5 REVIEW OF THE 2005 REDMP

The original 2000 REDMP was updated in 2005 to refine medium-term planning (2006-2010) and set new targets for the long-term electrification (2011-2025) of Namibia's rural areas.

The first step for the 2010 REDMP update was to ascertain to which extent the 2005 REDMP has been implemented. To assess in how far the 2005 REDMP has been implemented, the planned Localities vs. electrified Localities, as well as the estimated budget vs. expenditure are considered in further detail.

5.1 Main Findings

Tables 6 and 7 below show planned electrification (budget and planned Localities) against those which were implemented (actual expenditure and electrified Localities). No budget data for 2005 could be obtained for any of the country's regions (second column, Table 6).

Table 6: Planned Localities and budget per region, for the period 2005 to 2010

	2005		2006		2007		2008		2009		2010		Total	
REGION	Budget [N$]	Localities	Budget [N$]	Localities	Budget [N$]	Localities	Budget [N$]	Localities	Budget [N$]	Localities	Budget [N$]	Localities	Budget [N$]	Localities
Caprivi					5,133,145	3			15,732,280	7			20,865,425	10
Erongo			657,560	5	655,240	7	545,400	3	610,600	3	706,280	4	3,175,080	22
Hardap			1,697,040	11	2,006,200	4	7,341,280	6	4,888,880	4	8,624,440	7	24,557,840	32
Karas			1,386,280	8	1,583,280	3	1,444,880	3	2,021,160	5	1,599,760	5	8,035,360	24
Kavango			6,792,800	32	4,636,600	2	5,404,900	14	6,657,760	12	6,746,720	12	30,238,780	72
Kunene			2,099,030	2	3,808,345	12	5,188,805	9	2,133,880	9	3,519,095	8	16,749,155	40
Ohangwena	No data	44	7,963,110	24	8,130,850	11	8,901,710	12	8,681,550	11	9,079,640	12	42,756,860	114
Omaheke			2,236,275	7	2,576,295	3	3,244,545	3	3,209,340	5	1,729,560	4	12,996,015	22
Omusati			10,648,810	23	7,829,980	11	8,320,650	13	7,863,500	10	8,122,555	9	42,785,495	66
Oshana			4,994,285	9	4,175,835	6	4,091,225	4	5,111,745	5	4,204,900	6	22,577,990	30
Oshikoto			6,219,575	17	5,668,775	3	7,282,900	8	10,218,045	9	6,776,250	8	36,165,545	45
Otjozondjupa			2,301,305	5	5,696,790	5	3,419,170	3	4,507,420	7	3,493,595	4	19,418,280	24
Grand Total	0	44	46,996,070	143	51,901,335	70	55,185,465	78	71,636,160	87	54,602,795	79	280,321,825	501

Table 7: Electrified Localities and expenditure per region, for the period 2005 to 2010

	2005		2006		2007		2008		2009		2010		Total	
REGION	Cost [N$]	Localities	Cost [N$]	Localities	Cost [N$]	Localities	Cost [N$]	Localities	Cost [N$]	Localities	Cost [N$]	Localities	Cost [N$]	Localities
Caprivi	1,089,426	2	1,196,488	1	0	2					17,726,564	5	20,012,478	10
Erongo	1,455,977	3	1,044,796	2	405,358	2			3,333,132	2			6,239,264	9
Hardap	548,512	1	997,592	1	999,140	1	296,054	2	349,255	1	12,204,407	13	15,394,960	19
karas	665,699	1	782,150	1	1,249,865	1	493,421	1			4,374,335	4	7,565,471	8
Kavango	2,278,337	12	3,292,435	4	2,132,084	7			3,442,660	3	14,617,302	8	25,762,818	34
Kunene	1,362,260	2	2,514,000	4	11,000,000	4			4,223,694	4	16,013,443	7	35,113,397	21
Ohangwena	4,345,357	11	4,206,733	7	2,403,128	10			5,043,630	3	7,883,514	6	23,882,361	37
Omaheke	995,332	1	1,842,211	3	866,667	2	1,621,952	6	2,112,049	1	7,295,106	2	14,733,316	15
Omusati	2,188,297	10	5,712,178	11	2,403,142	8	9,098,544	13	1,882,762	2	9,628,460	7	30,913,383	51
Oshana	4,756,213	5	3,106,629	4	2,603,428	4			8,536,693	9	4,479,010	4	23,481,972	26
Oshikoto	2,796,703	7	5,578,988	9	2,723,671	6	2,048,224	3	2,683,789	4	4,092,611	4	19,923,984	33
Otjozondjupa			0	2	733,333	3	12,000,000	5					12,733,333	10
Grand Total	22,482,113	55	30,274,199	49	27,519,816	50	25,558,194	30	31,607,664	29	98,314,752	60	235,756,738	273

Figures 1 and 2 further illustrate the planned vs. actual electrified Localities, and the budget vs. the actual expenditure for electrification of the Localities respectively.

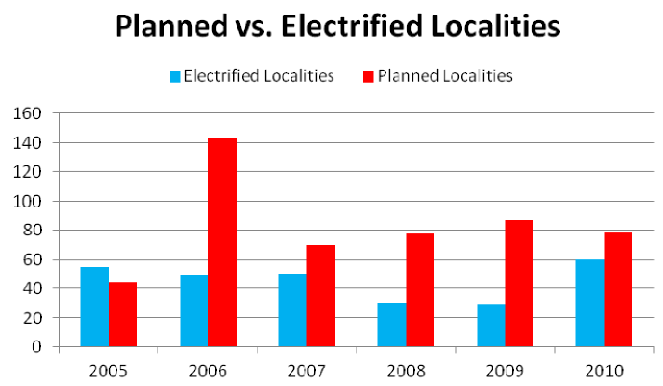


Figure 1: Planned vs. electrified Localities for the period 2005 to 2010

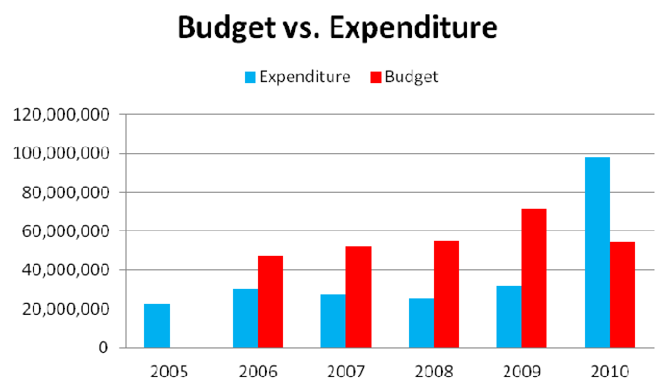


Figure 2: Budgets vs. expenditure for electrification of Localities in the period 2005 to 2010

By the end of year 5 (i.e. in 2010), the 2005 REDMP anticipated that a total of 501 Localities would have been electrified. The estimated total budget for the 5-year period was projected to be N$ 280,321,825. Based on the information received from the MME, a total of 273 Localities were actually electrified between the financial years 2005/06 to 2009/10, at a total investment of N$ 235,756,738.

It is noted that the completion dates of 14 Localities electrified under the European Investment Bank (EIB) was unavailable. Therefore, in order to ensure their inclusion in the statistics, these Localities were all considered to be completed in the year 2010. This contributes to a significant increase in the total expenditure in 2010, as shown in Figure 2, as these 14 Localities contribute approximately N$ 24m to that year's expenditure.

The 273 electrified Localities include only 107 Localities (39%) which were actually planned for implementation between the years of 2005-2010. The remaining 166 Localities (61%) were either planned for later execution, or not planned at all.

Figure 3 shows the number of electrified Localities against the year in which they were originally planned for electrification.

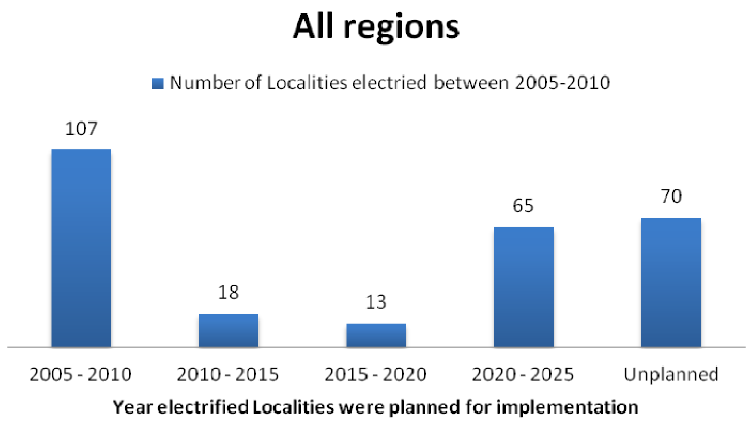


Figure 3: Distribution of 273 electrified Localities between 2005 and 2010

The 273 Localities include 50 Localities which were electrified under the EIB funding provision. This amounts to approximately N$ 77m. Considering the additional EIB funding, the variance between the budgeted amount and the actual expenditure is even more significant than shown.

Some key aspects for consideration, as derived from the data above, include:

- 273 Localities were electrified, compared to 501 planned (55%)
- 84% of the original estimated budget for 501 Localities was required to actually electrify these 273 Localities
- 107 of the total 273 Localities (39%) were electrified as planned (i.e. within first 5 years)
- 96 of the total 273 Localities (35%) were electrified earlier than planned, and
- 70 of the total 273 Localities (26%) were not planned for electrification under the 2005 REDMP, which accounts for some N$ 59m of the budget overrun.

5.2 Reflections and Conclusions

Both the execution as well as expenditure deviates quite significantly from the 2005 REDMP. Without analysing each and every Locality in detail, it is impossible to derive concrete conclusions as to why this occurred.

From the figures as described in Section 5.1, one can however gain some insight into possible reasons for the deviation. The outcome of the review provided useful input into the planning and methodology for the present REDMP.

A significant number of unplanned electrification activities were undertaken in the period between 2005 and 2010. The rationale for such unplanned activities are not known in all cases. Generally it is not desirable to undertake ad hoc electrification activities which have neither been planned nor properly budgeted for, as such electrification efforts may well have taken place in areas which would not have qualified for the systematic electrification in the first place. This points to a misalignment between national and regional electrification priorities and those envisioned in the 2005 REDMP.

5.2.1 Deviation from the Budget

Cost estimates in the 2005 REDMP were based on unit costs derived from '*various network development projects'*. Table 8 is an extract from the 2005 REDMP National Overview Report, and is included here for comparison with the 2005 NENA[7] unit rate costs.

The per kilometre rates for Gopher and Rabbit lines compare well with the 2005 NENA costs.

Table 8: Extract of unit rate cost table used in the 2005 REDMP

Item	*Description*	*Unit*	*Unit Cost [N$]*
1	Construct new single pole wood, 3-phase, 33kV Gopher lines	km	40,000
2	Construct new single pole wood, 3-phase, 33kV Rabbit lines	km	45,000
3	Construct new single pole wood, 3-phase, 33kV Hare lines	km	50,000
4	Re-conductor existing lines with Rabbit conductor (including rotten poles replacement)	km	28,000
5	Re-conductor existing lines with Hare conductor (including rotten poles replacement)	km	32,000
6	Install a 33 kV delta configuration voltage regulator	Units	600,000
7	Install new 33 kV feeder bay in substation	Units	500,000
8	Install new 10 MVA transformer in 66 kV substation	Units	1,600,000
9	Install new 2.5 MVA transformer in 66 kV substation	Units	1,200,000
10	Construct new 66 kV feeder bay	Units	800,000
11	Construct complete new 1x10 MVA 66/33 kV substation	Units	2,500,000
12	Upgrade SWER power lines to 3-phase	km	30,000

[7] The regulatory Namibian Electrical Network Assets (NENA) register, further described in subsection 6.2.6.2.

The NENA register includes a total of 267 unit rates for various electrical assets. As is evident from Table 8 above, only 12 items were included in the table of base costs in the 2005 REDMP. It is unclear from the report if budgeting ever considered the transformers and LV reticulations as part of the electrification costs, as these cost elements are absent from the unit rate table. This in itself accounts for a significant departure between the budgeted and actual expenditure, as implementation included LV reticulations.

Furthermore, a total of 70 Localities were electrified, but not included as part of the 2005 REDMP. These Localities were mainly funded by the EIB, and account for approximately N$ 59m of the total expenditure.

5.2.2 Deviation from the Plan

Based on actual expenditure, it is clear that insufficient funding was available for electrification of all 501 Localities, as planned in the 2005 REDMP. This resulted in the phased implementation of electrification projects, where the MV supply section was built in one financial year, and the LV connections were added in the following financial year.

Based on the results illustrated in Figure 3, Section 5.1, it would also seem that the national and regional rural electrification priorities were not aligned with those on which the planning was based. The reasons for such departure could include that the point score system was not reflecting the actual needs on the ground, or that external pressures to electrify certain Localities ahead of the proposed plan were becoming important.

5.2.3 Considerations for the 2010 REDMP Study

In order to address the discrepancy between budgeted and actual cost, the annual implementation cost and budget baseline need to be linked. As described under Costing in subsection 6.2.6.2, the input costs used to compute the estimated national and regional budgets in the 2010 REDMP Study are based on the regulatory NENA (Namibian Electrical Network Assets) register, which the ECB updates on a regular basis. This ensures that current unit rates are used for budgeting purposes, and also provide a method for retaining the relevance of costs during future REDMP updates and reviews.

To date, there has been no method to systematically update or adjust the REDMP on an annual basis, as circumstances or priorities change. In order to address this aspect, the 2010 REDMP develops a priority model (as described in detail in Section 6.2.6) to accommodate annual updates, and enable adjustments of the priority point scores. However, the model is only the tool used to derive a revised master plan, and still requires regular input in regard to the actual implementation that has taken place, so as to ensure an optimised output plan going forward. Annual updates also allow for the regular updating of budgets, based on latest rates as per the NENA database.

6 APPROACH AND METHODOLOGY

The purpose and aim of the Rural Electricity Distribution Master Plan (REDMP) is to provide the framework for the systematic long-term electrification of rural Namibia.

This section describes the process and methods that were developed to establish this framework for the next 20 years.

6.1 Overview

Relevant and up to date data was collected to spatially present the entire study area, as well as capture all attribute data relevant to rural electrification. In the process, a comprehensive Geographic Information System (GIS) database was established. Here, Esri's ArcGIS was chosen as the preferred platform, because of the ability to geographically reference and display datasets for further manipulation and management of the network planning process. All Government buildings and homesteads were identified, and consequent Localities for electrification defined.

Once the GIS database had been verified, an iterative network planning phase commenced. Network extensions and upgrades were planned for the electrification of all identified Localities. The sequence in which these Localities were to be electrified, as well as the associated costs for the grid connections, was determined using the purpose-built priority model. An output of this planning phase included the manual identification and listing of Off-Grid Localities for inclusion into an Off-Grid Master Plan. The most probable future scenarios were developed through demand forecasting and load flow studies to ensure the adequacy of the planned electricity networks for the next 20 years. The need for network strengthening was identified where required.

Optimised, annual electrification programmes, including costing of projects, for each of Namibia's 13 regions were developed. If implemented as projected, the implementation of the REDMP will ensure that national electrification targets can be met while remaining within forthcoming annual electrification budgets. It is therefore also essential that the REDMP is regularly reviewed, and updated where necessary. A section is included which highlights the importance of monitoring the progress as electrification projects are implemented in the coming years.

The Study concluded with the development of a financial model and economic assessment to analyse the impacts of implementing the proposed electrification programmes as foreseen by the REDMP.

6.2 The REDMP Development Process

6.2.1 Geographical Information System (GIS) as Management and Planning Tool

GIS was used as the platform to manage the data that was collected, but also as a planning tool in the REDMP review process. This tool therefore forms an integral part of the present study. GIS is designed to capture, analyse, manipulate, manage and display all forms of geographically referenced data. It allows the user to view, create interactive queries, interpret and visualise data in many ways that reveal relationships, patterns and trends. Output can be in the form of maps, globes, reports and charts. These are important features for purposes of the present REDMP.

As a planning tool, the GIS was primarily used to:

- capture homestead locations using orthophoto imagery
- identify and map all Government buildings
- create the Localities (electrification buffers with optimised potential transformer position)
- build an accurate spatial representation of the existing electrical networks (substations, transmission and distribution networks and transformer points)
- execute the network planning to all Localities identified for electrification
- create load zones to forecast demand
- model the networks by way of load flow studies
- capture and export the regional infrastructure, network and points, and Locality database files for prioritisation, and
- visually inspect the prioritised network building sequence to ascertain the planning logic and (where relevant) reveal network connection errors.

6.2.2 Data Acquisition

Having access to and working with an accurate database is one of the most important aspects when undertaking planning. The entire study is built on and developed from this consistent data platform. It is therefore crucial that a solid, consistent and verifiable platform is established. Due to numerous studies and electrification projects in recent years, large amounts of data pertaining to demographics and rural electrification in Namibia already exist. In using these, it was important to verify the datasets as far as possible and update if and where required. Here, regular in-depth consultation with the relevant stakeholders was essential. In addition, field surveys were conducted in selected areas, to supplement and validate datasets.

To a large extent, the data that was gathered during the study was collected with the aim of building a GIS database. Here, orthophoto[8] imagery and existing GIS spatial datasets were used as far as possible. Further mapping of structures was done through manual digitisation, based on actual data acquired during field surveys. In addition to creating the necessary databases to comprehensively capture and display demographic and network realities, the GIS system was also used for load forecasting. Data required for the load forecasting process included attribute data, in addition to the geographical data already mentioned.

Datasets used for the load forecast include:

- demographic data (e.g. population information)
- topographic information (e.g. roads, contours, nature reserves)
- cadastral data (e.g. land and farm boundaries)
- electrical data (line routes, substation locations, etc.)
- electrical connectivity (how loads summate to higher level network equipment)
- customer data and consumer load profiles
- billing information
- load readings (data, load loggers)
- growth rates and saturation loads
- projected population and load growth curves, and
- saturation ADMD per homestead.

The main datasets used during the REDMP study (and for creation of the GIS database) include:

- cadastral (information on town and town land boundaries, communal land boundaries and commercial farms) to determine which areas are to be included and excluded in the REDMP Study
- high-resolution orthophoto aerial imagery for identification and mapping of relevant infrastructure, such as Government buildings and homesteads
- spatial data of the existing electrical networks and transformer points
- demographic information to determine where people live and what the probable future growth trends are, as well as what the associated increase in electricity demand will be
- operating drawings for the electrical networks and latest metre readings if available (to determine base loads), and

[8] Ortho refers to images that have been corrected geometrically to ensure that the scale is uniform. Orthophotos can therefore be used to measure true distances between points, as they are an accurate representation of the Earth’s surface.

- digitised field survey data.

The orthophoto imagery was supplied by the Ministry of Lands and Resettlement and the National Planning Commission (NPC). As mentioned, high-resolution imagery is essential for proper identification of structures (especially in rural areas where buildings and homesteads tend to be smaller). The following imagery, as shown in Figure 4, was obtained and utilised:

- SPOT 2.5 meter pixel-resolution natural colour imagery as supplied by the NPC (acquired for purposes of the 2011 national census); year of photography 2010
- Orthophoto 1.0 meter natural colour imagery from 18°30' to 21° latitude as supplied by the Ministry of Lands and Resettlement; year of photography 2008, and
- Orthophoto 0.5 meter natural colour imagery of the Khomas region as supplied by the Ministry of Lands and Resettlement; year of photography 2009.

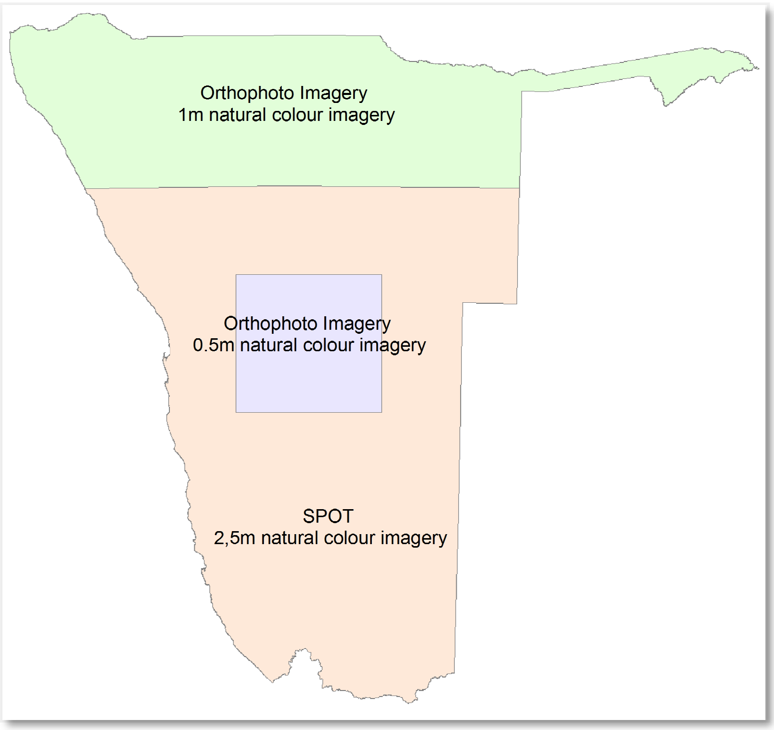


Figure 4: Orthophoto imagery used in the 2010 REDMP Study

The following GIS spatial layer data that was used was supplied by Geo Business Solutions, the NPC, RAISON and NamPower:

- up to date cadastral datasets by Geo Business Solutions
- provisional infrastructure spatial data as captured for the 2011 Census by the NPC
- data on schools by RAISON, and

- electrical networks including substations, transmission and distribution networks and transformer points from NamPower, including datasets for the CENORED and Erongo RED distribution areas.

Ancillary datasets, as supplied by the Ministry of Lands and Resettlement and Geo Business Solutions, included the locations of police stations, telecom transmitters, DART stations, Agri DVS offices, large irrigation schemes, quarantine facilities, regional stores, seed selling centres, veterinary services, airports, health centres, roads and 1:50,000 and 1:250,000 GIS spatial data.

Apart from the datasets that were gathered, a detailed field survey of the distribution networks and transformer points in the entire NORED area was completed at the end of 2010 (as part of another study). The survey data was digitised and used to verify, and in some cases replace, the existing GIS spatial base layer for the northern regions.

6.2.3 Creating the GIS Database

In ArcGIS, spatial and attribute data is stored in tables as part of a geo-database. The system is a collection of various types of GIS datasets that are held in a file system folder.

The base layer for the identification and counting of Government buildings and homesteads was created using the orthophoto imagery and existing GIS spatial data obtained from the various sources as described in Subsection 6.2.2. The mapping was done through image interpretation and manual digitisation of the structures.

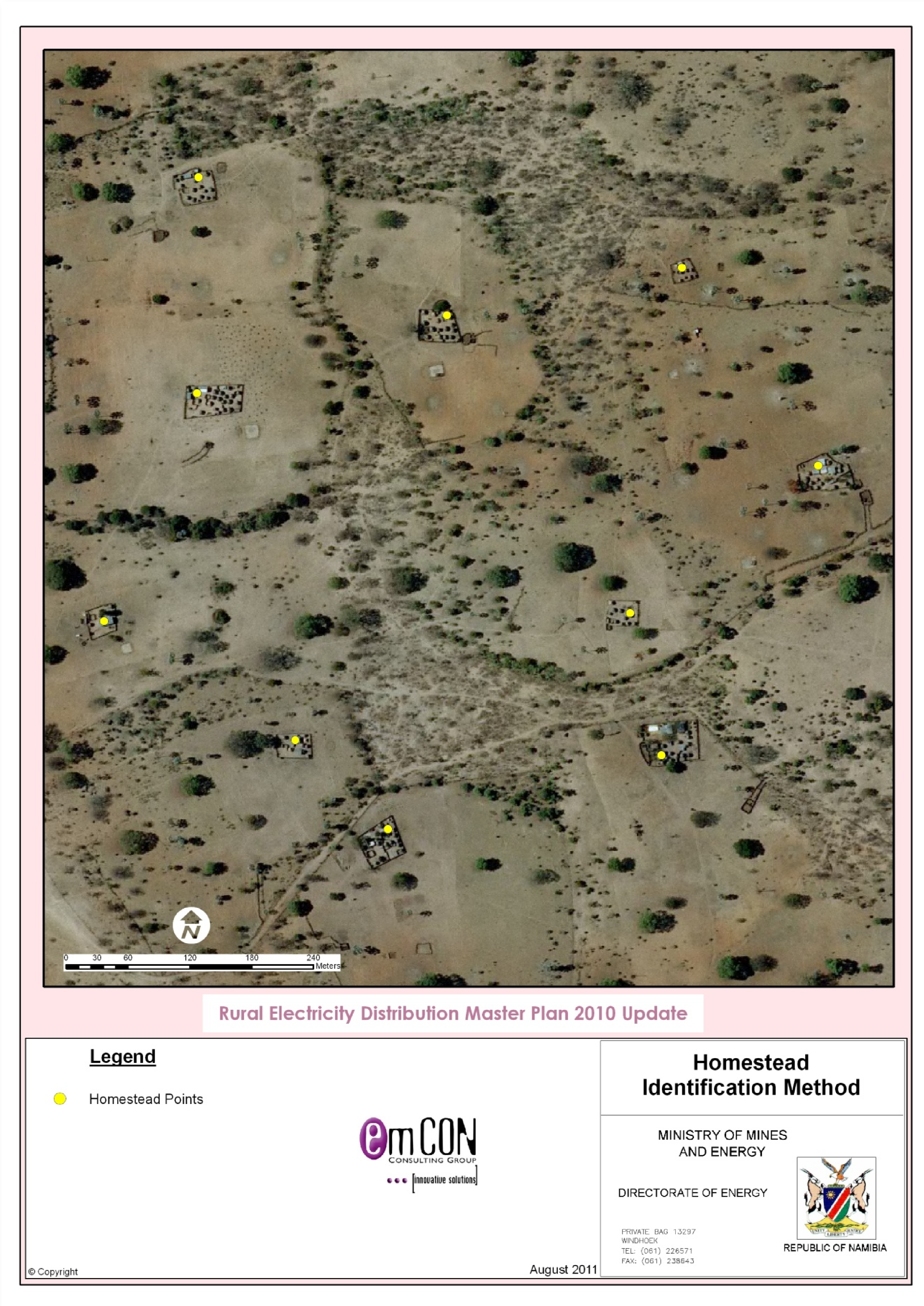
Different user classes were defined through the capturing process, including:

- Homesteads
- School buildings
- Health Centres
- Hospitals
- Clinics
- Health outreach points
- NamPost offices
- Colleges
- Mines
- MTC sites
- Government buildings
- Telecom transmitters
- Police stations
- DART station offices
- Unclassified commercial buildings
- Large irrigation schemes
- Quarantine facilities
- Regional stores
- Veterinary service offices
- Airports
- Communal land boundaries

All homesteads and individual building structures around small settlement areas were mapped by points. Communal land boundaries were mapped by polygons. The mapping and classification was done through image interpretation. The 2011 Census dataset as supplied by the NPC was used to verify the names of Localities and serve as supplementary data in the classification process. Rules to ensure the consistency of data points were developed.

The existing homestead points layer as supplied by the Ministry of Lands and Resettlement was also incorporated into the database. These points were overlain onto the SPOT 2.5 meter pixel-resolution image, and where new homesteads were found to exist, their capture posted to the database. As can be seen from Map 17, the mapping was done with points placed at the location of larger buildings (if these existed) within the homesteads.

The end result was an accurate geographical representation of the entire Study area and relevant features. While network planning was undertaken for the defined Rural Areas only, the capturing of relevant attribute data and mapping of structures was done for the entire country.



Map 17: Homestead identification method and mapping, REDMP 2010

6.2.4 Identification of Localities for Electrification

Localities[9] having one or several Government buildings were automatically included for electrification, while Localities without Government buildings were included for electrification if they included a minimum of 10 homesteads within a 500 meter radius. Using these inclusion criteria, some regions were found to have a large number of Localities that qualify for electrification. Therefore, the selection criteria was adjusted by way of a manual filtering process, which lists the largest Localities per constituency (a minimum of at least 20, if they exist). This additional criterion ensures that, as far as technically possible, at least one Locality per constituency per year is electrified for the duration of the entire 20-year REDMP implementation period.

Localities first had to be defined in the GIS, before filtering those that qualify for electrification. All identified homesteads and building structures were mapped as points, to create representative Locality points based on their spatial location.

An electrification buffer with a radius of 500 meters (as GIS polygon feature) was introduced to cluster points, so as to represent these as a single point, i.e. Locality. A specialised GIS script was applied to optimise the clustering process. Points that were closer to each other than the specified electrification buffer were converted to a single point, and the attributes representing the original cluster were saved under the new point created in this way.

The clustering process is illustrated in Figure 5. Note that even if only a single structure was found within the electrification buffer, it was converted to a representative point. These points do however not fulfil the second pass criteria of having at least 10 homesteads within a 500 meter radius (if the point is not a Government building).

[9] Refer to Subsection 2.4 for the definition of a Locality.

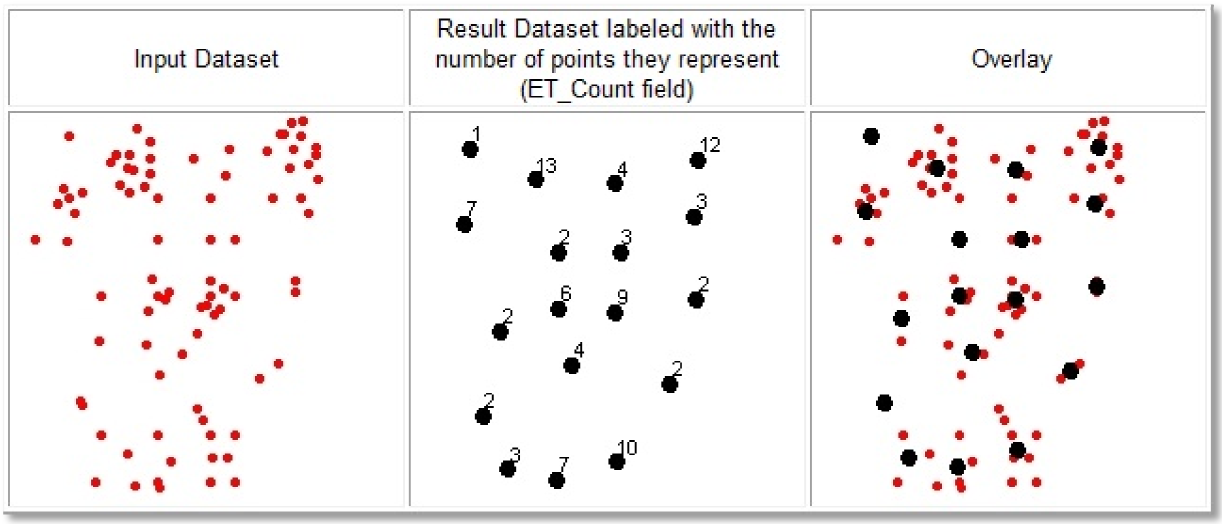


Figure 5: Illustration of the GIS clustering script used to create Locality points representing clustered dwelling- and structure points

All Localities with Government buildings and 10 or more homesteads were then identified for the entire country. Due to the large number of Localities and the fact that economically it becomes less viable to electrify every single one, a manual iterative process was used to identify the largest Localities as well as all Localities that contain Government buildings (essential Localities to electrify). This filtering process was applied down to constituency level, to ensure that each constituency has at least 20 Localities that includes all Government buildings.

Figure 6 is an extract of a table that is based on the above filtering process. It shows the number of Localities that were identified per region as well as on constituency level, and the selection criteria that were applied to select the largest Localities which are to be electrified.

Region	Constituency	Total Localities with 1 and more homesteads	Localities with less than 10 homesteads	No. Of localities between 10 and 19 homesteads	No. Of Localities between 20 and 29 homesteads	No. Of localities with 30 and more homesteads	Total Localities Identified for Electrification (homesteads & Government)	Selection Comment
Oshana		2268	1362	574	222	110	248	Cut-off for final locality selection was 20 homesteads and more
	Okaku	231	35	113	62	21	44	
	Okatana	278	147	75	41	15	26	
	Okatyali	174	151	17	3	3	17	Cut-off for final locality selection was 10 homesteads and more
	Ompundja	249	217	26	4	2	22	Cut-off for final locality selection was 10 homesteads and more
	Ondangwa	151	25	66	41	19	28	
	Ongwediva	172	35	79	34	24	39	
	Oshakati East	143	65	56	17	5	20	Cut-off for final locality selection was 10 homesteads and more
	Oshakati West	125	101	17	5	2	15	Cut-off for final locality selection was 10 homesteads and more
	Uukwiyu	268	136	106	13	13	21	Cut-off for final locality selection was 10 homesteads and more
	Uuvudhiya	477	450	19	2	6	16	Cut-off for final locality selection was 10 homesteads and more
Oshikoto		5999	4917	856	126	100	334	
	Engodi	1636	1518	99	12	7	73	Cut-off for final locality selection was 10 homesteads and more
	Guinas	546	434	86	13	13	32	Cut-off for final locality selection was 20 homesteads and more
	Okankolo	986	947	27	6	6	31	Cut-off for final locality selection was 10 homesteads and more
	Olukonda	185	114	54	6	11	24	Cut-off for final locality selection was 20 homesteads and more
	Omuntele	699	591	85	15	8	71	Cut-off for final locality selection was 10 homesteads and more
	Omuthiyagwiipundi	725	545	143	19	18	0	Cut-off for final locality selection was 10 homesteads and more
	Onayena	329	219	90	13	7	63	Cut-off for final locality selection was 20 homesteads and more
	Oniipa	325	125	157	25	18	20	Cut-off for final locality selection was 20 homesteads and more
	Onyaanya	568	424	115	17	12	20	Cut-off for final locality selection was 20 homesteads and more
	Tsumeb	0	0	0	0	0	0	Only localities located within communal land was considered

Figure 6: Tabulated representation of the filtering process to identify Localities for electrification, REDMP 2010

6.2.5 Network Planning and Modelling

The network planning process was developed to ensure that the targets and priorities for rural electrification, as defined by the MME, are met. An important aspect of master planning is also to ensure that industry standards in respect of existing load, future load forecasts and reliability requirements are achieved. Simulations were used to assess the ability of the existing and planned network infrastructure to meet these standards.

Network planning allows the planner to anticipate how much power must be delivered, as well as where and when it will be needed. Fundamental to distribution master planning is a structured medium- to long-term load forecast. This provides the prediction of future electrical demand in terms of the location, the magnitude and the temporal (time) characteristics. Planning should look as far ahead as possible, to ensure that the planning required for generation, transmission, sub-transmission, reticulation and demand side options is adequately integrated, and that the expansion of networks and the utilisation of assets are and remain optimised.

6.2.5.1 Network Planning Process

The flow chart in Figure 7 shows a schematic representation of the REDMP network planning process that was followed in this Study.

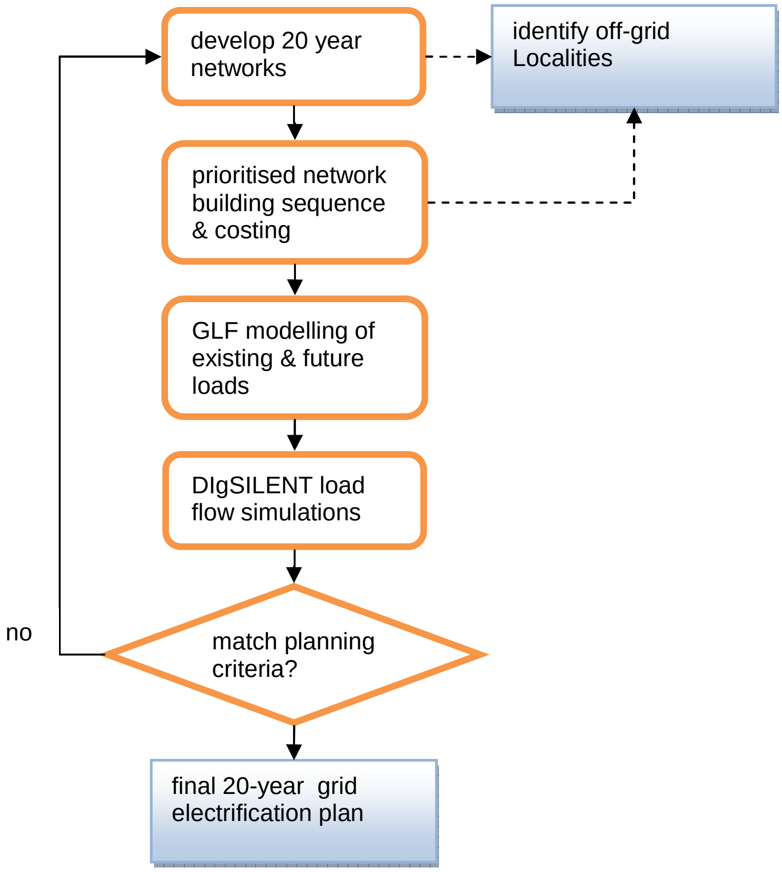


Figure 7: Iterative network planning process, REDMP 2010

The iterative network planning process starts with the development of the 20-year networks to all Localities that qualify for electrification. Here, ArcGIS provides an effective planning method through its geographical representation of existing networks as well as the location of Localities to be electrified. The distribution networks were extended to these Localities based on the specified guidelines (e.g. the preferred reticulation voltage, etc.), and captured in GIS. New lines were planned directly to Localities that include Government buildings (and more specifically schools), and from these lines t-off to other Localities on route.

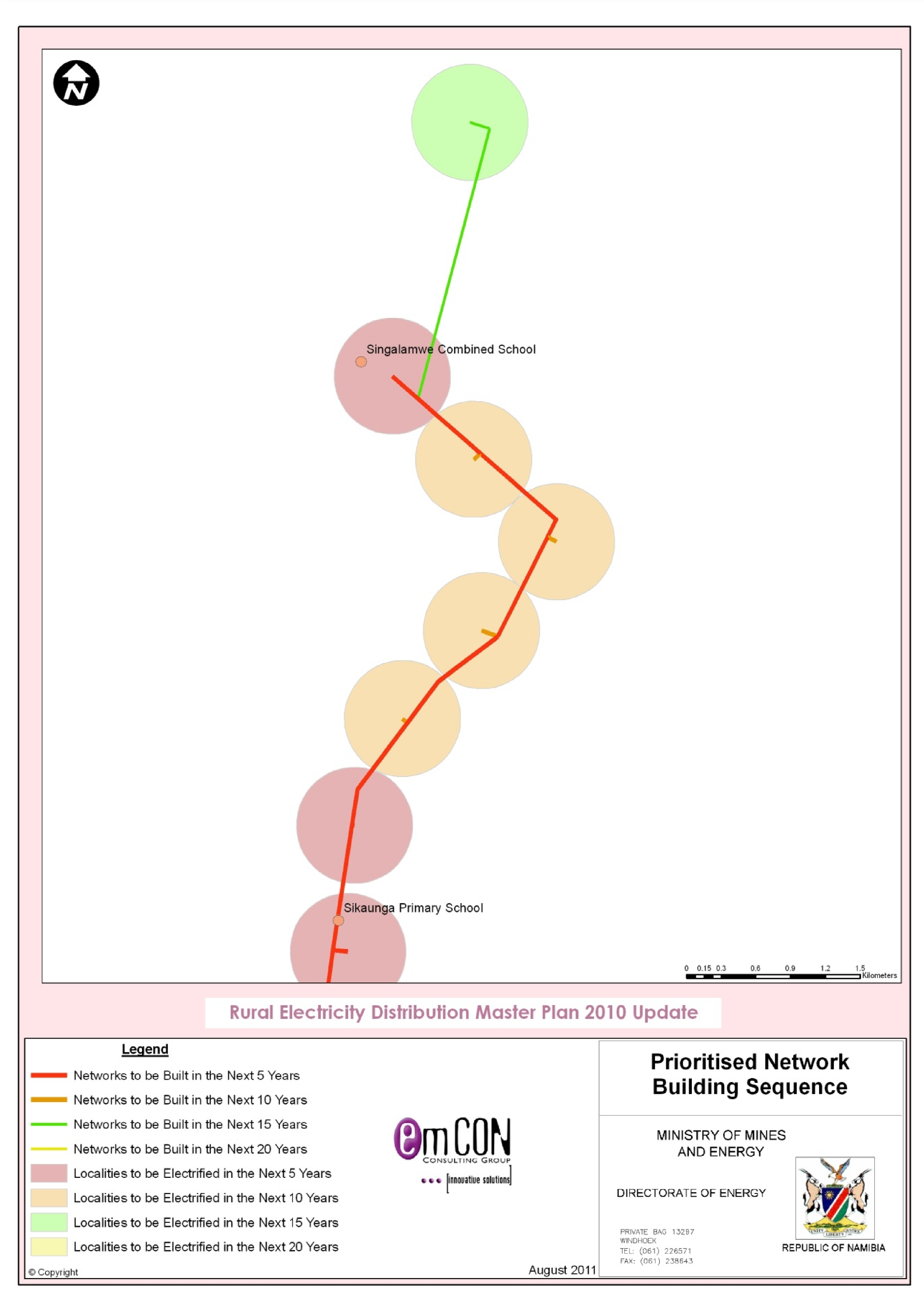
The 20-year networks were then fed as GIS database files into the priority model. The model determines the sequence in which Localities are to be electrified, based on the priority ranking obtained from the Locality point score and cost of electrification. Spatial and attribute datasets for the most cost-effective building sequence were imported back into the GIS, and visually checked for connection errors.

A Geographical Load Forecasting (GLF) model was set up to accurately present existing base loads and the network hierarchy ('connectivity'). The model takes into account the consumption and growth patterns of different customer types. Future customer loads were added to the network as inputs from the priority model (which provided information on the year of electrification as well as customer type). Spatial load zones to represent the base and future loads were created, and assigned as load portions to the GLF network summation hierarchy. Scenarios were developed to accurately simulate the most probable future circumstances. Once the model was complete, a load forecast for 20 years was run to determine the adequacy of network equipment to supply the long-term demand. Network strengthening (e.g. upgrade substation installed capacity) was proposed where and when required.

Apart from forecasting the total expected system consumption, the GLF load zones with its load portions were linked for the creation of a representative DIgSILENT model, to conduct further load flow studies. PowerFactory DIgSILENT simulations include scenarios for considering under- and over-voltages, in accordance with the ECB quality of supply code, as well as feeder and substation loading and reactive compensation requirements for long lines. This allows the network planner to make informed decisions in how best to strengthen the network and ensure its stability for the next 20-year period. In cases where network upgrades were required to strengthen network sections or a substation on the network, these changes were again captured as attributes in the relevant GIS datasets, and the entire network planning process was re-run before the 20-year electrification plans were finalised.

To illustrate the planning process, a section of new network to be built is shown in Map 18. Localities that contain Government buildings were prioritised based on the point score system. For the particular section shown in Map 18, two schools were identified, and both of these will be electrified within 5 years. If these were the only Localities the power line would have been planned straight to the Localities that contain the schools. However, due to the presence of other lower ranked Localities along the route, the planned line deviates to accommodate these Localities, even if they are only added to the network after 10 years. This process ensures that the electrification planning process is optimised and eventually includes all Localities.

The manual process to determine which Localities to classify as Off-Gird is described in Subsection 6.2.5.2. The guidelines followed to plan new networks is presented in Subsection 6.2.5.3, followed by an overview of the DIgSILENT simulations that were run to analyse the network stability for the planned 20-year networks (Subsection 6.2.5.4). A detailed description of the priority model as well as costing is presented in Section 6.2.6, while the development of the 20-year load forecast is described in Section 6.2.7.



Map 18: Illustration of the prioritised network building sequence to a Government building, REDMP 2010

6.2.5.2 Off-Grid Localities

Subsection 6.2.4 describes how Localities that qualify for electrification are identified. Localities include all points with Government buildings as well as the largest Localities to allow that a minimum of one Locality per constituency is electrified per year for the next 20 years.

This set of Localities were then modelled for technical compliance and priority. The modelling output was analysed for low priority as well as Localities that have technical and financial constraints (e.g. very remote with disproportionate cost, exceeding the load capacity of distribution lines, natural boundaries that prohibit construction, minimal Localities benefit along the route). Localities facing such financial or technical constraints were then earmarked for Off-Grid electrification. A detailed list of these Off-Grid Localities is presented in Section 7.4.

6.2.5.3 Technical Guidelines

The master planning guidelines were developed in consultation with key stakeholders within the energy sector, including MME, NamPower and the REDs. For further reference, these technical guidelines are included in Appendix A.

6.2.5.4 Network Modelling

The PowerFactory DIgSILENT software application integrates the functionality for modelling and the analysis of power systems. For purposes of the REDMP, the software was used to create a representative model of the existing and planned distribution networks, and also to determine its stability through load flow simulations.

The network simulations were performed to comply with the ECB's quality of supply standards.

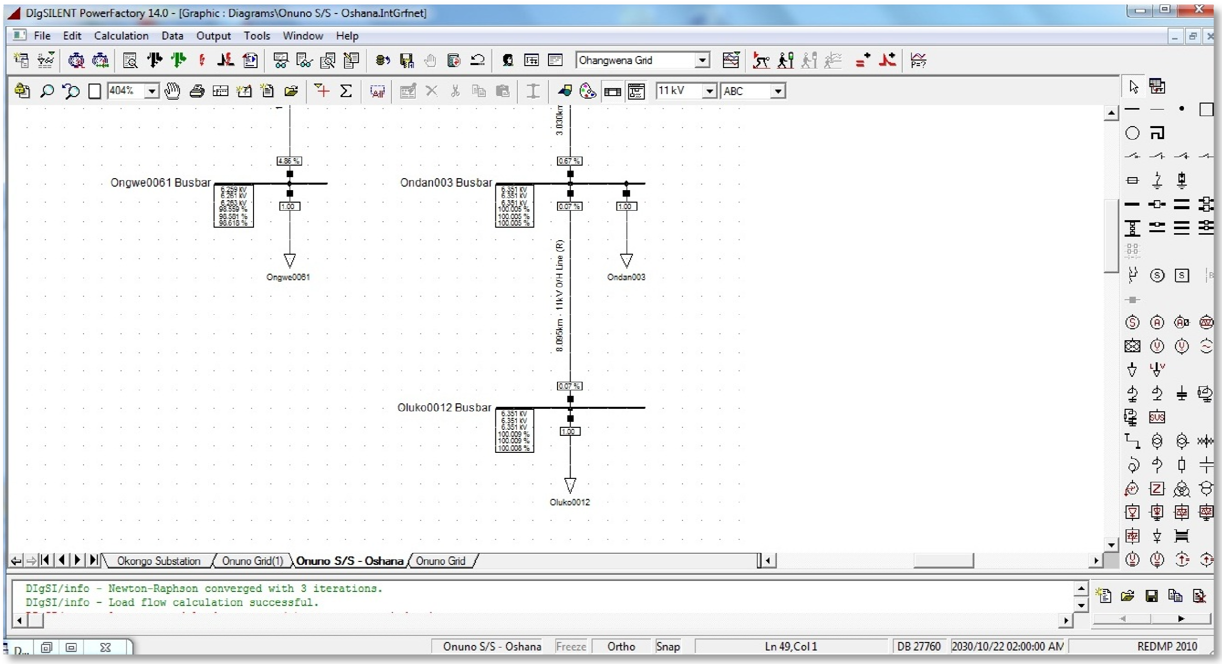


Figure 8: DIgSILENT busbars to represent GIS and GLF load zones

Busbars to represent the spatial GIS and GLF defined load zones were firstly created and linked to the GLF application. All busbars were further connected based on the network summation hierarchy, as defined in the GLF application (Figure 8).

A comprehensive power system library (Figure 9) was compiled to include all required network components (e.g. transformers, line and load types, tower models, etc.) to accurately model the entire distribution network.

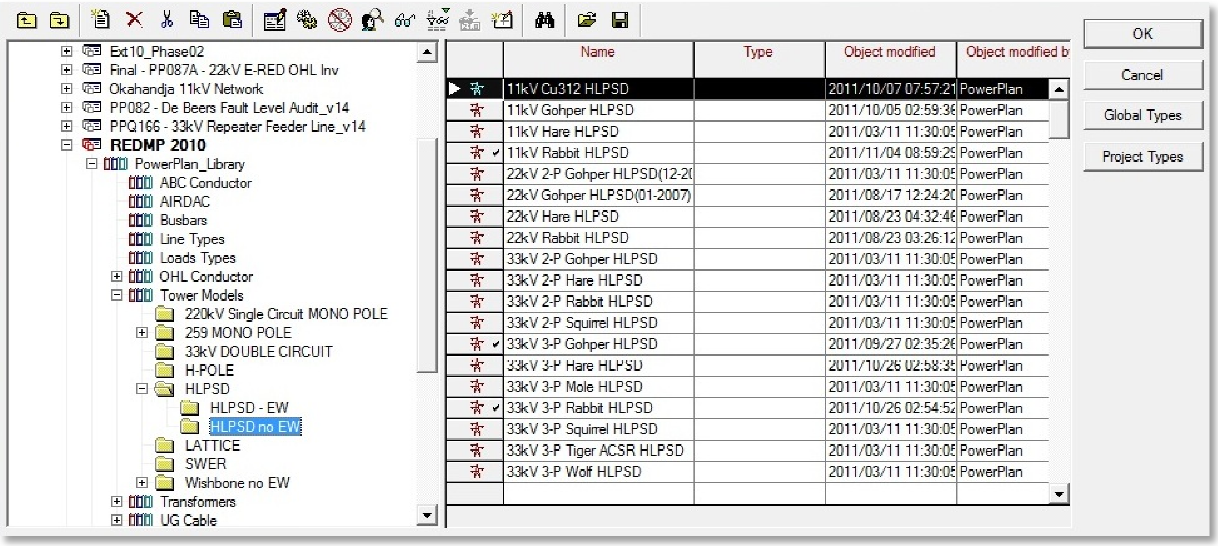


Figure 9: DIgSILENT power plan library of system components

Data exchange links were created between the GLF defined load zones, associated load portions and the DIgSILENT busbars, as can be seen in the highlighted export link in Figure 10.

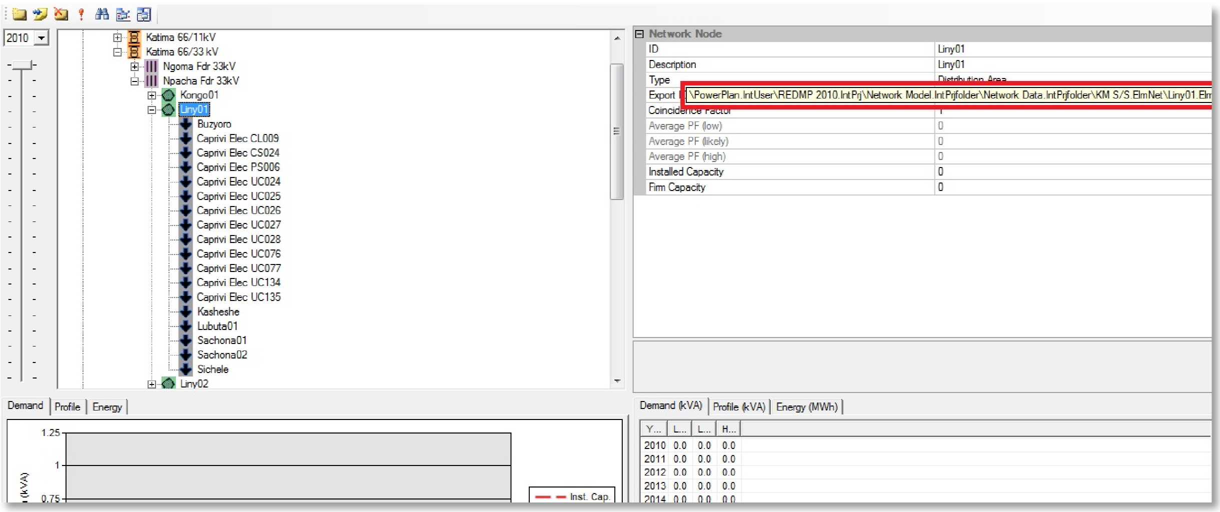


Figure 10: PowerGLF data exchange export link to DIgSILENT

All existing loads are attached to the busbar that represents a specific load zone. Load characteristics can be defined on a per element basis, and are time dependant. Future loads were therefore defined and triggered by the year in which new customer loads are added to the network. An in-depth simulation was run for each of the 20 years in order to determine the technical suitability of planned network extensions, and identify any areas where network strengthening is required as new loads are added. Scenarios that were considered include:

- Under- and over-voltages

- feeder loading
- distribution and bulk supply transformer loading, and
- reactive compensation for long lines.

Different colours are used in DIgSILENT to flag if and where any of the above conditions exist, e.g. line voltages that are outside the allowable range, transformer loading that has exceeded the installed capacity, and others. This is shown in Figures 11 and 12.

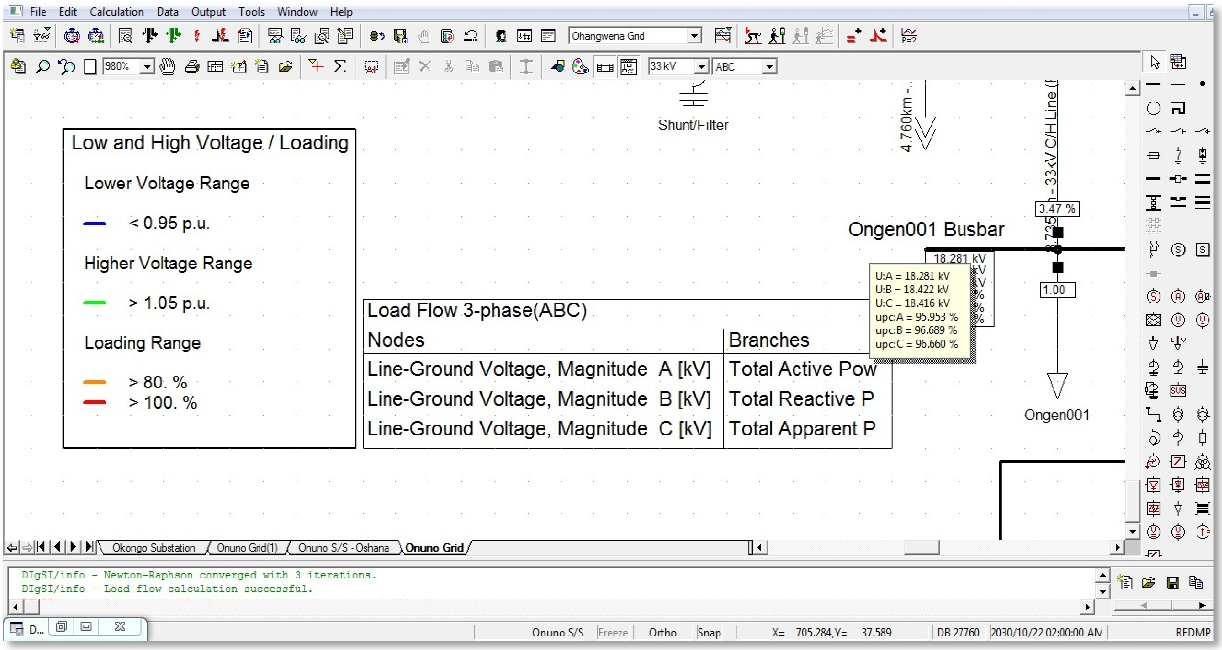


Figure 11: Colours used to indicate under & over voltages and loading level, DIgSILENT

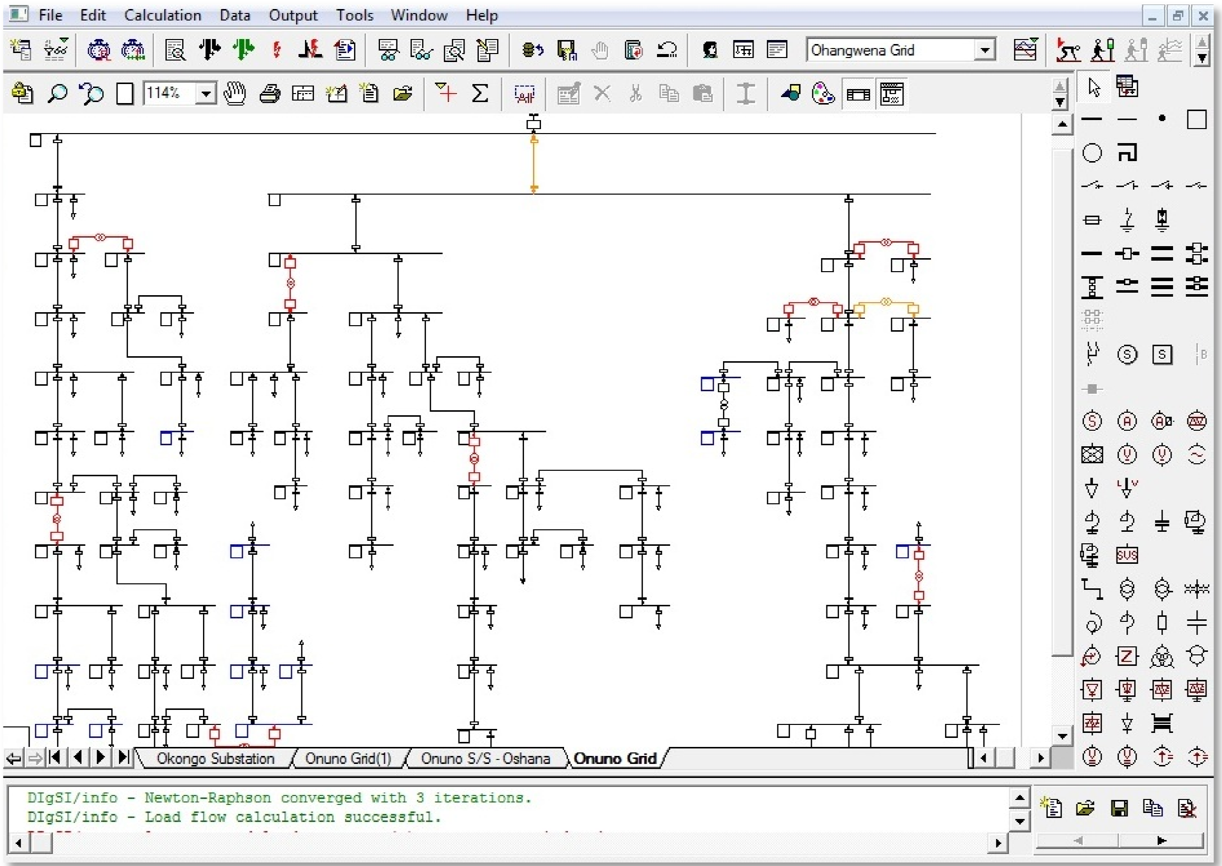


Figure 12: Problem areas highlighted during load flow calculations, DIgSILENT

The planning process allows the network planner to determine when to strengthen or upgrade which sections or components of the network, to ensure that stability is achieved throughout the 20-year master planning period.

Where required, the upgrade of a network line type and other methods to strengthen the network were captured before the network planning process was repeated in order to determine whether the priority ranking of a Locality was affected by the network changes. Once this was done, the simulations were re-run to ensure that the problem was resolved.

6.2.6 Priority Model and Costing

The purpose of a priority model is to have a systematic and objective method that determines the optimal sequence in which the identified Localities are to be electrified in the 20-year REDMP horizon. It is based on the principle of determining the most effective electrification sequence, and to expand and develop networks in order of their relative priorities as determined in the REDMP. The priority model is completely automated.

The priority model developed for this REDMP accurately reflects the priorities defined by the MME, and seeks to optimise the results based on the resources that are invested to create new electrification infrastructure. An important aspect of the priority model is that it needs to be adaptable, as regular updates will most likely be required in future, due to changing circumstances and priorities throughout the 20-year implementation period envisaged by the REDMP.

The need for an objective approach to the prioritisation of rural electrification projects is an essential building block of the REDMP, and ensures that all identified Localities throughout Namibia are considered on equal basis. Before this important aspect of rural electrification had been identified and addressed, the prioritisation process was often determined by socio-political factors, and was influenced by a lack of financial and skilled human resources, a lack of clarity in regard to the roles and responsibilities of the public sector and the wider electricity distribution industry, and limited knowledge about rural homestead income and energy use patterns.

6.2.6.1 Prioritisation

The Localities that have been identified for electrification are prioritised based on their total point score. This score gives an indication of the relative importance of a Locality in relation to others, as well as the estimated total cost of supplying a Locality with a grid connection.

$$Priority\ Ranking\ =\ (Points/Cost) \times 1000$$

The process of establishing the network building sequence is further driven by design considerations, as defined by the MME, as well as ensuring that the resulting electrification plan is cost-effective.

The points score system presented in Table 9 defines the various infrastructure types as well as its associated point scores for various infrastructure elements. The total points score per Locality is derived through summation over all applicable infrastructure elements. It is noted that the point scores were left unchanged from previous REDMPs.

Table 9: Infrastructure Points Score

Infrastructure Description	*Points*
Educational	
- Sr. Secondary school (11 & 12)	60
- Jr. Secondary school (8 - 10)	55
- Combined school (P & S)	50
- Sr. Primary school (5 - 7)	40
- Jr. Primary school (1 - 4)	30
- Primary school (1 - 7)	40
- Private school	50
- Hostel	60
- College	60
Health	
- Hospital	80
- Health centre	60
- Clinic	40
- Health outreach point	20
Other	
- Constituency capital	80
- Agricultural development centre	60
- Agricultural extension office	20
- Borehole	5
- NamPost	15
- Homestead	1
- Other Government building	20
- Unclassified commercial building	1
- Police/Military	30

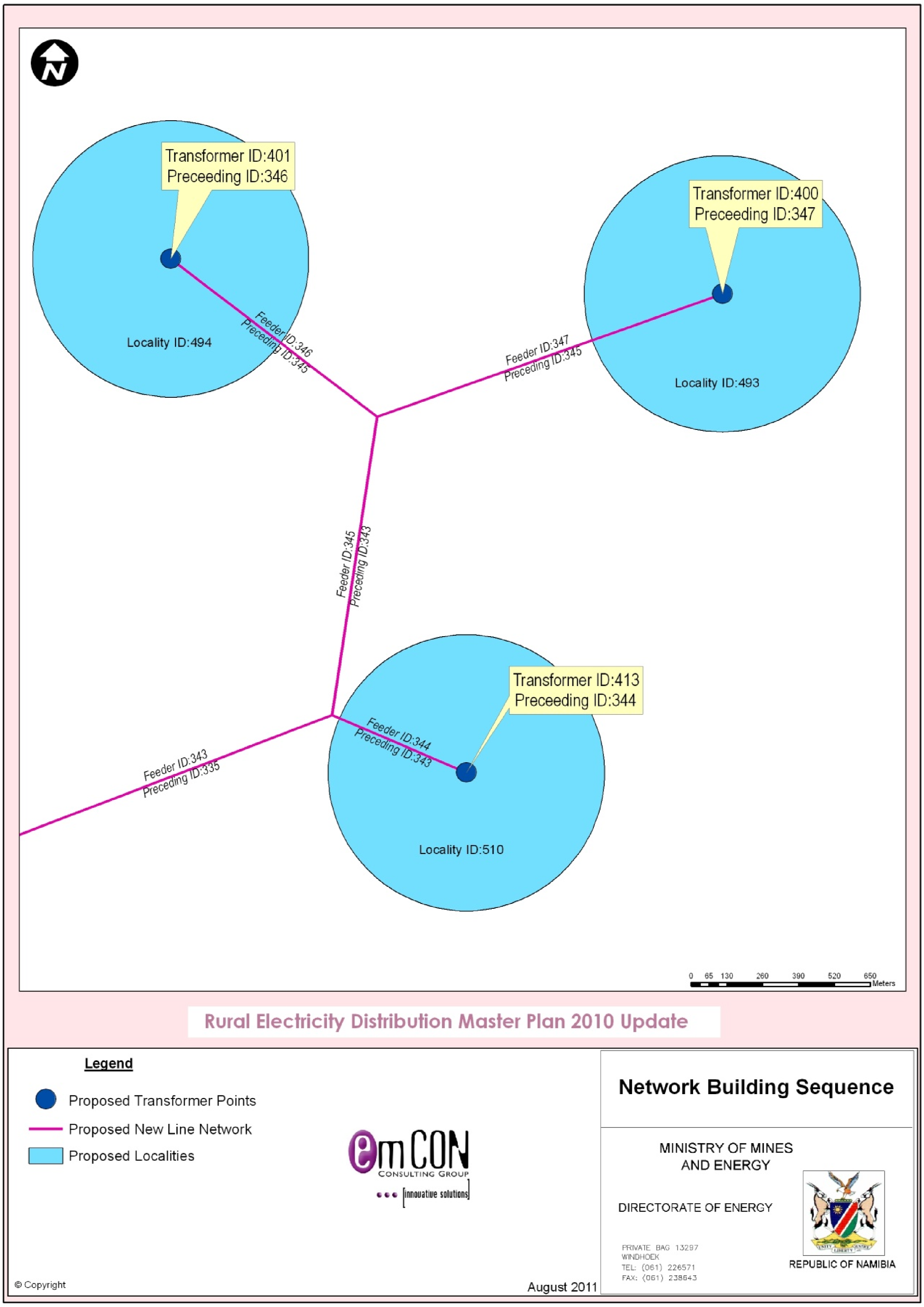
The priority model for the 2010 REDMP update was built and validated based on the agreed[10] modelling method of electrifying all identified Localities in the next 20 years. This overall design objective was refined to ensure that:

- as far as technically possible, at least one Locality per constituency per year will be electrified, and
- regions (and consequently constituencies) will only form part of the electrification programme up until all identified Localities per region have been electrified (even if this is before the end of the 20-years REDMP time horizon).

[10] As per the decisions taken at the technical clarification meeting, held at the MME on 22 September 2011.

After running the prioritisation model, the output files detailing a prioritised sequence in which networks are to be built in future are visually inspected in the GIS to identify connection errors or inconsistencies. Map 19 illustrates the building sequence determined by the prioritisation model.

The budget required for the annual electrification programmes is computed by the prioritisation model. It is noted that the method applied in this REDMP differs from the algorithm used in previous studies, which provided a predetermined budget as input parameter.



Map 19: Network building sequence determined by the priority model, REDMP 2010

An overview of the most important building blocks of the prioritisation model is given in Figure 13, where the dotted arrows indicate optional functionality. The model was developed to be flexible in terms of certain key aspects, and as such, has built-in optional functionality including:

- an available selection option to prioritise only Localities that contain Government buildings while rejecting Localities that have been defined based on the 10-homestead criteria, and
- an option to compute the budget required versus one which uses a given budget.

As mentioned, for the 2010 REDMP update the model is configured to prioritise all Localities identified for electrification, and compute the annual budget required for this purpose.

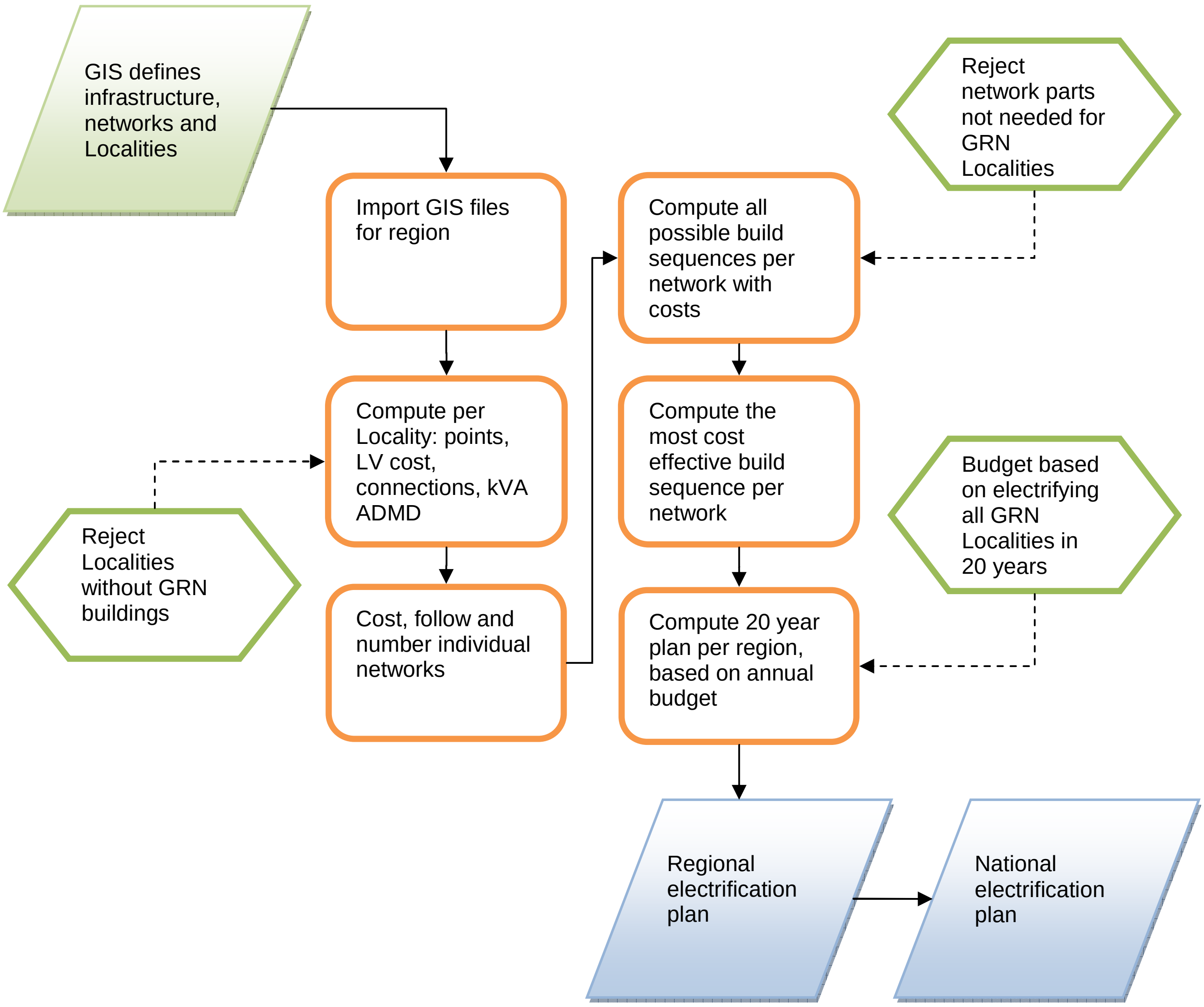


Figure 13: Overview of the priority model, REDMP 2010

An optimised annual electrification programme and associated national budget and budget for each region constitutes the main output of the prioritisation model, and includes information on

- all names of Localities to be electrified
- associated electrification costs
- number of homesteads, schools and other infrastructure connected
- transformer capacity added
- distance in kilometres of electrical network added
- estimated cost per connection, and
- the energy consumption added.

An example of the proposed electrification programme for the Epupa Constituency in the Kunene Region is shown in Figure 14, with the different columns containing the information described above.

Namibia REDMP

Locality Plan by Region and Year for Region: Kunene

Constituency: Epupa

Year	Locality	Network	Cost	Points	Priority	House holds	Schools	Must Elec's	Total Connect	Cost / connect	Line km	ADMD	Total Trfr kVA	kWh p.m.
2012	Ehomba03	695	519 849	38	0.0730980	38			38	13 680	0.630	29	50	3 800
2012	Omuangete	688	178 607	48	0.2687460	8	1	1	9	19 845	0.450	21	25	2 800
2012	Okoupaue	694	209 472	41	0.1957300	1	1	1	2	104 736	2.170	16	25	2 100
2012	Ovituambu	778	152 513	45	0.2950570	5	1	1	6	25 419	0.560	19	25	2 500
2012	Otjitanga01	698	249 220	53	0.2126640	3	1	1	4	62 305	5.880	17	25	2 300
2012	Ombandaondu	778	338 683	33	0.0974360	3	1	1	4	84 671	3.880	17	25	2 300
2012	Okarukoro	711	488 740	61	0.1248110	21	1	1	22	22 215	2.370	31	50	4 100
2012	Orue01	697	71 218	40	0.5616560		1	1	1	71 218	0.340	15	25	2 000
2012			**2 208 302**	**359**		79	7	7	86	25 678	16.280	164	250	21 900
2013	Oroutumba01	699	638 550	38	0.0595100	38			38	16 804	5.160	29	50	3 800
2013	Okatutura02	706	219 765	13	0.0591540	13			13	16 905	0.610	10	25	1 300
2013	Otjimuhaka01	699	266 701	16	0.0599920	16			16	16 669	1.990	12	25	1 600
2013	Okatutura01	706	819 884	49	0.0597650	49			49	16 732	3.120	37	50	4 900
2013	Ehomba04	696	351 618	23	0.0654120	23			23	15 288	0.960	17	25	2 300
2013	Omumbonde	692	190 422	13	0.0682690	13			13	14 648	0.140	10	25	1 300
2013			**2 486 940**	**152**		152			152	16 361	11.980	114	200	15 200
2014	Ruiter02	691	239 014	13	0.0543900	13			13	18 386	0.910	10	25	1 300
2014			**239 014**	**13**		13			13	18 386	0.910	10	25	1 300
2015	Orue02	698	274 916	12	0.0436500	12			12	22 910	3.980	9	25	1 200
2015	Ombaka	689	946 674	40	0.0422530		1	1	1	946 674	14.100	15	25	2 000
2015	Otjikuina	693	414 171	17	0.0410460	17			17	24 363	3.010	13	25	1 700
2015	Okahozo	694	1 357 974	62	0.0456560	22	1	1	23	59 042	16.060	32	50	4 200
2015			**2 993 735**	**131**		51	2	2	53	56 486	37.150	68	125	9 100
2016	Oruseu	689	492 727	40	0.0811810		1	1	1	492 727	6.860	15	25	2 000
2016			**492 727**	**40**			1	1	1	492 727	6.860	15	25	2 000

Figure 14: Prioritised electrification plan, Priority model 2010

6.2.6.2 Costing

The input costs used to compute the estimated national and regional budgets are based on the regulatory NENA (Namibian Electrical Network Assets) register as at 2011 level. The software provides a systematic approach to costing by defining common asset categories and assigning unit values to asset types within these categories. These values represent total costs and include all material, transport, labour and engineering fees associated with the installation and commissioning of the specified electrical asset types (and are therefore expressed either as per unit or per kilometre length costs). It was initially developed in 2003, and the NENA database has since regularly been updated by the ECB, based on actual construction costs and subject to the input from major distribution companies in Namibia.

The total cost estimate per Locality is the sum of the individual component costs for

- the Medium Voltage (MV) line from an existing grid connection point to the specified Locality
- step-down transformer costs, and
- the cost of the Low Voltage (LV) services within the Locality, up to and including the consumer connection.

Excluded from the costing (and therefore the estimate annual budgets) are

- upgrades of the transmission- and distribution substations, as determined from the 20-year load forecast
- upgrades and network strengthening to meet quality of supply standards, as identified from the load flow studies (e.g. the installation of voltage regulators and reactors).

Costs associated with the planned MV line extensions were determined from the NENA asset types used to define individual line segments. The total value computed captures all relevant costs, including the type of conductor and structures required per kilometre of line that is to be built.

Transformer options (i.e. asset types) that were considered include those required for the various MV lines (11, 22 and 33 kV as well as the 19.1 kV SWER), but with ratings of only 25 and 50 kVA (and 16 and 32 kVA for SWER). These transformers and NENA unit costs are shown in Table 10. The principle applied was to rather have a number of smaller transformers installed, as opposed to a single large transformer, to supply the required demand. In this way, the overall availability of network services can be improved, especially when technical problems associated with a specific transformer occur.

Table 10: Transformer unit costs for 11, 22, 33 and 19.1kV lines

Transformers	*NENA unit costs [N$]*			
Line Voltage [kV]	11	22	33	19.1 (SWER)
Rating 25kVA; 16kVA (SWER)	44,700	46,400	58,200	43,100
Rating 50kVA; 32kVA (SWER)	49,000	57,400	64,500	50,500

The installed transformer capacity that is required depends on the total estimated demand for each Locality. An ADMD (After Diversity Maximum Demand) value was defined for each of the infrastructure types included in the point score system. These ADMD values, together with information on the components and costs associated with an LV consumer connection, are shown in Appendix B. Through summation of all the identified infrastructure elements within an electrification buffer forming the Locality, the total ADMD is determined.

The prioritisation model follows the logic as presented in Tables 11 and 12, namely to first determine the combination of transformers that are required to supply the Locality, and subsequently calculate the total cost from the specified NENA asset types (Table 10 summarises the relevant unit costs).

Table 11: Transformer logic for 19.1kV SWER lines

ADMD [kVA]	*Installed capacity required [kVA]*	*Transformers [unit]*
< 16	16	16kVA
< 32	32	32kVA
< 64	64	32kVA + 16kVA*2
< 128	128	32kVA*2 + 16kVA*4

Table 12: Transformer logic for 11, 22 and 33kV lines

ADMD [kVA]	*Installed capacity required [kVA]*	*Transformers [unit]*
< 25	25	25kVA
< 50	50	50kVA
< 100	100	50kVA + 25kVA*2
< 150	150	50kVA*2 + 25kVA*2
< 200	200	50kVA*2 + 25kVA*4
< 250	250	50kVA*3 + 25kVA*4
< 300	300	50kVA*4 + 25kVA*4
< 350	350	50kVA*5 + 25kVA*4

The last cost component taken into account to determine the total cost estimate per Locality, is the cost associated with all individual LV consumer connections, and the individual segments that make up an LV service connection. As can be seen from Appendix B, NENA asset types were specified for the different LV infrastructure connections. These costs were then summed for each identified infrastructure element, as well as for all connections within a given Locality, to arrive at the total LV service connection cost.

6.2.7 Demand Forecasting

Demand forecasts provide the underlying data to test network capacities and accommodate load diversity. Demand is defined as the level at which electricity is delivered to end users at a given point in time, and is measured in volt-ampere (VA), which is the total power unit incorporating both active and reactive power. For the correct sizing of electrical infrastructure, including distribution networks, the electrical load is referred to as the capacity, and the highest demand which occurs is generally referred to as the peak demand.

The purpose of a geo-based load forecast (GLF) is to derive a realistic prediction of the electrical load for a supply area over a medium- to long-term period (in this case 20 years). Geo-based load forecasting is based on the principle that a geographic area is divided into homogeneous areas that relate to specific land use. For each of the areas, customers are described through their electrical requirements, by assigning specific consumption and typical growth patterns to an area. Demand forecasting is done for each of the areas. Computing the sum of a group of zones supplied by an electrical network gives an indication of the expected long-term demand requirements. It is to be noted however that GLFs do not provide a highly accurate future load forecast, but provide sufficient information to inform and support the network planning process.

Demand forecasts were undertaken using the PowerGLF application as a modelling tool, which uses load growth to forecast and model spatial growth (land use change, electric usage). This provides a strategic and realistic approach to long range forecasting, while also ensuring that the forecast can be used to justify electrification project. The model allows for multi-scenario development, which is useful because of the unpredictable nature of future events which influence the load forecast. By creating different future scenarios, the uncertainty in future load growth is modelled.

The various activities required to establish the load forecast can be grouped into two main parts:

- base load definition, consisting of all activities required to extract and manipulate data to be used to define the Study area and build a model that represents the current situation, and
- the development of a load forecast.

The base load definition is further grouped according to:

- different customer types, including the definition of consumption profiles and growth curves as well as the specification of different forecast parameters for the defined customers
- existing load identification to identify known loads in the Study area and zone the remaining areas into homogeneous load zones
- model setup, whereby load zones are classified according to their customer type and base loads, assigned for compilation of a model that accurately represents the real word such that the total base load computed corresponds to measured values.

Each of the above elements and how they relate to the 2010 REDMP are described in more detail in Subsections 6.2.7.1 to 6.2.7.3. Similarly, the forecast activities can be grouped to contain the activities required to compile the future vision of developments which will occur, and the calculation of the associated future load, as is further described in Subsection 6.2.7.4.

6.2.7.1 Load Identification and Zoning

Here, the objective was to identify the known loads within the Study area, and zone the remaining areas in a way that each zone represents a homogeneous land use for which a specific sub-class can be assigned. Zoning refers to sub-dividing the geographical study area into load zones with the objective of determining a total load for each zone and forecasting this load into the future.

Load identification and zoning was achieved through the definition of base load objects that form the buildings blocks for which the forecasts were prepared. A load object is determined by the granularity of the forecast, for example, it may represent a single customer, a group of customers, a specific area, town, substation and others. The forecast for the entire system is the result of the summation of the individual load object forecasts. In a geo-based forecast, these entities are usually based on geographic areas (load zones).

For the REDMP Study area, large power users (LPUs) were identified first. These mainly include small mining and NamWater operations, as well as large scale agricultural irrigation schemes. This approach reduces guesswork and minimises errors in the load allocation to smaller base load zones. Other specific base load zones and subsequent load objects that were created include towns and town lands (urban areas), as well as existing distribution areas and complete areas supplied by SWER networks. LPUs and towns were only included if these zones were supplied from distribution networks (in some cases NamPower supplies directly to these key customers).

In general, load zones essentially distinguish only between urban and more specifically rural land use, which is the focus of the REDMP. Load zones were selected to support future growth scenarios (i.e. the load zones itself cannot change its boundaries during the 20 years forecast). As such, these future changes were planned for in the base load zone set.

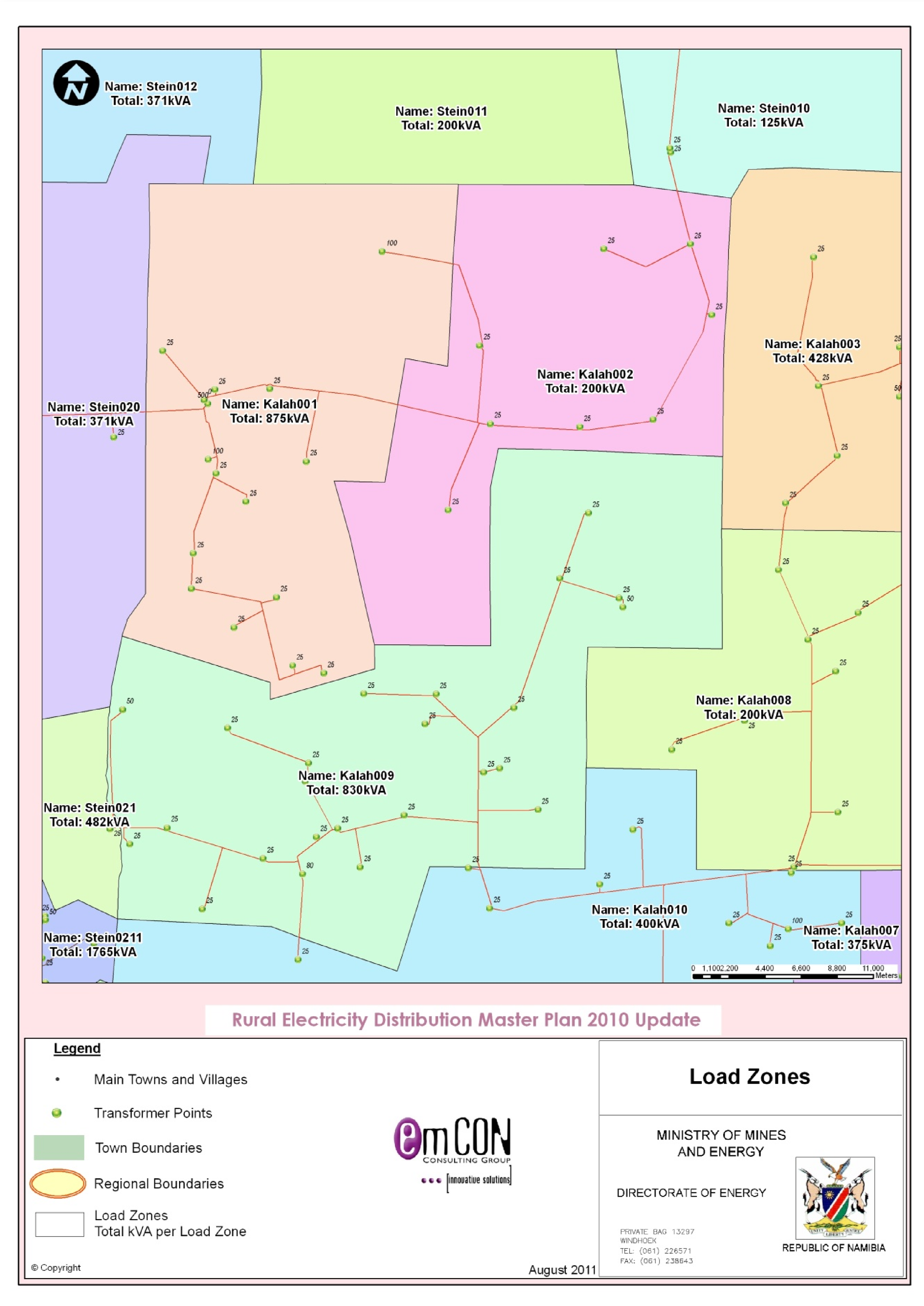
The load zones created for existing- and future distribution in rural areas were typically made up of multiple load portions, to describe the different sub-classes (e.g. rural homesteads, schools, clinics) of consumers living in these areas. The prioritised electrification programme was used when phasing-in the expected additional future loads.

The general rules that were applied during zoning include:

- all areas within the Study area were zoned (even if the contribution to the load is zero)
- zoning was done to accommodate the 20-year networks (as per master planning)
- load zones of roughly the same size were used to adhere to network equipment boundaries (loads calculated can easily be verified with known results), and
- load zones were created to follow regional and constituency boundaries.

The network summation in a load forecast represents how the load is aggregated to higher network levels (the load hierarchy to some extent represents the network connectivity). It can be described by a child-parent relationship; one parent can have many children, but a child can only belong to a single parent.

When zoning the area, network equipment (e.g. feeders) was kept in mind as a single load zone boundary should not span across multiple zones higher up in the network summation. Map 20 shows a plot of an area of load zones and their respective names as well as the feeders with information on the total installed transformer capacity per load zone (which was used to determine the contribution of individual load zones to the total load).



Map 20: Created load zones with feeders and transformer installed capacities, ArcGIS

6.2.7.2 Sub-Classification

Load zones are associated with a specific land use. The development of customer libraries includes the interpretation of socio-economic data, definition of growth curves and per unit consumption profiles, as well as specifying different forecast parameters for the defined customers. Customers were grouped, including residential, commercial, industrial and agricultural groups. Typical characteristics associated with customer classifications include:

- load profiles
- load saturation values (this attribute will give an indication of the saturation load to which the load of customers within this classification will grow, which is typically an ADMD per customer figure)
- consumer demand design parameters, and
- growth curves.

Daily load profiles and growth curves were created to describe all rural and urban customers. As an example, the daily load profile of a typical rural homestead during a 24-hour period, is shown in Figure 15.

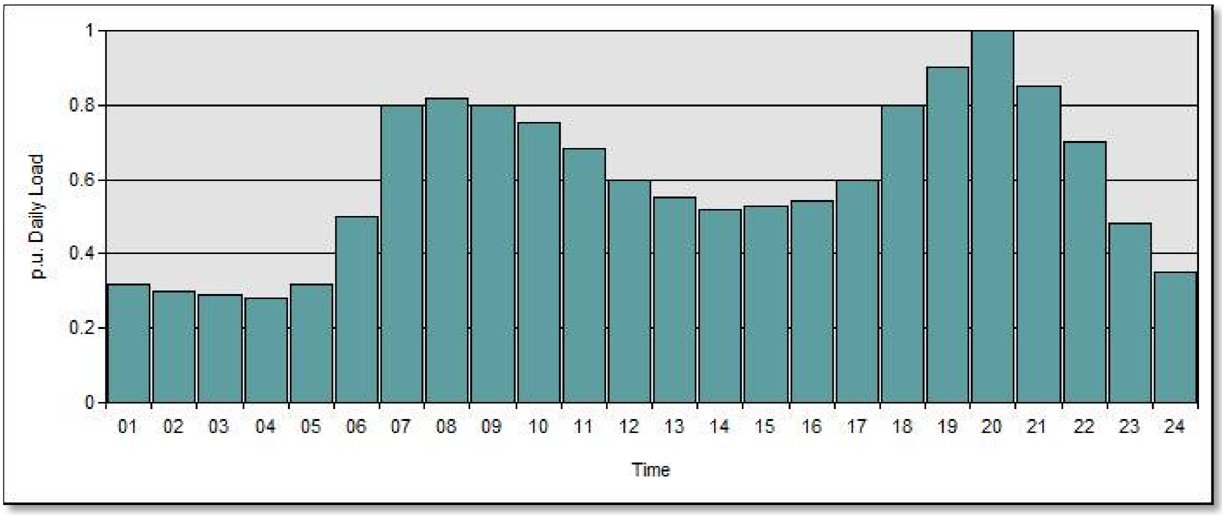


Figure 15: Daily load profile of a rural homestead, PowerGLF

For rural homesteads added as part of the prioritised electrification programme, a rural residential custom curve is defined to grow from an initial 0.5 kVA to a saturation load of 0.75 kVA in 15 years (shown in Figure 16).

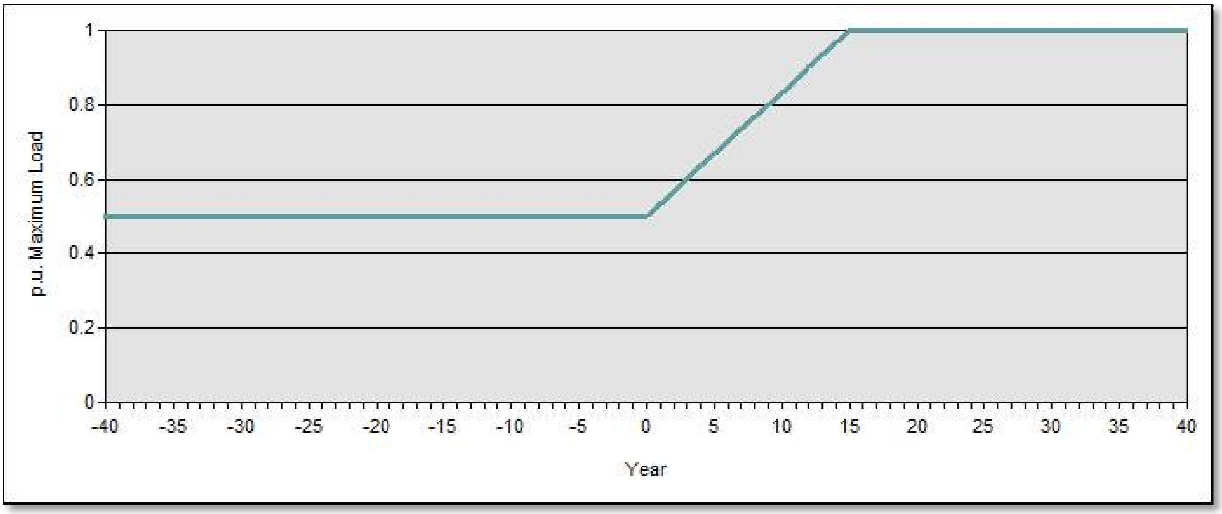


Figure 16: Rural residential custom growth curve, PowerGLF

Apart from defining the daily load profiles and growth curves, other forecast parameters that form part of the classification of customers, include load- and power factors, and the specification of the appropriate forecast methods. High load, most likely, and low load scenarios are also used to model the upper and lower limits of how loads are expected to grow in the future.

For purposes of this REDMP, the following forecast methods for existing and future customers were applied:

- Some of the Large Power Users (LPUs) identified for the REDMP indicated when their load would increase and by how much, which made it possible to manually specify future load values (no growth curve required);
- The future contribution of towns and town lands (urban areas excluded from the Study) as well as existing rural distribution areas on the total system consumption are forecasted using fixed percentages based on the regional population growth recorded during the 2006 Namibia Intercensal Demographic Survey (NIDS); and
- The future contribution of Government buildings and homesteads in Rural Areas (as per prioritised sequence) is forecasted based on the knowledge of how many new buildings and homesteads will be added to the network each year. Homesteads added starts off at year 0 on the individual growth curve and its contribution added to those of other homesteads which have progressed further along the growth curve as they were electrified earlier.

Sub-classes are therefore created to describe customers with similar consumption, behaviour and growth traits, and assigned to base load objects. For a more detailed description of how the customer libraries (sub-classification) for the REDMP Study were developed, refer to Appendix C.

6.2.7.3 Model Setup

Load zones are classified according to customer types and base loads assigned to individual zones. The network summation hierarchy is defined with load zones allocated to appropriate nodes, so as to have a model that accurately represents the real world (summated base loads correspond to measured values).

Essential data sources include the relevant network operating drawings and GIS spatial data, as well as load recordings (e.g. feeder data).

Having developed a library of sub-classes that describe the different customer types, the first step in building the model is to define the load objects that make up the individual load zones. Then, base loads are assigned to these base load objects, while the contribution of future loads is incorporated under the forecasting. Figures 17, 18 and 19 illustrate this process.

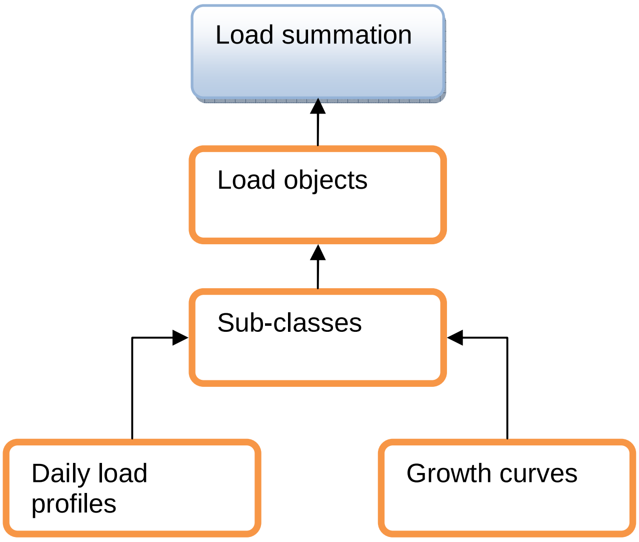


Figure 17: Customer load classification process, PowerGLF

Load Object	Forecast Results
Load Object	
ID	Amins015 Existing Load
Description	Amins015 Existing Load
Forecast Type	Load Based
Can be bulk scaled	True
Load Based Forecast	
Base year load	30
Short Term Parameters	
Sub-class	Distribution Feeder Omaheke
Load Factor	0.65
Power Factor	0.9
Load forecast method	Fixed %
Long Term Parameters	
Change-over year	2030
Sub-class	Distribution Feeder Omaheke
Load Factor	0.65
Power Factor	0.9
Load forecast method	Fixed %
Historical Load Data	
Year 2010	30
Year 2009	0
Year 2008	0
Year 2007	0
Year 2006	0
Year 2005	0
Year 2004	0
Year 2003	0
Year 2002	0
Year 2001	0
Year 2000	0

Figure 18: Load object defined for an existing load portion of the Amins015 load zone, PowerGLF

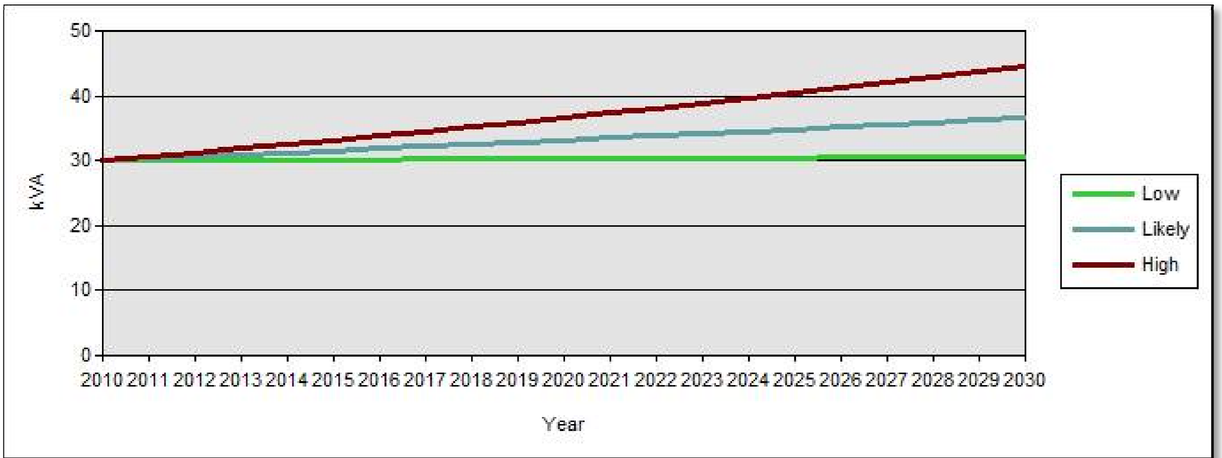


Figure 19: Base year actual load (for the existing load portion in the Amins015 load zone) forecasted for 20 years

The load summation hierarchy is used to compute the sum[11] of the load across the network components. The summation nodes are selected to represent real network components, where the summated load from the load forecast is compared with actual measured values.

Network operating drawings provided by relevant stakeholders (e.g. NamPower, REDs) are used to confirm these with the GIS spatial representation. The parent-child relationships which indicate how loads are to be summated are defined for all 13 regions in Namibia (Figure 20). Although this load hierarchy is integral to the load forecast and gives a view of the forecasted load at higher network levels, it does not include the actual forecasting.

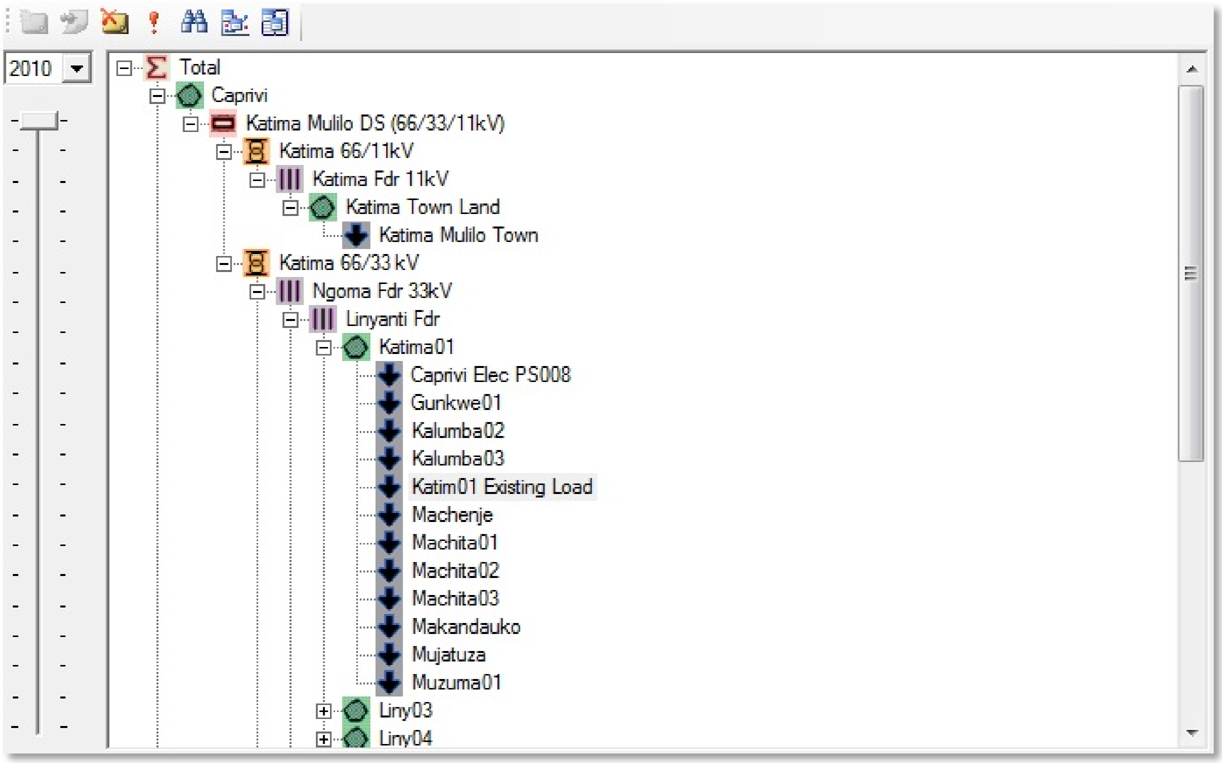


Figure 20: Section of the load summation hierarchy as defined for Caprivi, PowerGLF

The load forecast base year refers to the last year for which actual load values exist (in this case 2010). This base year actual load is one of the key parameters which influences the accuracy of the forecast. The following base load allocation method is used:

- Feeder data for all substations was obtained from NamPower, and assigned to the feeder zones to represent the base load at a known measured point;
- By assigning known loads (typically LPUs) to zones within the feeder area, the remaining load to be distributed to the rest of the load zones is calculated;

[11] This is a statistical sum which takes both real and apparent power into account.

- The resulting load is distributed proportionally between the remaining feeder load zones by calculating the percentage contribution of each. For rural land use areas this is done by looking at the estimated total installed transformer capacity of each zone to proportionally distribute the load; and
- Summation of the calculated base loads for each load zone on the feeder back to the first measured component (which in this case was the feeder zone) is used to verify that the measured value is reached.

6.2.7.4 Forecast

The base load forecast is expanded to include changes (if any) to land use and model new loads as the REDMP electrification programme progresses. This simulates how existing areas are expected to grow and develop into the future. The load forecasts available to load portions depend on how the sub-classes are assigned to the load portions.

The principles of forecasting and associated methods were described in Subsection 6.2.7.2. The application of these methods to specific customer types is described below. An overview of the process is provided in Figure 21.

- **Manual forecast**

  A manual forecast requires all future year load values to be specified. This method is used mainly for NamWater operations and agricultural development centres. Annual values for these load portions are entered manually from data that was provided by the respective LPUs.

- **Load based forecast**

  The fixed percentage forecast method applies a constant year on year percentage change to the base year load value to determine the forecast values.

  The fixed percentage load model is used to forecast future load levels of towns and town lands, as well as existing distribution areas. Growth percentages are specified on a regional basis (urban and rural), and were derived from the 2006 NIDS.

- **Customer based forecast**

  The customer based forecast models the load growth of individual customers. The number of rural Government buildings (e.g. schools, hospitals, clinics) and homesteads to be connected each year is fed from the priority model. The electrification forecast then uses the yearly connected infrastructure count and forecasts the load, based on the individual customer growth curve applied to the connected customers in the various forecast years. The forecast method utilises a per unit growth curve and saturation ADMD value per infrastructure type for each of the scenarios, as defined in the customer sub-class.

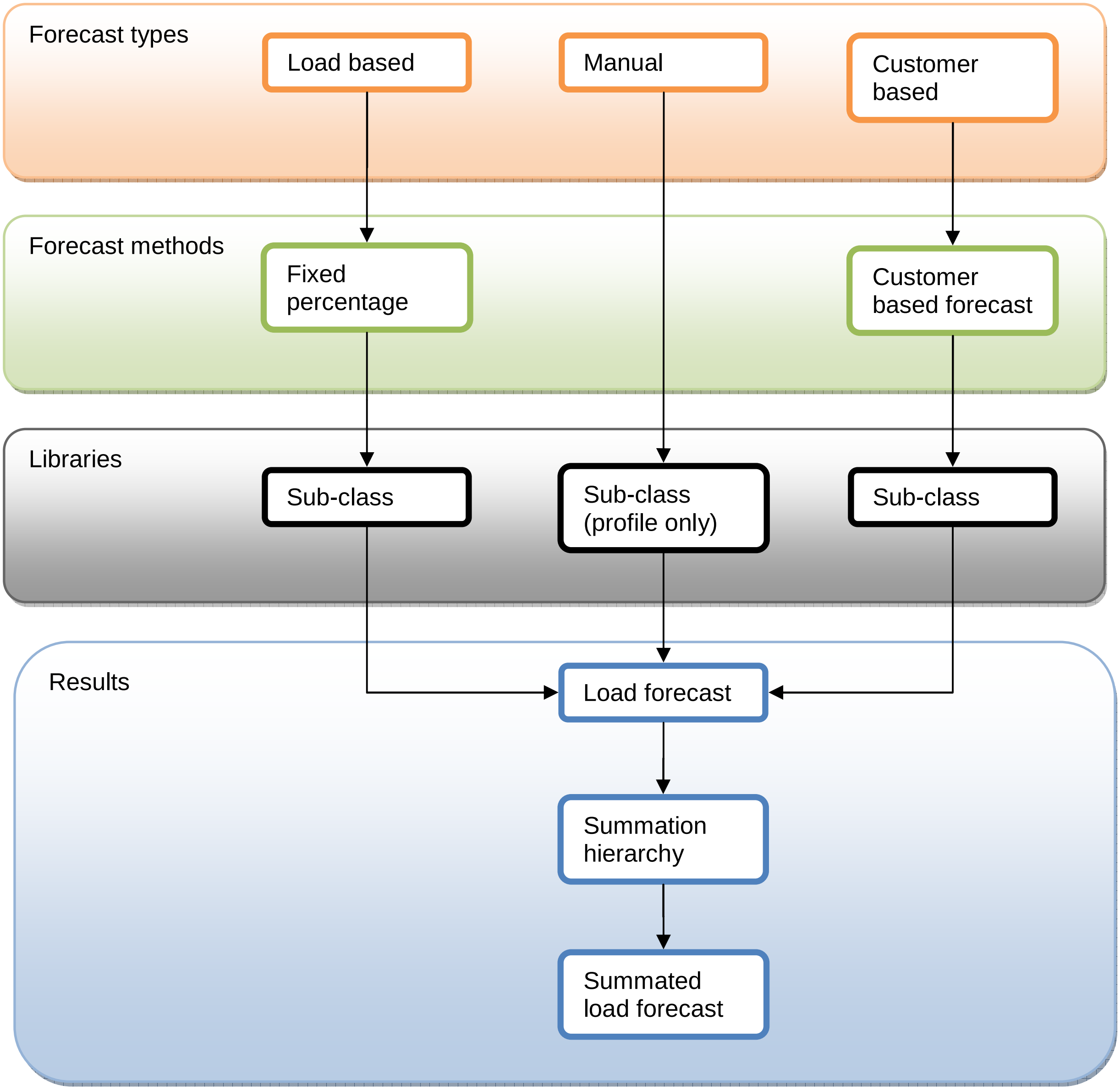


Figure 21: Load forecast process, PowerGLF

An example of a new rural school to be connected in 2012 is shown in Figures 22 and 23. This new load portion (that forms part of the Katim01 load zone) is described by the 'Rural School' sub-classification, that includes the unity growth curve as well as saturation loads of 10, 15 and 20 kVA that has been specified for the different scenarios.

Network Node	
ID	Caprivi Elec PS008
Description	Katim01
Type	Load Point
Export ID	
Exclude from Low Scenario	False
Exclude from Likely Scenario	False
Exclude from High Scenario	False
Average PF (low)	0
Average PF (likely)	0
Average PF (high)	0
Installed Capacity	0
Firm Capacity	0
Sub-Class	Rural School

Demand (kVA) | Profile (kVA) | Energy (MWh)

Y...	Lo...	Li...	High
2010	0.0	0.0	0.0
2011	0.0	0.0	0.0
2012	10.0	15.0	20.0
2013	10.0	15.0	20.0

Figure 22: Future load portion to be added to the network summation hierarchy in 2010, PowerGLF

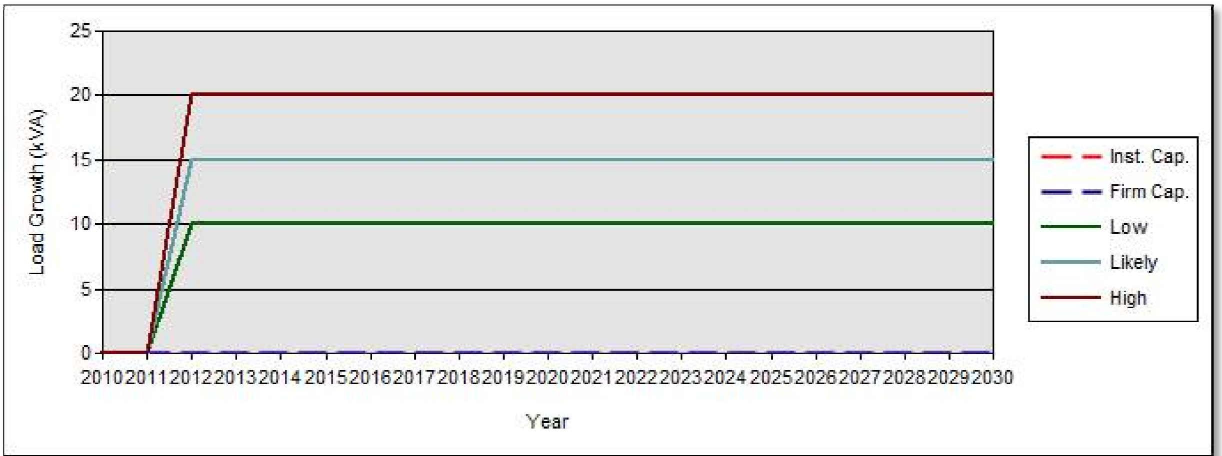


Figure 23: Customer based load forecast of the load portion from when it is connected in 2012, PowerGLF

Once all the existing and future load objects and portions for all load zones are defined and allocated to the network summation hierarchy, the future loads are forecasted for the 20-year period. These are then summed on a regional as well as national level (Figure 24).

Network load summation enables the planner to study the substation and feeder loading during the 20 years, make the necessary amendments to feeder supply points, and determine when a particular substation capacity requires upgrading, or when and where a new load centre is required.

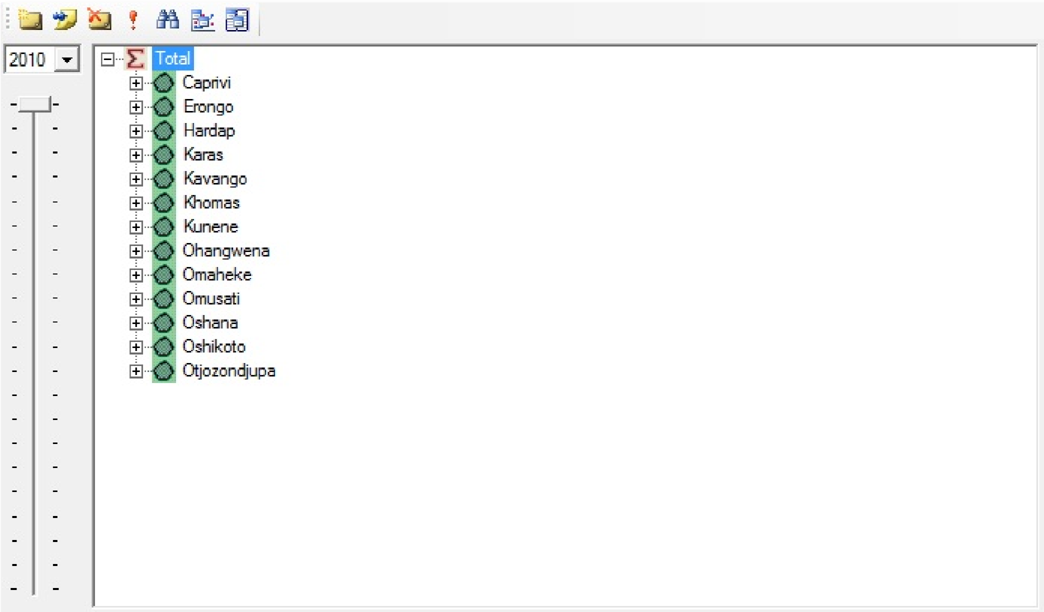


Figure 24: Total network summation hierarchy, PowerGLF

6.3 Special Cases and Assumptions

The general approach and methodologies developed for the REDMP process (as described in Section 6.2) is applied to all 13 regions in Namibia. Exceptions and additional issues, in the form of special cases and assumptions that were identified during the process, are covered in the individual regional reports, as and when these arise.

There are, however, practical issues and limitations that apply to all regions. These are therefore briefly discussed here.

6.3.1 Delays in Critical Data Collection

This section is included primarily as background, and to emphasise the importance of keeping relevant datasets updated and in one central location for easy access, as is discussed as part of the recommendations formulated in Section 8.

Significant delays in the provision of some of the critical datasets requested from relevant stakeholders were experienced. Table 13 summarises these requirements as well as reasons for the delays.

Table 13: Delays in critical data collection, REDMP 2010

Data requirement	*Stakeholder*	*Date requested*	*Date received*	*Reason for delay*
2010 colour orthophoto imagery	SG	16 Nov '10	05 Apr '11	Contract for release of the data needed to be drafted. Imagery for the central region was incorrect.
Updated schools dataset	NPC	16 Nov '10	15 Jul '11	NPC dataset only became available after internal processing and verification.
NPC/CBS GRN buildings dataset	NPC/CBS	16 Nov '10	19 Jul '11	CBS released data for Census purposes, after delays in internal verification of data.

In order to reduce the impact of the delays in acquiring the data, the Consulting Team, EMCON Consulting Group, in consultation with the MME, proceeded to procure data from other external parties, as well as mobilise additional resources that enabled tasks to be completed in parallel (rather than in sequence). If the work programme had not been re-aligned, the project would have been delayed by 5 months.

6.3.2 Transformer Rating Estimates

As-built drawings and operating diagrams from NamPower and the REDs are used to derive transformer ratings (i.e. installed capacities). This information is also captured during the field survey of the distribution networks in the NORED area.

In cases where definitive data for transformers could not be obtained (whether because of outdated as-built drawings and operating diagrams, or because of inaccessible areas due to floods in the northern regions), a transformer capacity of 50 kVA is assumed[12], or alternatively (if the 50 kVA is seen to be insufficient) an appropriate capacity based on the number and type of connections is used.

6.3.3 Networks that Cross Regional Borders

In general, when planning for the electrification of Localities, the closest grid connection points are used for the extension of the network. In some cases, mainly in the northern regions, these connection points are outside the regional boundaries in which the specific Locality is located (i.e. a feeder that originates outside the region, but as closest connection point, is extended to electrify a Locality across a regional border).

In such cases, apart from the fact that the connection is associated with a different region, all other electrification aspects are included in the region in which the Locality is located, including the electrification programme prioritisation, costs and associated budget.

6.3.4 Limitations of the REDMP

The prioritisation of Localities is an automated process. As such, it is not always possible to electrify (at least) one Locality per constituency per year. Even though the REDMP ensures that a minimum of 20 Localities (if they exist) are electrified per constituency during the 20-year REDMP period, there are circumstances in which a particular constituency will not necessarily have a Locality electrified each and every year. This is due to the precedence of other networks in the building sequence that first have to be established.

It is therefore likely that a particular constituency may not have any Localities electrified for two or three years, after which a few Localities are electrified in one year. Again, this is due to the fact that the networks are now much closer.

Although not strictly a limitation of the REDMP, it is re-emphasised that the identification of Localities for off-grid electrification is a manual process which requires the consideration of individual Localities. As stated before, Localities that become outliers because of a low priority ranking (in most cases due

[12] This is the most commonly used transformer capacity in rural areas.

to disproportionate electrification costs) or technical constraints, are generally earmarked for further consideration as part of an Off-Grid Master Plan.

6.3.5 Implementation Aspects

The 2010 REDMP envisions how and when rural areas will be electrified in the coming 20 years. It is a systematic and rational tool. If implemented as projected, the implementation of the REDMP will ensure that national electrification targets can be met while remaining within forthcoming annual electrification budgets. It is recognised that a major limiting factor of many plans is if they are not consistently implemented, or changed too often, or only partially rolled out. Therefore, fundamental to reaching the set targets as defined for rural electrification in the coming 20 years, is the assumption that electrification programmes can be followed and implemented properly, and in a timely manner. This will continue to be a challenge for the MME.

The purpose of developing the REDMP is to ensure that planning and electrification projects are justifiable and guided towards reaching the 20-year targets set. Through implementation of the programme, rural Localities are electrified in order of descending priority. This electrification priority ensures that the most important Localities, as determined through the point score system developed through stakeholder consultation, are electrified first, and that implementation takes place in an optimal and most cost-effective way. If electrification projects are therefore not implemented according to the set plans, targets will most likely not be met, and financial resources exhausted in achieving results that are not necessarily beneficial in terms of the defined national priorities.

Reasons why national plans such as the REDMP are not fully implemented may depend on several factors. Under Section 8, some of these practical issues and constraints are identified, and possible solutions are proposed.