 | 2,857.5 |
| Sorghum | Stalk | 29.5 | 59.0 |
| Millet | Stalk | 49.4 | 98.8 |
| Paddy Rice | Straw+ husks | 11.7 | 34.0 |
| Sugar cone | Bagasse (50%wet) | 1,313.3 | 459.7 |
| Cotton | Stalk<br>Gin trash | 42.0 | 147.0<br>126.0 |
| Groundnuts | Shell,<br>Stalk | 39.9 | 19.95<br>115.7 |
| Soya beans | Straw | 24.8 | 62.0 |
| Sunflower | Stalk | 13.2 | 23.1 |
| Irrigated Wheat | Straw | 58.6 | 102.5 |
| Cashew nuts | Shell | 2.5 | 5.0 |
| Coffee | Kernel | 1.4 | 0.7 |
| Castor oil | Stick | 0.2 | 0.7 |
| Irish potato | Straw | 11.1 | 3.3 |
| Sweet potato | Straw | 5.0 | 2.0 |
| Mixed beans | Straws/peels | 19.0 | 43.7 |
| Cassava | Stalks/peels | 122.3 | 89.5 |
| Cashew nuts | Shell | 2.7 | 5.5 |

Source: Annual Report of Department Agriculture 2001

Among the residue of major crops produced in Zambia, the proportion of stems of sugarcane and maize are relatively large. In case these materials are planned to use for biomass generation, it is carefully noted that the procurement of raw material significantly affects the power generation potential.

There are three commercial sugar factories in Zambia namely Zambia Sugar Factory in Mazabuka (Southern Province), Kafue Sugar Factory in Kafue (Lusaka Province), and Kalungwishi Sugar Factory in Kasama (Northern Province). The Government expects that these sugar factories would contribute to the production of bio-fuels. Table 10-4 shows rough outline of the production of the three sugar factories.

**Table 10-4 Rough Outline of Production in the Major Sugar Factories in Zambia**

| Sugar factory | Cultivated acreage | Quantity of production (Sugar) | Quantity of production (Molasses) | Yield |
|---|---|---|---|---|
| Zambia Factory | 15,800ha | 233,765t | 52,000t | 111,178t |
| Kafue Factory | 4,200ha | 6,500t | 15,000t | N.A. |
| Kalungwishi Factory | 3,000ha | 4,000t | 800t | 38,000t |

Source: Final Concept Paper by The renewable Energy committee 2004

## 10.3. Review of Existing Other Renewable Energies Development Plans

### 10.3.1. Wind-power

#### (1) About Wind-Power Generation

Conditions suitable for wind-power generation are high average wind velocity, stable wind direction and small turbulence.

Selection of suitable areas for wind-power generation takes the following steps: first, select areas where annual average wind velocity is over 5m/s, preferably 6m/s at a height of 30m from the ground[26], and then select areas among them where the high velocity conditions covers a wide area.

Although annual average wind velocity in country of Zambia is 3.2m/s, in some sites the annual average wind velocity of 5m/s or more is observed. Table 10-5 shows the classification of windmills by size.

**Table 10-5 Classification of Windmills by Size**

| Classification | | Capacity |
|---|---|---|
| Micro windmill | | Less than 1kW |
| Small sized windmill | | 1 - below 50kW |
| Medium sized windmill | I | 50 - below 500kW |
| | II | 500 - below 1,000kW |
| Large sized windmill | | Over 1,000kw |

Source: International Electro technical Commission (IEC)

[26] In Japan the criterion for determining the possibility of wind-power generation business is that annual average wind velocity is preferably over 6m/s at a height of 30m from the ground (Wind-power Generation Introduction Guidebook, NEDO, 2005).

(2) Past Projects of Wind-Power Generation in Zambia

Zambian Government has no wind-power generation project at the moment. Micro windmills are sometimes used by private sector, but full-fledged utilization of wind power is rare.

**Figure 10-1 Shiwang'andu – Chinsali District in Northern Province – Wind Power Generation**

### 10.3.2. Biomass

A biomass project in Zambia has been implemented in Kaputa, Northern Province, financed by the grant aid from Global Environment Facility (GEF), which is under United Nations Industrial Development Organization (UNIDO). The project's objective is to provide electricity to mini-grid from biomass gasification system.

Various methods of biomass energy utilization are discussed and planned for the future expansion, but at the time of the Study actual project plans had not materialized.

No technical standards had been developed either.

### 10.3.3. Others

Geologically, Zambia is covered with sedimentary rocks and on contrary to the general observation that in the lands like Zambia hot springs are scarcely available compared to the lands that are dominated by igneous rocks, hot springs are found in over 80 sites in areas with intrusive rocks formed through the geological process.

Two sets of 120kW turbine were established as pilot sites in Kapisya Hot Spring in mid-1980s under the initiative of the Italian Government. Due to the absence of a nearby load the facility was not used. The Zambian Government planned to revive geothermal development projects in other sites though their potential for electricity generation was not known.

# Chapter 11

# Environmental
# and
# Social Considerations

# Chapter 11. Environmental and Social Considerations

## 11.1. National Environmental Strategies and Legislation

### 11.1.1. National Policy on Environment

In 2006, the Ministry of Tourism, Environment and Natural Resources finalized a Draft Policy on Environment that recognizes the requirements set out in the national constitution and acknowledges the responsibility of civil society and all citizens to protect and conserve the environment. The Policy calls for the importance of managing the environment in partnership with the private sector, non-governmental organizations (NGOs) and the local people for the benefit of the present and the future generations. The planning and executing agency for the Policy is the Ministry of Tourism, Environment and Natural Resources (MTENR).

### 11.1.2. The Environmental Protection and Pollution Control Act, 1990

The Environmental Protection and Pollution Control Act (EPPCA), the supreme environmental law in Zambia, was passed in 1990. The Act established the Environmental Council of Zambia (ECZ), which assumes sole responsibility to protect the environment and control pollution so as to ensure the health and welfare of people and wildlife in Zambia.

EPPCA specifies the functions and authority of the ECZ. Membership of the board for ECZ is drawn from specified stakeholders regarding the protection of the environment and natural resource use. The MTENR appoints the Chairperson of the board. The board appoints the Director, who is the Chief Executive Officer. The Director executes the policies and directives of the board.

ECZ is empowered;

- to identify projects or types of projects, plans and policies for which environmental impact assessment are necessary and to undertake or request others to undertake such assessments for consideration by ECZ;
- to monitor trends in the use of natural resources and their impact on the environment;
- to request information on projects proposed, planned or in progress by any person anywhere in Zambia;
- to request information on the quantity, quality and management methods of natural resources and environmental conditions from any individual or organization anywhere in Zambia; and
- to consider and to advise the GRZ on all major development projects at an initial stage and on the effects of any sociological or economic development on environment.

### 11.1.3. The EIA Regulations, 1997

The Environmental Impact Assessment Regulations were set out in 1997. The EIA regulations in conjunction with the EPPCA of 1990 provide a sound legal framework for the process and requirements for environmental clearance in Zambia. The EIA Regulations articulate specific procedures that anyone who takes on development activities listed in the regulations must follow. Authorization licenses granted by ECZ under the EIA Regulations remain valid for three years from date of issue. The EIA Regulations also provide a framework for post-assessment environmental audits as well as an appeal procedure for any party aggrieved by the decision of ECZ.

### 11.1.4. Other Regulations

In addition to the above environmental legislation, there are other pieces of legislation administered by various Government Departments that project developers need to take into consideration, such as the;

- Public Health Act, 1930
- Water Act, 1949
- Noxious weeds Acts, 1953
- Agricultural Lands Act, 1960
- Factories Act, 1967
- Natural Resources Conservation Act, 1970
- Zambezi River Authority Act, 1987
- National Heritage Conservation Commission Act, 1989
- Local Government Act, 1991
- Town and Country Planning Act, 1995
- Electricity Act, 1995 and Energy Regulation Act, 1995
- Lands Act, 1995 and Lands Acquisition Act, 1995
- Fisheries Act, 1998
- Zambia Wildlife Authority Act, 1999
- Forestry Act, 1999
- Rural Electrification Act, 2003
- Project developers also need to consider other International and Regional Conventions such as;
  - Convention on the Protection of World Cultural and Natural Heritage
  - Convention on Wetlands of International Importance, especially as waterfowl habitat
  - Statutes for the International Union for the Conservation of Nature and Natural Resources
  - Convention on the African Migratory Locust
  - SADC Protocol on the Environment
  - SADC revised Water Protocol
  - African Convention on the Conservation of Nature and Natural Resources
  - Convention on International Trade in Endangered Species of Wild Fauna and Flora
  - Vienna Convention for the Protection of the Ozone Layer
  - Montreal Protocol on Substances that Deplete the Ozone Layer
  - Agreement on the Action Plan for the Environmentally Sound Management of the Common Zambezi River System
  - Convention on Biological Diversity
  - United Nations Framework on Climate Change
  - United Nations Convention to Combat Desertification
  - Bonn Convention

## 11.2. Environmental Process and Regulations Relating to Rural Electrification

### 11.2.1. Environmental Clearance Process

The purpose of the environmental clearance process is to determine whether development projects are likely to have potential adverse environmental and social impacts, to determine appropriate mitigating measures for those impacts, to ensure that those mitigation measures be incorporated into the project design, and to monitor social and environmental indicators during implementation and operation. The level of the environmental assessment required depends on the nature of projects. ECZ provides EIA Guidelines with a checklist and project classification categories.

Section 3 (1) of Statutory Instrument No. 28 of 1997 of the Environmental Protection and Pollution

Control Act No. 12 of 1990, namely, the EIA Regulations stipulate that "A developer shall not implement a project for which a project brief or environmental impact statement is required under these Regulations, unless the project brief or an environmental impact statement has been concluded in accordance with these regulations and the ECZ has issued a decision letter."[27] An EPB is the first stage of the environmental and social impact assessment process and is supposed to cover the results of preliminary investigations on the impacts of the project on both society and environment.

The items to be described in an EPB constitute the followings:

- Environment of the project site/area
- Objectives of alternatives to the project
- Main activities to be conducted in the preparation, construction, and operation phases
- Raw materials in the project
- Products, by-products, including solid, liquid and gaseous wastes
- Noise level, heat, and radioactive wastes in normal/emergency operation states
- Socio-economic impacts expected in the project, number of people who would be directly forced to resettle or those who would be employed in construction /operation phases of the project
- Anticipated impacts on environment by implementation of the project taking into consideration the above
- Biodiversity, nature, geographical resources, and land/water area affected in terms of time and space
- Mitigation measures and monitoring plan to be implemented

[27] The EIA Regulations apply to specific projects and not to a Master Plan. However, it would be appropriate for the Master Plan to be subjected to a Strategic Environmental Assessment (SEA) once it is finalized. The SEA enable a proponent or planner to overview the environmental aspects and comprehensive impacts of the Master Plan. The present EIA Regulations do not provide for approval of the Strategic Environmental Assessment. The SEA would be very useful for formulation of a whole Master Plan, thus providing useful information for decision making.

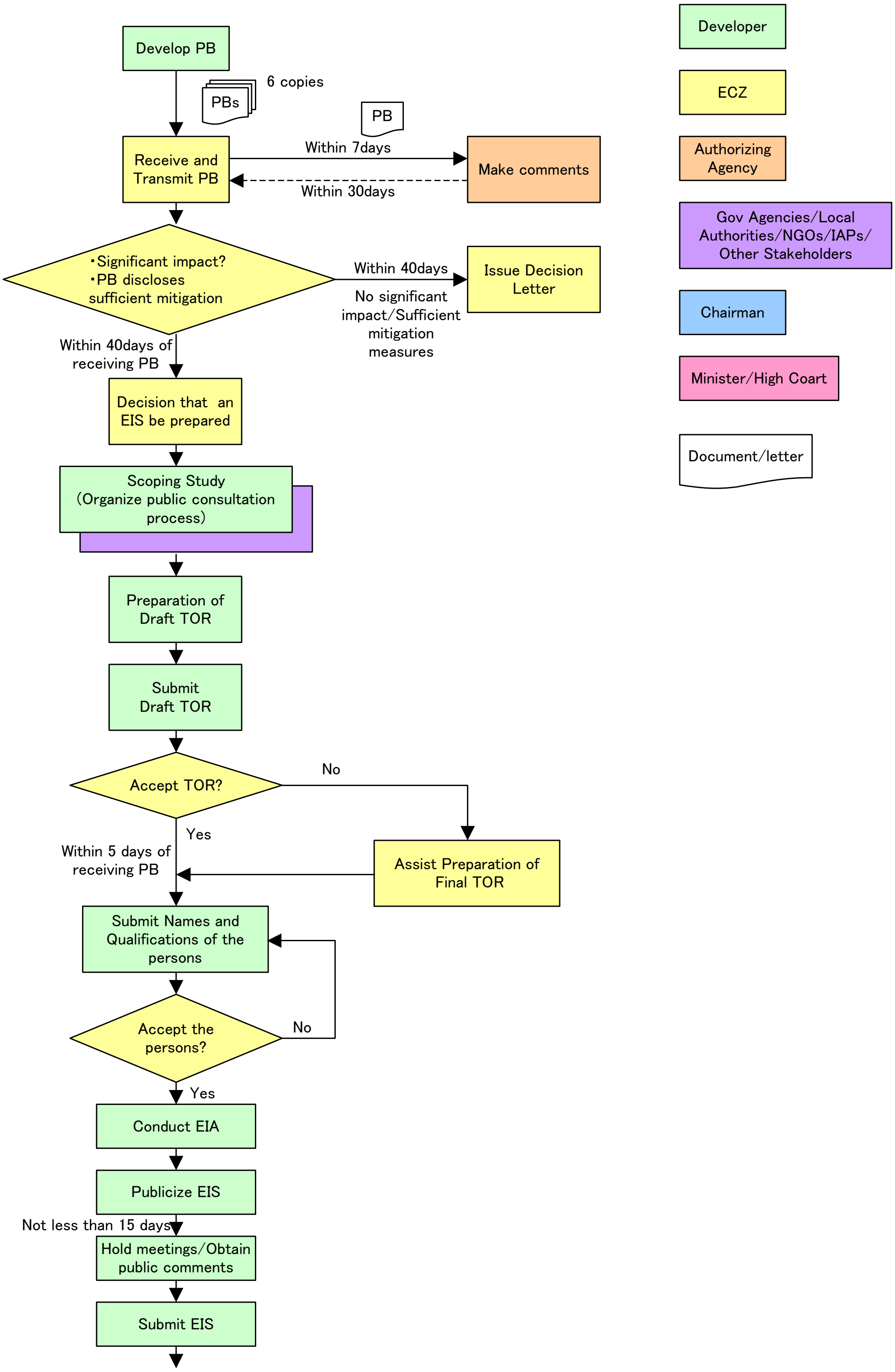



**Figure 11-1　Environmental Clearance Process in Zambia**

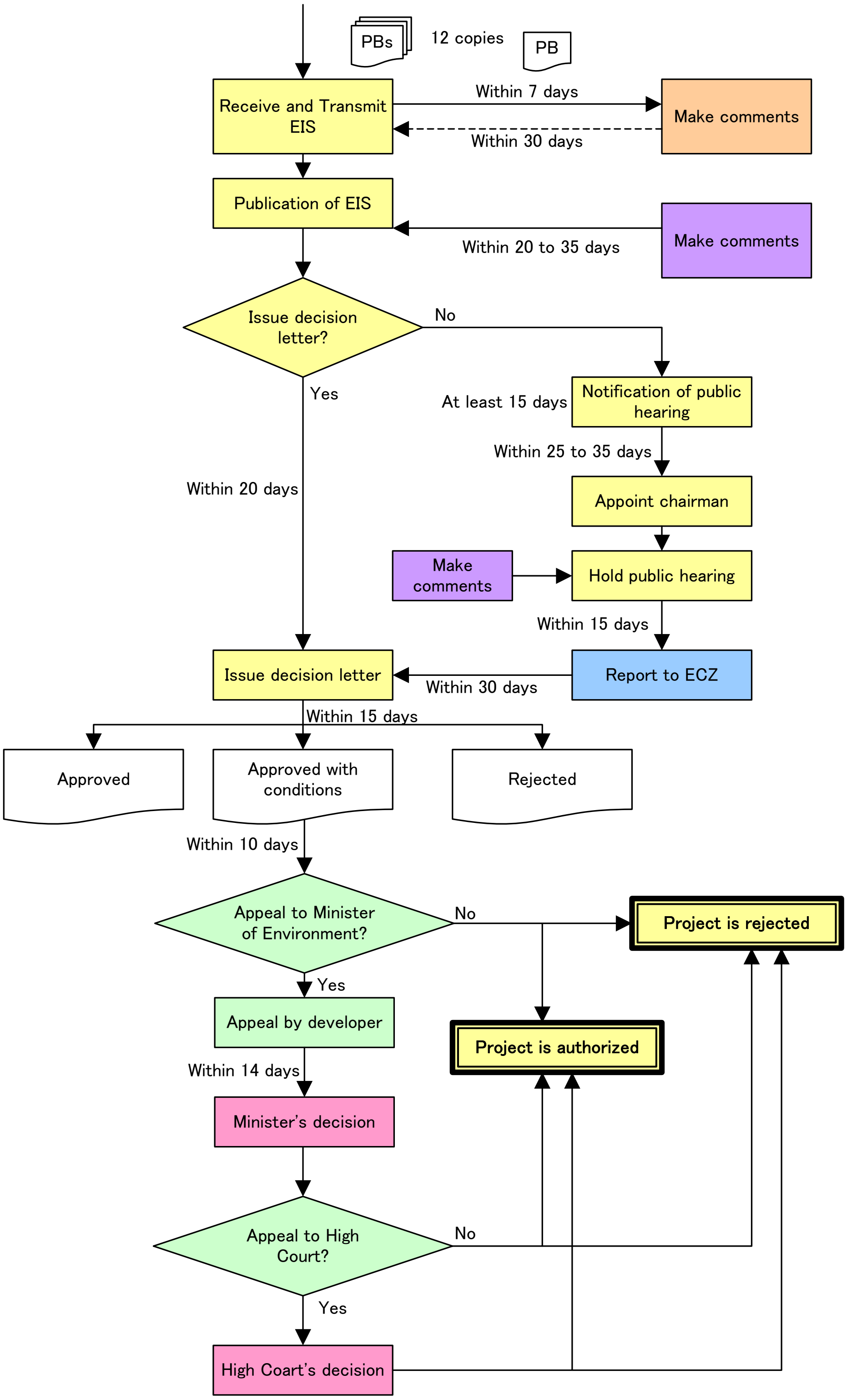



**Figure 11-1　Environmental Clearance Process in Zambia (Cont.)**

After receiving an EPB[28] submitted by a developer, ECZ makes a reference to the authorizing agency, and then carefully review the EPB taking into account the reference results. If ECZ concluded that no significant impact on environment is anticipated by the project, it suggests approval and issues a decision letter, in other words, development permission. If certain negative impacts of the project are identified, ECZ proceeds to review of the impact mitigation measures. When ECZ recognize that the PB in question shows sufficient mitigation measures, it authorizes the project implementation and issues the decision letter as same as it does for the first case. In case where ECZ regards the project's adverse impacts on environment as significant, it decides to either reject the project or recommend further in-depth environmental assessment.

In case ECZ sees the need for further assessments, the developer is then directed to undertake detailed social and environmental impact assessment studies. The developer starts from scoping then prepares the draft terms of reference (TOR). In determining the scope of works, the developer is obliged to engage in public hearing with government agencies, local authorities, NGOs, civil society, and a variety of stakeholders. The developer submits the TOR's including the names and qualifications of the persons who will conduct the EIA study and prepare the EIS. The draft TOR is then scrutinized by ECZ and the developer is then advised whether to go ahead with the EIA study or improve on the study team composition and terms of reference before doing so. Following approval of the TOR's and study team composition, the developer commences with the EIA study. Upon completion of the study, the developer submits the draft Environment Impact Statement (EIS) report to the ECZ for review and comment. The developer incorporates the comments received from the ECZ and submits the final report. Upon receiving the final EIS, ECZ sends the EIS to relevant ministries, government departments, local governments, parastatals, NGOs, and the Interested and Affected Parties (IAPs) for their review and comments. ECZ makes the EIS available for public at public buildings in the vicinity of the proposed project site to obtain public comments. Public meetings may be held in the vicinity of the proposed project site if ECZ considers it necessary. Based on the all comments it has received, ECZ scrutinizes the EIS, examining whether the proposed measures are appropriate as well as adequate. Upon completion of the procedures, ECZ makes a decision whether it authorizes project implementation with conditions, without conditions, or rejects the project.

Therefore, the administration of the environmental clearance process in Zambia involves a variety of stakeholders. Project developers, sectoral agencies, and environmental authority (namely ECZ) assume respective responsibility.

As was mentioned in the previous section, a project developer kicks off the environmental clearance process when a certain project materializes. After screening, the project developer prepares necessary documents such as EPB and EIS, conducts environmental impact assessments complies with management and monitoring requirements resulting from the assessment and the public recommendations. The project developer has to collect and disclose information regarding the scope of the project, its socio-environmental impacts, and management- and mitigation measures and monitoring programs.

ECZ and Sectoral agency or related authorities collaborate on behalf of the public to ensure that ecological, cultural, social, and economic issues are properly addressed in line with government policy and legislation. The sectoral agency retains responsibility to ensure that the proposed project meets all the sectoral requirements for which the agency is mandated.

### 11.2.2. Projects which require Environmental Project Briefs

Below are the types of projects that require the preparation of Environmental Project Briefs. The

[28] According to MTENR, only sub-projects in the Rural Electrification Master Plan require submission of EPBs and ECZ's approval when these projects are actually decided to be implemented, basically, these do not fall into the project category which requires EIA.

Environmental Regulations have a long list of types of projects that require the preparation of Environmental Project Briefs, but only those projects, which relate to the operations of power development, are highlighted as follows[29]:

- Hydropower schemes
- Transmission lines development
- Distribution line construction of more than one 1 km long
- Projects affecting wetlands
- Projects affecting natural forests
- Flood control schemes
- Diesel powered generating plants
- Pumped water storage plants
- Resettlement schemes
- Hospitals, clinics, health centres, schools, colleges and universities
- Housing schemes
- Recreations facilities, hotels, restaurants and lodges
- Renovations or expansions to all the above infrastructure

### 11.2.3. Projects that require Environmental Impact Statement (EIS)

The Environmental Regulations have a long list of the types of projects that require the preparation of EIAs, but only those projects, which relate to power development, are highlighted as follows:

- Electricity generation stations
- Transmission line development more than 1 km long
- Access roads along transmission lines for more than 1 km
- Dams and barrages covering a total of 25 hectares for irrigation, water supply or generation of electricity
- Sewerage disposal sites with a capacity of 15,000 litres or more a day
- Sites for solid wastes disposal with 1,000 tonnes and above a day
- Sites for hazardous waste disposal
- Major road construction and large scale improvements to existing roads of over 10 km or 1 km if it passes through a national park or forest reserve
- Clearance of forests in sensitive areas such as watershed areas for agricultural, industrial and other uses

### 11.2.4. Review Fees

According the Environmental Protection and Pollution Control Act (Environmental Impact Assessment) (Amendment) Regulations of 1998, the project proponent is required to pay specified amount of money to Environmental Council of Zambia (ECZ) for reviewing (reading through the report to give approval) the Environmental Impact Assessment (EIA) reports and Environmental Project Briefs. Currently for Environmental Project Briefs, the project proponent is required to pay K7,799,940. The amount to be paid for the review of EIA reports depends on the value (total investment cost) of the project and ranges between K7,799,940 and K584,995,500. These fees are subject to periodic review.

[29] According to MTENR, none of the rural electrification projects will fall into the category of those projects that require full environmental impact assessment. However, there are some examples of rural electrification projects that were required to conduct EIA by ECZ. Even for the rural electrification projects, full EIA could be required depending on the scale of the project and degree of adverse impacts on environments.

**Table 11-1 Review Fee Tariff**

| Project Cost | Fee (K) | US$ Equivalent |
|---|---|---|
| Review of project brief | 7,799,940.00 | 1,950 |
| Less than US $100,000 | 7,799,940.00 | 1,950 |
| US $100,000 – 500,000 | 38,999,700.00 | 9,750 |
| US $500,000 – 1,000,000 | 97,499,160.00 | 24,375 |
| US $1,000,000 – 10,000,000 | 194,998,320.00 | 48,750 |
| US $10,000,000 – 50,000,000 | 389,997,000.00 | 97,499 |
| US $50,000,000 or more | 584,995,500.00 | 146,249 |

Note: Exchange rate of 1US$ = K4,000 was applied for currency conversion

### 11.2.5. ZESCO's Environmental Management

ZESCO, a key national power sector operator in Zambia, has developed an environmental policy in line with the provisions of the Environmental Protection and Pollution Control Act of 1990. The policy is also in conformity with international standards and public expectations in environmental management. The ZESCO Environmental Policy is presented as follows;

- ZESCO's ambition is to satisfy customers' demand for efficient, safe and environmentally friendly supply of electric energy.
- The natural resources on which our operations depend shall be harnessed with utmost possible care.
- In our effort to achieve environmental excellence in our operations, we shall continuously train and motivate all employees to perform their duties in an environmentally responsible manner.
- Facing our responsibility to enhance environmental protection, we shall take the interest of future generations into consideration when carrying out our development projects.
- In openness and with commitment to environmental issues related to power development, we shall endeavour to create and enjoy the confidence of our customers and other stakeholders in our actions and operations.

The Environment and Social Affairs Unit (ESU) was established in June 1996 under Engineering Development Directorate of ZESCO. The Unit was tasked to handle environmental and socio-economic issues pertaining to the operations of ZESCO.

The main function of ESU is to ensure that ZESCO operates within the provisions of the environmental regulations. Specifically, the major functions of ESU are:

- to ensure that ZESCO operates in accordance with Zambian environmental regulations;
- to develop environmental guidelines and environmental operational plans for ZESCO on various aspects;
- to advise engineering and other ZESCO staff on environmental and social issues;
- to train ZESCO staff in environmental and social issues;
- to represent ZESCO on environmental and social issues in national and international form;
- to liaise with Government ministries and other institutions responsible for management of water, land and other natural resources, environmental regulation and socio-economic affairs;
- to develop baseline environmental and socio-economic database for catchment areas where ZESCO operates;
- to conduct environmental impact assessments for ZESCO projects to identify the impacts, recommend mitigation measures and monitoring implementation of recommended mitigation measures;

- to supervise consultants hired to do environmental work for ZESCO projects pertaining to power generation, transmission and distribution;
- to manage land acquisition, resettlement programmes and compensation related to implementation of ZESCO projects; and
- to conduct public meetings in project areas to ensure that the public understands the projects being undertaken by ZESCO and to get their input on various aspects of each project.

The ESU of ZESCO comprised sixteen officers, namely, the ESU Manager, Chief Environmental Scientist, a Principal Soil Scientist, Information Specialist, Ecologist, Hydrologist, four Way-Leave Officers, an Environmental Assistant, Environmental Technologist (Ecologist), Environmental Technologist (Geophysist), and Environmental Technician (Hydrology). Throughout extensive project experience, ESU has built its capacity on environmental impact assessment studies. For donor-assisted projects, ESU has conducted EIA studies in association with international and national leading environmental consultants, meeting international social and environmental requirements.

### 11.2.6. REA's Environmental Management

The Rural Electrification Authority (REA) is a new statutory body established in April 2004 and now expanding its operational capacity. The REA structure includes the position of environmental specialist reporting to the Senior Manager, Planning and Projects. As part of its environmental management system, the REA prepares EPB's and EIS's for its rural electrification projects. This helps in meeting legal obligations under the EPPCA as the REA undertakes its projects. In future, the REA may also play a role of making comments on EPBs and EISs submitted by developers and transmitted to the REA by ECZ in the environmental clearance process and to categorize power generation projects based on generation and supply capacity.

ZESCO, which has cumulative project experience, may actively assist REA in developing social and environmental assessment capacity, for example, by involving REA personnel in ZESCO's EIA study team and by giving lectures and workshops on EIA techniques.

## 11.3. Environmental and Social Considerations to Rural Electrification Master Plan

### 11.3.1. Environmental and Social Impact of Master Plan

There is no direct environmental and social impact in the master plan stage. However, in implementing specific components to be proposed in the Master Plan may involve some social and environmental considerations. Therefore, The concept of the Strategic Environmental Assessment (SEA) should be taken into consideration to prepare appropriate Rural Electrification Master Plan in view of environmental and social aspects.

Two proposed mini-hydropower project sites were selected by the field survey conducted in June and August 2007. The JICA Study Team in collaboration with the Zambian Counterpart team conducted preliminary environmental impact assessment activities and prepared EPBs, for capacity development purposes.

The following Table 11-2 shows the revised scoping of social and environmental considerations in the Rural Electrification Master Plan.

## Table 11-2 Scoping of Social and Environmental Considerations

| | No. | Item | Rating | | | | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Master Plan Stage | D/L | | Minihydro | | PV | | Wind | | Biomass | | |
| | | | | Construction | Operation | Construction | Operation | Construction | Operation | Construction | Operation | Construction | Operation | |
| Social Environment | 1 | Involuntary Resettlement | D | D | D | B | C | D | D | B | C | D | D | |
| | 2 | Local economy such as employment and livelihood, etc. | D | D | D | B | B | D | D | D | D | D | C | |
| | 3 | Land use and utilization of local resources | D | B | D | B | B | D | D | D | D | B | B | |
| | 4 | Social institutions such as social infrastructure and local decision-making institutions | D | C | D | C | D | D | D | D | D | D | D | |
| | 5 | Existing social infrastructures and services | D | B | B | B | B | B | B | B | B | B | B | |
| | 6 | The poor, indigenous and ethnic people | D | D | D | D | D | D | D | D | D | D | D | |
| | 7 | Misdistribution of benefit and damege | D | D | B | D | B | D | B | D | B | D | B | |
| | 8 | Cultural heritage | D | B | D | B | D | D | D | B | D | B | D | |
| | 9 | Local conflict of interests | D | D | D | D | D | D | D | D | D | D | D | |
| | 10 | Water Usage or Water Rights and Rights of Common | D | D | D | B | B | D | D | D | D | D | D | |
| | 11 | Sanitation | D | D | D | D | D | D | D | D | D | D | C | |
| | 12 | Hazards (Risk)/Infectious diseases such as HIV/AIDS | D | B | D | B | D | B | D | B | D | B | D | |
| Natural Environment | 13 | Topography and Geological features | D | C | C | B | B | D | D | C | C | D | D | |
| | 14 | Groundwater | D | D | D | D | D | D | D | D | D | D | D | |
| | 15 | Soil Erosion | D | B | B | B | B | D | D | C | C | D | D | |
| | 16 | Hydrological Situation | D | D | D | B | B | D | D | D | D | D | D | |
| | 17 | Coastal Zone | D | D | D | D | D | D | D | D | D | D | D | |
| | 18 | Flora, Fauna and Biodiversity | D | C | C | C | C | C | C | C | C | C | C | |
| | 19 | Meteorology | D | D | D | D | D | D | D | D | D | D | D | |
| | 20 | Landscape | D | B | B | B | B | B | B | B | B | B | B | |
| | 21 | Global Warming | D | D | D | D | D | D | D | D | D | D | D | |
| Pollution | 22 | Air Pollution | D | B | D | B | D | B | D | B | D | B | B | |
| | 23 | Water Pollution | D | C | D | C | D | C | D | C | D | C | D | |
| | 24 | Soil Contamination | D | D | D | D | D | D | D | D | D | D | D | |
| | 25 | Waste | D | B | D | B | D | B | D | B | D | B | D | |
| | 26 | Noise and Vibration | D | B | D | B | D | B | D | B | D | B | C | |
| | 27 | Ground Subsidence | D | D | D | D | D | D | D | D | D | D | D | |
| | 28 | Offensive Odour | D | B | D | B | D | B | D | B | D | B | B | |
| | 29 | Bottom sediment | D | D | D | D | D | D | D | D | D | D | D | |
| | 30 | Accidents | D | B | B | B | B | B | B | B | B | B | B | |

Note: Evaluation categories are as follows:

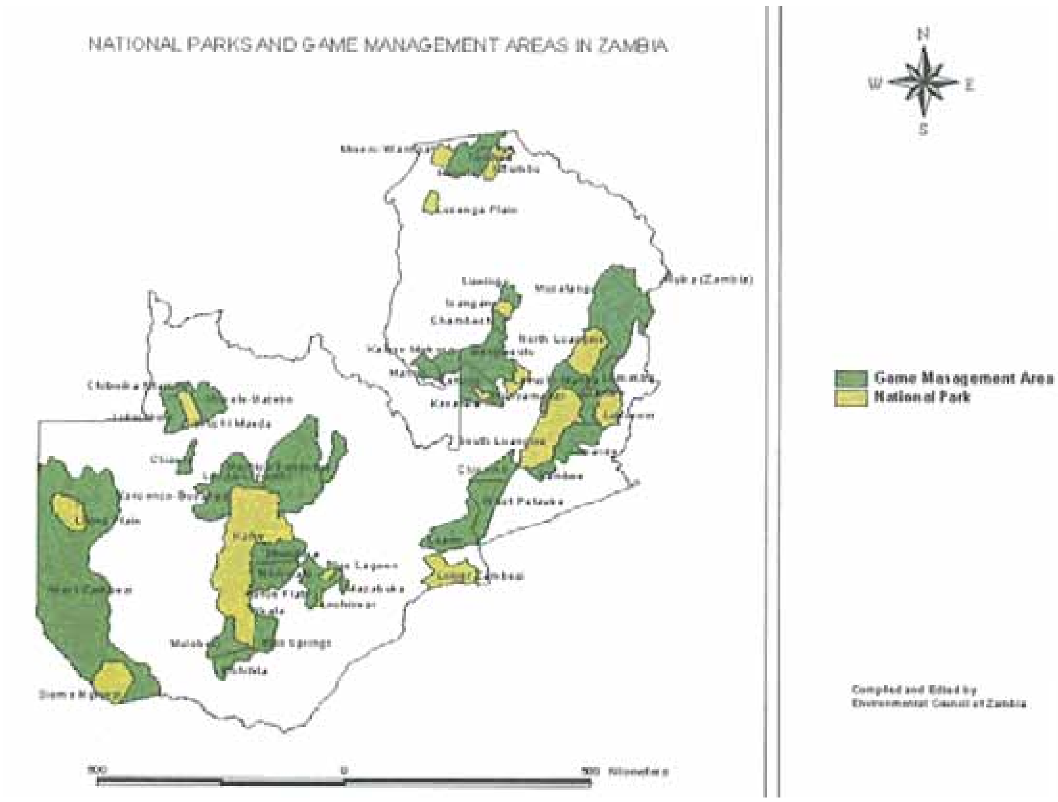
A : Significant negative impact is expected
B : Negative impact is expected to some extent
C : Negative impact is now known at this stage
D : Negative impact is not expected/negative impact is insignificant

### 11.3.2. Potential Social and Environmental Impacts of Rural Electrification Master Plan Sub-Projects

In the Rural Electrification Master Plan in Zambia, several rural electrification options will be presented. The least cost option is grid system extension, followed by micro-hydro micro-grid, photovoltaic (SHS) and other renewable installations in the remote areas. The followings are the potential social and environmental impacts to be studied and mitigated for under the REMP Projects.

#### (1) Vegetation and Wildlife

The clearance of vegetation along the distribution lines and access roads, as well as micro-hydropower generation sites is unavoidable in the construction phase. Disturbance of vegetation may also occur on rocks and soil disposals and camp areas for construction workers. Some rare or endangered vegetation and wildlife species in such areas may be affected. In the operation phase, routine maintenance of the right-of-way (ROW) will inevitably require tree cutting or vegetation clearance within certain way leave. Figure 11-2 shows the map of National Parks and Game Management Areas and Figure 11-3 also shows the National Parks, Environmentally Sensitive Areas, and the Wetland Bird Habitats, including the positions of all RGCs. Among the RGCs, some are located in such environmentally sensitive areas; thus there may be significant negative impacts on the environment. Execution of more detailed impact assessment prior to project implementation in such areas is essential to avoid the risk.




Source: Statement of Environment in Zambia 2000 Figure 7.2: National Parks and Game Management Areas of Zambia

**Figure 11-2 National Parks and Game Management Areas in Zambia.**

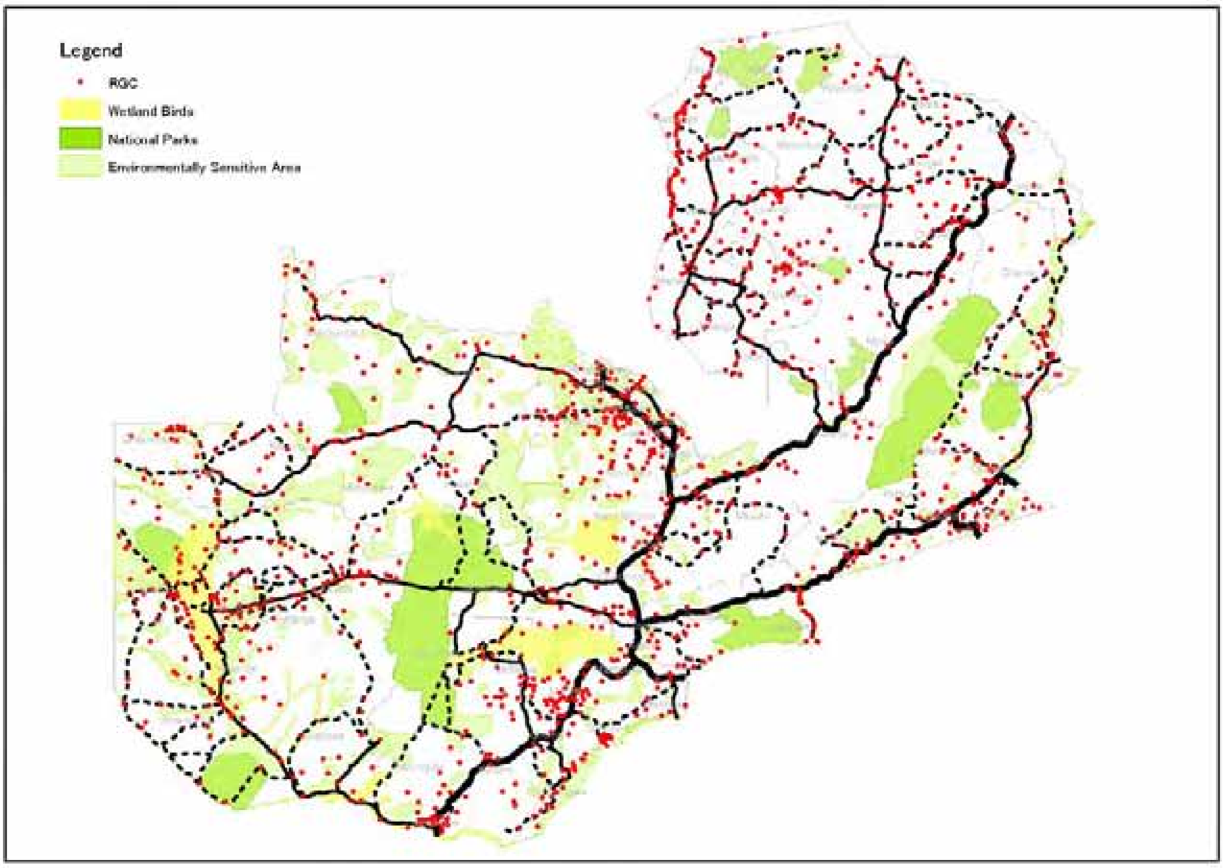
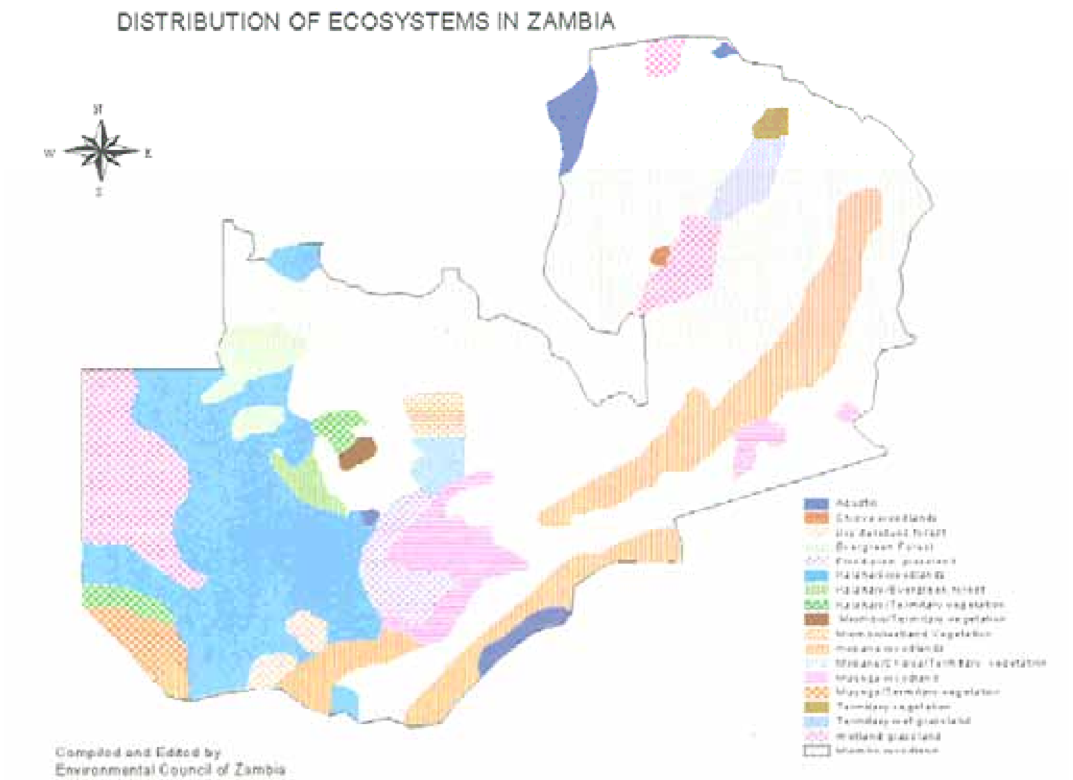



**Figure 11-3 National Parks, Environmentally Sensitive Areas, Wetland Bird Habitat, and RGCs**

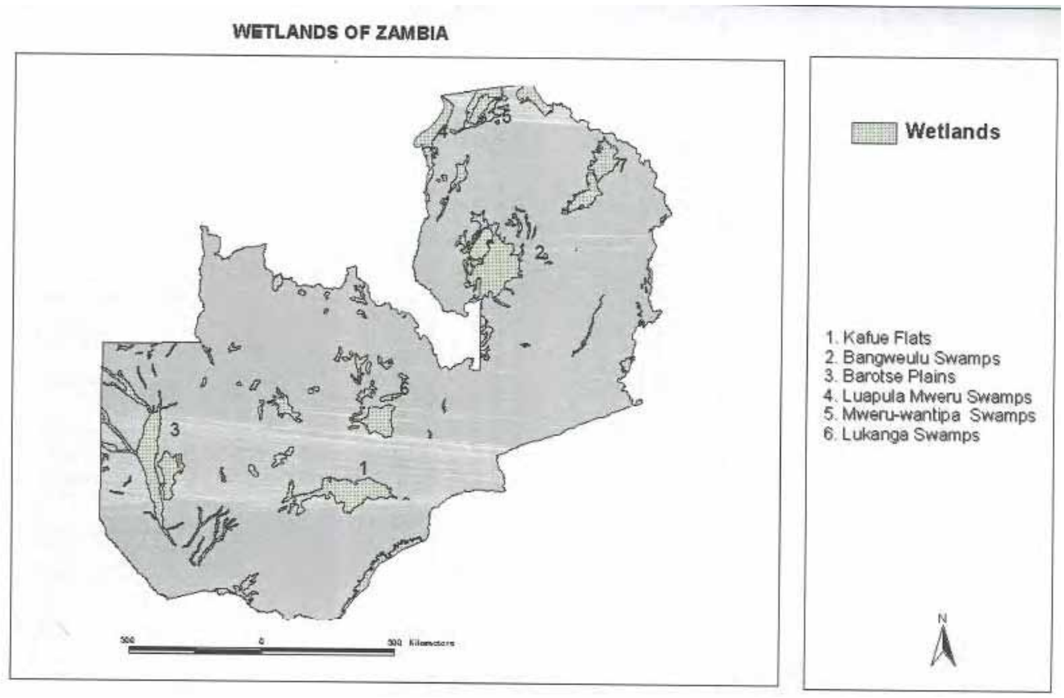
(2) Natural Habitat

Master Plan sub-projects may construct distribution lines and power facilities that may traverse habitats with rare or endangered flora and fauna. Construction of access roads, micro-hydropower plants, camps, rock and soil disposals, excavations, etc. may lead to habitat destruction and compel some species to be displaced from where they used to be. Micro-hydropower sub-projects may divert courses of rivers away from the natural habitats and alter the conditions of the habitats. Figure 11-4 and Figure 11-5 show the distribution of ecosystem and the distribution of wetlands in Zambia, respectively.




Source: Statement of Environment in Zambia 2000 Figure 3.2: Distribution of ecosystems in Zambia

**Figure 11-4 Distribution of Ecosystem in Zambia**

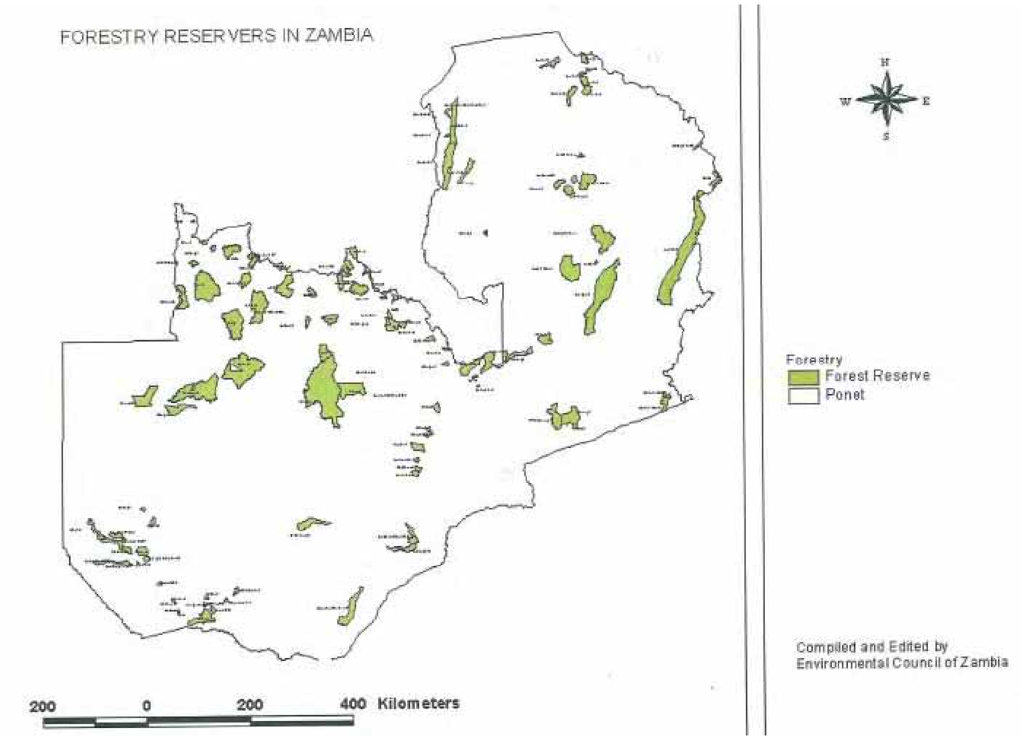



Source: Statement of Environment in Zambia 2000 Figure 4.2: Distribution of Major Wetlands in Zambia

**Figure 11-5 Distribution of Wetlands in Zambia**

### (3) Impacts on Forestry

Construction of distribution lines as well as micro-hydro power plant may require the temporary use of the land for waste treatment/disposal, storage of construction materials, office camp, housing for workers and the like. In rural areas, it will be a rare case that such spaces for temporary use have been cleared in advance. Thus tree cuts are sometimes unavoidable and possible impacts on forestry including non-timber forest products must be carefully examined on a project-by-project basis. Figure 11-6 shows the distribution of forest reserves in Zambia.




Source: Statement of Environment in Zambia 2000 Figure 6.2: Distribution of Local and National Forests

**Figure 11-6 Forest Reserves in Zambia**

### (4) Impacts on Water Quality

In the construction stage of micro-hydropower sub-projects, local water quality may change. Turbidity of water caused by construction of weirs, water channels, and tunnels may causes damage of safe drinking water and negative impacts on some aquatic organisms. Careless handling of fuel, oil, lubricants and other chemicals for construction machinery have a potential risk of spills of them into the river. In the operation stage, leakage of lubricants for hydraulic turbines may cause deterioration of water quality. Thus potential impacts on water quality must be carefully studied.

### (5) Soil Erosion

Any construction activities may potentially cause soil erosion. Some sort of soils may result in progressive soil erosion triggered by access road or distribution line construction. Clearing vegetation along distribution lines may also cause soil erosion. Construction of micro-hydro may make the site more vulnerable to flooding or landslides.

### (6) Pollution

Any construction activities lead to pollution such as noise, vibration, waste, offensive odour, and air and water pollution, to some extent. On the other hand, pollution during operation is considered to be minimal or negligible for the Master Plan sub-projects. Environmental assessment should recommend measures to minimize such impacts, identify the level of pollution during construction, and calculate compensation adequately if impacts are unavoidable.

### (7) Impacts on Landscape

Distribution lines, micro-hydro facilities, and other renewable power facilities, once installed, may result in changes to the landscape, which may lead to social and economic adverse effects, harming local religious and cultural values or damaging potential tourist opportunities. EIA must propose measures to minimize or eliminate impacts and estimate compensation costs if the impacts are residual even after operation.

### (8) Loss of Cultural, Spiritual and Religious Properties

In planning, losses of cultural, spiritual and religious properties may be avoidable. However, construction activity sometimes encounters cultural properties such as archaeological sites and historical settlements when excavating. Such kind of cultural properties could be negatively impacted unless proper treatments, conservation of the properties by transferring them to a new location, will be offered in consultation with appropriate authority such as National Heritage Conservation Commission and/or stakeholders. EIA must address compensation and mitigation policies for those important properties.

### (9) Involuntary Resettlement

For micro-hydropower sub-projects, temporarily resettlement may be necessary during the construction period for safety reason. For distribution line construction, some houses, which are along the proposed corridor, may have to be demolished or shifted to give way to the proposed lines between substations if it is not avoidable even with deliberate route planning. Any involuntary resettlement, whether temporary or permanent, due to Master Plan sub-project, has to be managed and compensated in a fair and transparent manner. For a sub-project inevitably requiring involuntary resettlement, compensation costs should be carefully assessed at the feasibility study stage of each sub-project. The project developer has to prepare a Resettlement Action Plan (RAP) in line with EIA.

### (10) Health and Safety

It is anticipated that construction of distribution lines and micro-hydro allow workers and camp followers to project sites in remote areas. The influx of outsiders may risk remote communities with the potential spread of waterborne diseases and sexually transmitted diseases (STDs) including HIV. In addition, in newly electrified villages, safety in electricity usage becomes significant issues. EIA may address issues regarding health and safety by proposing measures to control any potential health and safety hazard risks.

### (11) Dam Safety

The Dam Safety Policy of the International Commission on Large Dams (ICOLD) applies to dams with heights of 15 meters or more, no matter what types of hydropower plants. Micro-hydro power plant sub-projects to be proposed in line with the Master Plan may not exceed this dam height.

### (12) Impacts on Locality

An introduction of electricity will change the well being of local people who have not used electricity before the installation of any kinds of power facilities. Reduction in kerosene use may erode sales opportunity of vendors/service providers of kerosene and kerosene appliances such as lamps and refrigerators. The new distribution alignment may trigger or enhance local disputes. Electrification may benefit only those who are originally wealthy if sub-projects are inequitably designed. The Master Plan Study tries to formulate sub-project packages in order to distribute benefits from electrification in a highly equitable manner. EIA for each sub-project has to consult with wide local stakeholders in order to identify potential local issues.

### (13) Compensation

All the residual impacts, social or environmental, must be compensated through the project. Any temporary or permanent loss of houses, physical structure, land plots, agricultural crops and trees due to the project implementation as well as operation will require compensation to households, communities, and private businesses. Formulation of transparent, equitable compensation policy and procedures is crucial in order to gain confidence and trustworthiness of project affected people and community. There is currently no specific law in relation to involuntary resettlement; however, there are a variety of articles of relevant laws that provide guidance for legal provision for resettlement. Under the Land Acquisition Act, the principles of compensation are centered on the ground that the value of the property for compensation shall be the value of the amount of the property in question which may expected to be realized if sold on an open market by a willing seller at the time of publication of notice to yield up possession of the property. Besides, under the Part VI of the same Act, a Compensation Advisory Board has been established to advise and assist the Minister in the assessment of any compensation payable under the Act. Under the Part III Environmental Impact Statement of the EIA Regulations, a project developer is responsible for provision of the Environmental Management Plan (EMP) as a part of the Environmental Impact Statement and in the statement, the developer should propose specific compensation policy for the project in question.[30]

### (14) Positive Impacts on Social Environment

Some kinds of positive impacts on social environment by implementation of rural electrification sub-projects are envisaged. Agricultural production is likely to increase, as the people will be able to use electricity for irrigation. Medical care in night time by provision of lighting, preservation of medicines using refrigerators, and use of electronic medical equipment by supply of power will enable RHCs to provide higher quality medical services. Schools will be able to conduct classes in the evening. With the availability of electricity, schools may be able to acquire computers for use by both pupils and teachers, thus improving level of education. Pupils will be able to study at night and this could lead to improvement in overall academic standards of the schools in the project catchment area. In social service sector, influx of construction workers will provide a larger customer base for goods and services. Business people will be encouraged to build more and even bigger shops and/or other social amenities. With all above positive social impacts, it is envisaged that implementation of sub-projects will lead to development of local economy and in turn in the standard of living.

## 11.3.3. Possible Mitigation Measures

Table 11-3 shows major potential impacts of sub-projects in the Master Plan and possible mitigation measures. The mitigation measures that should be considered for specific electrification method(s) are followed by the type of electrification with parenthesis (Ex. (M/H)). Mitigation measures without such description is thought to be applicable to all types of electrification methods shown in the table. The mitigation measures should be properly reviewed and updated based on more detailed environmental impact assessment prior to implementation of each sub project.

In the Rural Electrification Master Plan study, pre-feasibility-study-level case studies were conducted for two proposed mini-hydropower projects in both North-western and Northern Province for the purpose of capacity development. As a part of case studies, the Study Team in collaboration with the Counterpart conducted preliminary environmental impact assessment studies and identified project specific potential impacts on environment. The study results are detailed in Chapter 12 Case Study.

[30] Resettlement Policy Framework for the Increased Access to Energy and Information and Communication Technology Services Project, MEWD, DOE, October 2006

## Table 11-3 Mitigation Measures for Adverse Social and Environmental Impacts

| No. | Item | Rating D/L C | D/L O | M/H C | M/H O | PV C | PV O | Wind C | Wind O | Biomass C | Biomass O | Possible Mitigatrion Measures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Involuntary Resettlement | D | D | B | C | D | D | B | C | D | D | · Avoid construction near settled areas<br>· Consultations with project affected persons (PAPs)<br>· Resettlement plans and alternatives for PAPs<br>· Strengthening of local authorities and agencies responsible for resettlement implementation<br>· Empowerment of PAPs with possible involvement of NGOs |
| 2 | Local economy | D | B | B | B | D | B | D | B | D | C | · Relocation support and agricultural extension programs<br>· Compensation for economic damage |
| 3 | Land use | B | D | B | B | D | D | D | D | B | B | · Avoid construction near settled areas<br>· Cousultations with PAPs<br>· Fair mechanism for prompt compensation payments, monitoring and grievance procedures |
| 4 | Social institutions such as social infrastructure and local decision-making institutions | C | D | C | D | D | D | D | D | D | D | · Consultaions with PAPs and local leaders |
| 5 | Existing social infrastructures and services | B | B | B | B | B | B | B | B | B | B | · Public awareness program<br>· Consultaions with PAPs and local leaders |
| 6 | The poor, indigenous and ethnic people | D | D | D | D | D | D | D | D | D | D | |
| 7 | Misdistribution of benefit and damage | D | B | D | B | D | B | D | B | D | B | · Public awareness program<br>· Consultaions with PAPs and local leaders |
| 8 | Cultural heritage | B | D | B | D | D | D | B | D | B | D | · Avoidance of all culturally important sites<br>· Consultations with local and spiritual leaders<br>· Provisions for relocation of important cultural sites* |
| 9 | Local conflict of interests | D | D | D | D | D | D | D | D | D | D | · Public awareness program<br>· Consultaions with PAPs and local leaders |
| 10 | Water use rights and rights of Common | D | D | B | B | D | D | D | D | D | D | · Minimum bypass flows (M/H)<br>· Measures to reduce organic and inorganic waste (M/H) |
| 11 | Sanitation | D | D | D | D | D | D | D | D | D | C | · Proper treatment of gas emissions (Biomass) |
| 12 | Hazards (Risk)/Infectious disease such as HIV/AIDS | B | D | B | D | B | D | B | D | B | D | · Strengthening of existing health facilities with possible involvement of NGO as support<br>· Health awareness programs on hygiene, malaria, other water-borne diseases and STD<br>· Supervision of healthcare institutions and worker safety measures during construction<br>· Provisions to ensure safe drinking water |
| 13 | Topography and Geological features | C | C | B | B | D | D | C | C | D | D | · Topographically friendly design and construction of the right of way, access road and facilities<br>· Confine construction works within designated access areas<br>· Revegetation and its periodical maintenance |
| 14 | Groundwater | D | D | D | D | D | D | D | D | D | D | |
| 15 | Soil Erosion | B | B | B | B | D | D | C | C | D | D | · Drainage and erosion prevention and flexible modification technique in construction<br>· Backfilling of excavated soils and rubble from blasted rocks<br>· Restriction of access loads within power station zone (M/H) |
| 16 | Hydrological Situation | D | D | B | B | D | D | D | D | D | D | · Minimum bypass flow (M/H) |
| 17 | Coastal Zone | D | D | D | D | D | D | D | D | D | D | |
| 18 | Flora, Fauna and Biodiversity | C | C | C | C | C | C | C | C | C | C | · Sensitization against poaching and general conservation methods<br>· Sensitization of local community for sustainable fishing methods and conservation practices (M/H)<br>· Vegetation establishment around the reservoir (M/H)<br>· Rehabilitation of construction sites through landscaping, planting of trees and grass, and clearing of any disused materials (M/H) |
| 19 | Meteorology | D | D | D | D | D | D | D | D | D | D | |
| 20 | Landscape | B | B | B | B | B | B | B | B | B | B | · Consideration of aesthetic and cultural values in design of project features<br>· Revegetation treatment |
| 21 | Global Warming | D | D | D | D | D | D | D | D | D | D | |
| 22 | Air Pollution | B | D | B | D | B | D | B | D | B | B | · Limited use of construction machinery |
| 23 | Water Pollution | C | D | C | D | C | D | C | D | C | D | · Construction of appropriate sanitation facilities and domestic water supply services |
| 24 | Soil Contamination | D | D | D | D | D | D | D | D | D | D | |
| 25 | Waste | B | D | B | D | B | D | B | D | B | D | · Measures to reduce organic and inorganic waste in construction<br>· Appropriate material waste disposal such as landfill site<br>· Reuse of construction wastes<br>· Limited use of pesticides |
| 26 | Noise and Vibration | B | D | B | D | B | D | B | D | B | C | · Limited use of construction machinery<br>· Avoid construction near settled areas |
| 27 | Ground Subsidence | D | D | D | D | D | D | D | D | D | D | |
| 28 | Offensive Odour | B | D | B | D | B | D | B | D | B | B | · Limited use of chemicals, pesticides and oil during construction<br>· Appropriate material waste disposal such as landfill site<br>· Appropriate odour prevention measures such as storage methods and deodorization equipment |
| 29 | Bottom sediment | D | D | D | D | D | D | D | D | D | D | |
| 30 | Accidents | B | B | B | B | B | B | B | B | B | B | · Independent review of dam design and safety (M/H)<br>· Electricity safety education for new users and settlements near the new power facilities<br>· Safety education for construction and operation & maintenance workers |

Note: Evaluation categories are as same as Table 11-2

*: Rf. 11.3.2 (8) Loss of Cultural, Spiritual and Religious Properties

### 11.3.4. Alternative Rural Electrification Schemes And Their Impacts On Environment

Besides the proposed electrification schemes in the Rural Electrification Master Plan Study, namely, both mini-hydropower and extension of existing distribution network, alternative rural electrification schemes include more diesel power stations, solar home system (SHS), other renewable energy such as wind power and biomass, and the zero option were compared.

#### (1) Diesel Power Station

ZESCO has 11 diesel power stations and the green house gas emitted from the facilities contribute towards negative impacts on the environment. Emission of nitrogen oxide (NOx) and sulphur oxide (SOx) generated by sulfur in diesel fuel cause atmospheric pollution and acid rain problems. Thus, a significant negative impact could be expected from an increase in the number of diesel power stations, compared with other electrification schemes such as grid extension and micro hydropower generation, which do not emit such air contaminants in their operation stage.

On the other hand, since Zambia heavily depends on imported diesel fuel, soaring oil prices in recent years have negatively impacted the cost of service provision by ZESCO. Revenues from the areas electrified by diesel generations accounts for only 6% of the fuel cost (in 2004), therefore the replacement of such diesel power stations by either connecting to 66kV transmission lines or construction of micro hydropower stations is an urgent matter for ZESCO.

Increasing the number of diesel power stations may lead to rise in electricity tariffs as a consequence of increased oil prices. People in rural areas have low income and may not be able to pay the tariff or receive the full benefit of electrification. According to the National Energy Policy of GRZ, all District Administrative Centres in the 72 districts are supposed to be electrified. Some areas which are located near the borders and are difficult to reach by means of grid extension due to long distances from the existing distribution grids, new diesel power stations were planned to be installed by January, 2007. However such cases are exceptional. Widespread use of diesel power stations is not feasible because of the aforementioned reasons.

#### (2) Solar Home System

Zambia’s large area and low population density are factors that favour the use of renewable energy for rural electrification. Compared to other generation schemes which burn fossil fuels like diesel, environmental impacts of the solar energy generation like SHS, are considered insignificant in that its very nature of not emitting pollutants such as NOx and SOx, which will cause air pollution. However, the lead used in the batteries of SHS is a hazardous material and could, if not handled properly, affect human health. Diluted sulphuric acid, used as electrolysis solution, may also affect human health as well as cause ground water pollution when improperly treated. To avoid such negative impacts appropriate measures should be taken to ensure proper disposal used batteries.

#### (3) Wind-power

With respect to effective energy capture by pinwheel, the conditions suitable for wind power generation are high average wind velocity, stable wind direction, and small turbulence. According to Wind-power Generation Introduction Guidebook (published by the New Energy and Industrial Technology Development Organization (NEDO), 2005), minimum recommended wind velocity at 30m height above the ground is over 6m/s for determining the possibility of wind-power generation business. On the other hand, from the data obtained from the Zambia Meteorological Department for the period 2002 to 2005 the country’s annual average wind speed is 3.2m/s. Therefore, the implementation of large-scale development of wind-power projects may difficult not be feasible. Nevertheless, if, through future studies suitable sites are identified, it will be necessary to conduct studies on impacts on biophysical and socio-economic environments.

#### (4) Biomass

Biomass power generation is among the environmentally-friendly electrification methods because of its effective unitization of agricultural and/or livestock waste and its carbon neutral characteristics[31]. However, it would be difficult to implement large-scale biomass projects nationwide since the power generation potential is so dependent on the procurement of sufficient raw material significantly. Realization of biomass projects on a large scale in the future would also need to careful account of proper treatment of gas emissions and odour control.

#### (5) Zero Option

Without implementation of projects by utilization of proposed electrification schemes, in which are proposed in the Rural Electrification Master Plan Study, the target household electrification rate of 35% by 2002, which was set in the PRSP, will have to be accomplished mainly by installation of diesel power stations on a large scale. The possibility of accomplishment is, nevertheless anticipated to be quite low due to aforementioned reasons. Doing nothing therefore, would go against Governmental Policy on rural development.

### 11.3.5. Monitoring Plan for Environmental and Social Impacts

Under the current legislation on environmental management in Zambia, the monitoring plan for environmental and social impacts is part of the EIS, which is submitted by a project developer to ECZ prior to implementation of the project, and is subjected to review by ECZ under the EIA process. The detailed procedures are stipulated in the EIA Regulations. Thus, both the organizational structure and implementation methods are proposed by the developer depending on the project conditions.

On the other hand, the necessary capacity strengthening framework of institutions for implementation of monitoring plans has been proposed in the Environmental and Social Management Framework for the Increased Access to Electricity Services Project, which was reported in October 2006 by DOE. The project was prepared by GRZ for financing by the World Bank, Global Environmental Facility, other donors, and the Prototype Carbon Fund (PCF). The recommended approach includes training for electricity sector planners, senior design construction and maintenance staff, MEWD and REA staff, and support for Environmental Inspectors and District Environmental Officers. The training take the form of short seminars conducted under the auspices of REA by staff of MTENR, ECZ and the private sector working in environmental management.

According to the Framework, the monitoring plan is to be implemented under the Planning and Projects Department of REA, as follows:

- Establishment of environmental performance indicators for monitoring
- Implementation of projects
- Development of standardized format for recording monitoring and auditing information
- Commissioning of evaluations every 3 years

[31] Being **carbon neutral**, or **carbon neutrality**, refers to neutral (meaning zero) total carbon release, brought about by balancing the amount of carbon released with the amount sequestered. (Source: WIKIPEDIA http://en.wikipedia.org/wiki/Carbon_neutral)