Energy outlook for Mozambique 2012-2030 LEAP-based scenarios for energy demand and power generation

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Energy Outlook for Mozambique 2012-2030
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Mozambique has abundant and yet largely unexplored natural resources. For many decades the energy sector was characterized by decline, disruption and initial post-war reconstruction. This situation is now changing rapidly. The Cahora Bassa hydro dam (HCB) – with 2,075 MW is one of the largest hydropower installations in Africa; it has become clear that Mozambique has large sedimentary basins of natural gas: on-shore three large reserves of gas (in Pande, Temane and Buzi) have been discovered, and off-shore the Rovuma basin is now researched because of the probable existence of major gas and oil reserves. Over the last couple of years this has attracted substantial foreign direct investments in large energy-intensive industries as well as in the mining, exploration and transformation sectors. Several new large energy projects are planned or already under construction, including the construction of new hydro dams (Mphanda Nkuwa, Cahora Bassa North) and new power plants (Benga, Moatize, Moamba, Kuvaninga, Ressano Garcia). Paradoxically, despite Mozambique's abundant energy resources including the production of electricity, only some 18% of households have access to electricity. Challenges and strategies by which the energy sector can help to reduce absolute poverty and promote growth include the development of domestic infrastructure within and across regions, affordability of energy access across the country (cf Mulder and Tembe 2009), promotion and participation of the private sector in the energy sector, and reduction of environmental impact of non-renewable resources (cf. Prasad 2008, Winkler et al. 2011). This paper presents, for the first time, an integral and detailed insight in the (development of) the energy sector of Mozambique. The analysis makes use of LEAP, the Long range Energy Alternatives Planning System (Heaps 2012). Calibration of our model is based on a newly developed comprehensive database of the recent past (2000-2011) and the latest developments and plans as regards the production and transformation of energy in Mozambique. The paper gives a thorough overview of the Mozambican energy production and consumption patterns, including specific planning.

I. INTRODUCTION

Mozambique has abundant and yet largely unexplored natural resources. While the Cahora Bassa dam (HCB), with 2075 MW of capacity, is one of the largest hydropower installations in Africa, Mozambique could build another 5000 MW of hydropower. The country has large sedimentary basins of natural gas: on-shore reserves (in Pande and Temane) have been discovered and off-shore areas in the Rovuma basin is now researched and could contain more than 100 trillion cubic feet of gas.

Recently, massive deposits of coal in Tete province have been discovered, with an estimated size of about 23 billion tons. Its sustainable biomass and biofuels potential is untapped, with estimates of 30+ million ha. of arable land currently unused. Over the last few years this has attracted substantial foreign direct investments in large energy-intensive industries as well as in the mining, exploration and transformation sectors. Paradoxically, despite Mozambique's production of electricity, and in spite of considerable achievements by EdM (600 thousand new clients in 5 years) only some 15 to 20% of households have access to electricity. Like most of their African peers, Mozambicans are heavily reliant on non-commercial energy, or traditional forms of energy (biomass such as wood and charcoal). In its national strategy to combat poverty, the Government of Mozambique has identified the energy sector as one of the main areas for investment, notably foreign direct investment.

The country is on the brink of its industrial revolution[1], and it cannot develop without strengthening its energy sector. The challenges are enormous, and the choices to be made in the next few years will shape the Mozambique of tomorrow.

At the same time, in a country ranking 4th from bottom in Human development worldwide (UNDP), access to modern energy forms can be a major motor to lift the population out of poverty. Energy is therefore destined to play an increasingly important role in the economic development of Mozambique over the next decades.

Challenges and strategies by which the energy sector can help to reduce absolute poverty and promote growth include the development of domestic infrastructure within and across regions, promotion and participation of the private sector in the energy sector, and reduction of the sector's impact on environment, health and resources such as forests.

By 2030, urban population will have doubled, GDP per capita will have tripled, GDP could be multiplied by four, EdM will have three times more clients, 18 million people could still be reliant on biomass for their energy needs, there could be five times more cars as today in the streets, and Mozambique could be a worldwide top-five exporter of Coal and LNG.

[1] From "Mozambique, the start of the industrial revolution" Energia & Indústria extractiva, Jan/Mar. 2012

In an attempt to estimate the impact of these developments on the energy sector, this report presents a long-range scenario analysis for the Mozambican energy sector, based on long term energy demand analysis. It also looks at the energy supply options. The analysis makes use of LEAP, the Long range Energy Alternatives Planning System – an integrated modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy (Heaps, 2012).

The report considers likely scenarios for growth in energy demand through 2030, a study period sufficient to explore the efficacy of various energy technology investments and configurations of electricity supply and energy service distribution systems (beyond electricity) in satisfying demand. The forecast period also includes the anticipated surge in coal mining and gas explorations, and explores their potential impact on energy demand and their possible articulation with the current energy infrastructure of Mozambique.

To our knowledge, no integrated energy modeling and future planning study had been conducted as of date on Mozambique. Studies so far have considered adding new large loads on a simple top-down projection of EdM's peak load (Norconsult, 2011), or, limited by their purpose, have considered only the electric sector (Norconsult, Generation Master Plan, 2009) or limited themselves to assessing the current situation (Cuvilasa, Jirjisa, Lucas, 2009). The only comprehensive long term energy planning study for Mozambique so far (Mulder, 2007) was very rudimentary and included little sectorial disaggregation.

This Mozambique Energy Outlook presents, for the first time, an integral and detailed insight in the energy sector of Mozambique, based on a newly developed comprehensive database of the recent past (2000-2011) and the latest developments and plans as regards the production and transformation of energy in Mozambique. Our 2030 energy demand scenarios are based on a complete study of energy supply and demand in Mozambique, sector by sector, including all energy forms.

The analysis in this Energy Outlook went as far as the authors could do with the data at their disposal. Still, in the future, with additional information[2], the analysis of energy supply alternatives could be taken further and the demand scenarios improve in accuracy.

[2] Information at our disposal in areas such as regional disaggregation, costs and prices data, load curves detail, was incomplete for this study. Additionally, bottom-up and sectorial data are not available for the electricity sector. The future energy-intensity of the mining sector is particularly difficult to estimate.

Data

For this study, original data for the base years (2000-2010) comes from a variety of official sources, national and international. Data from the United States Geological Survey (USGS 2012), the Energy Information Administration (EIA/DOE), the Worldbank, the United Nations Department of Social Affairs (UNStats) and British Petroleum's Statistical review of world energy (2012 Report) were used. Information from the following institutions or companies was compiled: Electricidade de Moçambique (EDM, Statistical Reports), Mozambique Transmission Company (MOTRACO), SASOL, ESKOM, Norconsult, Vale Moçambique, and Petromoc (Statistical Reports). The authors also refer to the Balanço do Plano Económico e Social (PES, MPD, 2011), the Estatística de Energia 2000-2005 and 2006 (Ministério da Energia, Mozambique, 2007) and to the Integrated Ressource Plan (Department of Energy, South Africa, 2011). In addition, demographic and economic data on Mozambique was obtained from the National Institute of Statistics (INE) and Banco de Moçambique (BM, the country's Central Bank). Some economic data and projections come from the International Monetary Fund (IMF) and the African Development Bank (AfDB). Finally, financial press releases from private companies (in Bloomberg, Reuters, Mining Weekly, AIM, O País) were also used for basic information on specific projects' developments. Data for 2011 was used whenever available[3].

II. SCENARIOS

Energy outlooks, usually give three basic scenarios: medium, high and low – based on GDP and population growth expectations. However, Mozambique's economy is still very small, and its GDP structure could be hugely impacted by the development of extractive industries. The GDP growth section of this study will therefore focus on the possible evolution of the GDP structure of Mozambique towards an extractive industries-heavy economy.

[3] In spite of considerable efforts made in the statistics area in the past 15 years, and excellent database management by EdM and INE, Mozambique is still not exempt from the unfortunate African pattern of having a rather weak statistics field. There is a chronic lack of up-to-date, detailed data, and barely any data is available online. Statistical disaggregation at the sectorial and provincial levels is hard to access. Additionally, an energy planner may also be confronted to a tendency by some people or institutions to retain proprietary data, or to be defiant to sharing it. This is especially true for information relative to costs and prices, which is understandable considering the sensitive nature of it.

An industry-driven GDP growth is indeed completely different, in energy terms, than a finance-and-services-driven growth, or a "green revolution-driven" growth. These industries, Coal Mining, Natural Gas, other Mining (Table1.1), if developed to their potential, could possibly outweigh the current country GDP and therefore shift the GDP structure to that of an extractive industries-dominated economy[4]. The effect of a shift in GDP structure needs to be assessed, firstly, regardless of the GDP growth rates[5]. Different national growth rates would then be applied to the scenarios. The impact of different economic growth rates are examined on the Reference Scenario, with a "High" and a "Low" variant.

Table 2.1: Projected GDP for Reference and Extractive Scenarios

	Scenario	
% of total GDP	**Reference 2025**	**Extractive 2025**
Mining Sector	16,5%	23,3%
Gas Sector	2,8%	6,5%
Extractive industries	19%	30%

a. <u>Reference Scenario and Extractive Scenario</u>

We have envisioned qualitative scenarios:

- A *Reference scenario*: A scenario analyzing growth following current pattern: analyzing the impacts of different GDP growth rates but with the conservation of current GDP structure (or following the recent evolution of this structure). The "*Reference scenarios*" are not exactly "business as usual" scenarios, but rather a "most likely" scenario: it is a scenario modeling the most likely development of each sector, ministry or company, are modeled.
- The *Extractive scenario*: A scenario analyzing a strong growth in the extractive industries sector, in which the Mining and Gas extraction sectors would be the main drivers of growth, and see their share of total GDP considerably increase. In this scenario, foreign companies would look to exploit the national resources to the fullest, and electricity demand from South Africa would increase according

4 As a comparison, the share of extractive industries in major raw materials producers: Angola 45% (Oil), Mongolia 22% (Mining), Venezuela 18% (Oil), Gabon 50% (Oil), South Africa 5% (Mining), Russia 30% (Oil & Gas), Qatar 58% (Oil & Gas) Malaysia 20% (Oil & Gas); World Cia Factbook.

19 Theoretically, even with GDP growth equal to zero, a switch of GDP structure from Agriculture (Currently 27% of GDP) to manufacturing (Currently just 14% of GDP) would increase energy consumption.

to the South African Department of Energy's high estimate. It is more of a "business as planned" scenario than an optimistic scenario.

The *Extractive scenario* is an attempt to model the development of extractive industry (Mining, Natural Gas) up to its potential. It is optimistic in its estimate of the development of the Mining and Gas sector.

- Natural Gas production: up to 12 LNG trains build by 2030
- Coal Mining production: up to 120 mtpy of production by 2025
- Heavy Sands Mining: 5 large projects modeled
- Electricity demand from South Africa reaches 3349 MW (High Estimate of South Africa's integrated Resource Plan)
- The Demand from South Africa means that this scenario is entirely dependent on the completion of the CESUL line
- The quantity of extraction modeled means that this scenario is entirely dependent on the completion of major Rail projects such as the Moatize-Malawi-Nacala line, the Moatize - Beira additional line, and the Nacala deep water port terminal.

Table 2.2: Key features of the Reference and the Extractive Scenarios

Reference scenario	**Extractive Scenario**
Includes all the large industry and mining projects which are most surely going to be commissioned in the near future.	Includes all the potential projects that have been discussed or identified for the future, but with no certainty on the year of commissioning
Includes Coal mines currently in construction, combining production after ramp-up of 72 mtpy - 4 LNG projects totaling 20 mtpy	Includes 12 LNG projects for a production of about 60 mtpy after ramp-up[6]. - Coal production of 120 mtpy by 2030
Does not include MOZAL III and demand from South Africa is deemed constant	Includes MOZAL III and increased demand from South Africa (up to 32 TWh)
Extractive Industries grow 25%/y on average; weigh 20% of GDP by 2025.	Extractive Industries grow 30%/y on average; weigh 32% of GDP by 2025.

[6] Qatar, the world's leading LNG exporter, produced 77 mt LNG in 2011.

b. Variants of the Reference Scenario

To the *Reference scenario*, we apply two variants: a “High” and a “Low” variant:

- The “Reference – High” variant is an optimistic growth scenario: GDP sections for the non-extractive sectors would all grow one percentage point higher than in the “Reference – 2012” scenario. Urbanization levels would be higher and for population we apply the UN’s low variant.
- The “Reference – Low” variant is a rather pessimistic growth scenario: each year’s GDP projections are lowered by a full point, population would increase at a fast pace while urbanization would remain on the current track.

In each scenario the extractive sector’s GDP remains the same (since the same projects are modeled).

Table 2.3: Variants of the Reference Scenario

Item	“Reference – High”	Reference Scenario	“Reference – Low”
GDP Growth	8,2%	7,2% per year	6,2%
New connections	147 000/ year	120 000/ year (avg.)	108 000/ year
Number of cars in 2030	2,26	1,91 Million cars	1,62
Electrification rate	47%	38% of households	33%
Population[7]	32,7 M *57% Urban*	34,8 Million People *52% Urban*	37,1 M *47% Urban*
Agriculture	0,49 MJ/US$ to 0,65	0,49 MJ/US$ (Constant USD) to 0,60	0,49 MJ/US$ remains constant

c. Demand scenarios from South Africa

South Africa’s power utility (Eskom) is facing major supply-side challenges, and has identified Mozambique as a potential supplier in its “Integrated Resource Plan 2010” (IRP, 2010). One of the scenarios in the IRP is to make available 2600 MW of power from Mozambique, including 2135 MW from the new hydro projects. Eskom is mostly interested in new hydro power from Mozambique, as its current generation mix is carbon-intensive. HCB currently represents 40% of Eskom’s carbon-free generation (Annex f. 18).

It has yet to be seen whether Eskom will act upon the plans drawn in the IRP. Electricity purchases from Natural Gas plants at the Mozambique-RSA border is not looked at in the IRP. As of date, South Africa gets 92 MW from Gigawatt plant in Ressano-Garcia, and could get an additional 150 MW from Sasol’s plant in the same area).

[7] For this report, we have used the UN’s High population evolution variant (37,1 Million people by 2030) for our ‘Reference - Low’ Scenario, considering that lower development proved to be linked with higher fertility. The UN’s Low variant is used for “Reference – High”, which models a faster pace towards development. In the three scenarios the urban population in 2030 is about the same, but its percentage of total population is different.

Another possibility not studied in the IRP but considered by the industry, is the importation of thermal coal from Tete to supply for Eskom's power plants in South Africa. In this model, we are counting on the CESUL backbone transmission line to be built around 2019, enabling the sale of power from new hydro but also the new coal to Eskom.

Table 2.4:

RSA IRP 2010 Reference	Plant	Scenario	MW Capacity	MW for ESKOM in PPA	Total GWh/a	Energy for ESKOM (TWh)	Energy for EdM and Industry (TWh)
HCB	HCB (1997)	*REF*	2 075	*1 300*	16 359	10,25	6,11
Import Hydro Mozambique A	Mphanda Nkuwah	*EXTR*	1 500	*1 125*	9 566	8,87	0,70
Import Hydro Mozambique B	North Bank	*EXTR*	1 245	*850*	6 505	4,44	2,06
Import Hydro Mozambique C	EdM Hydro Luia	*EXTR*	444	*160*	3 500	1,26	2,24
Import Coal Mozambique	Jindal Steel Phase 2/4	*EXTR*	1 320	*500*	8 094	3,07	5,03
not mentioned	Ncondezi	*EXTR*	600	*500*	3 679	3,07	0,61
not mentioned	Gigawatt (2012)	*REF*	107	*92*	844	0,73	0,12
not mentioned	Electrotec	*EXTR*	107	*92*	844	0,73	0,12
TOTAL IRP 2010	New From Mozambique	4 pj.		**2 635**	19 571	**17,64**	**10,03**
TOTAL REF	New From Mozambique	2 pj.	2 182	92	17 203	10,97	6,23
TOTAL EXTR	**New From Mozambique**	8 pj.	7 398	**3 319**	49 391	**32,40**	**16,99**

According to the IRP the forecasted peak demand in South Africa will grow from 38.9 to 67.8GW (growing about 2.8% p.a.) by 2030. Further, 89,5GW of generating capacity is required by 2030, mostly from renewables. Therefore in our *Extractive Scenario*, we have modeled 3320 MW of capacity dedicated to Eskom, of which 1900 to 2100 GW would have to be firm. This amount would represent just 7% of Eskom's projected capacity requirements for 2030 (89,5 GW).

In the longer-term assessment of Robert Jeffrey, energy economist at South African consulting firm *Econometrix*, Eskom will have to grow the country's electricity generation capacity to between 100,000 MW and 120,000MW from the current 43,000MW between now and 2049, assuming annual economic growth of 3%[8]. Mozambique should be able to further help South Africa meet that demand (Annex f. 77), but would have to tap into its thermal coal potential, and exploit more intensely its hydro potential, demanding enormous investments. This goes beyond our planning period for this study.

[8] "Eskom's miner issues", David McKay, Fri, 25 May 2012; miningmx.com

d. <u>GDP growth outlook</u>

The economy of Mozambique is ending its post-conflict recovery period and is now experiencing the start of an industrial revolution. While the structure of GDP had remained stable so far, growth is likely to accelerate in the medium term.

Regarding the short term, a recently released forecast by the UK's Economist Intelligence Unit (Table 1.5) credits Mozambique with 7,2% growth in 2011, 8,0% in 2012, 8,5% in 2013, 8,0% in 2014 and 7,8% in 2015. Our growth estimates beyond 2012 are much higher in both scenarios, which we explain by a underestimating of Mining sector growth by the For instance, a recent Standard Bank report cited by AIM (Ref) indicated that GDP in Tete province grew 31% in 2011, while the latest INE release showed that the Mining sector grew 25,4% in the first quarter of 2012.

Table 2.5: Growth forecasts

	2012	2013
Africa (WB)	*5,2%*	*5,6%*
Africa excl. RSA (WB)	*6,4%*	*6,4%*
Mozambique (EIU)	8,0%	8,5%
Mozambique (AfDB)	7,5%	7,9%
Reference Scenario	8,3%	9,1%

Portuguese Bank BPI's research team in Mozambique (June 2011) acknowledged that the current growth estimates by EIU and AfDB could be very conservative, due to the uncertainty faced by forecasters in accounting for Mining sector growth. A July 2012 statement by Rating Agency Fitch® acknowledged similar difficulties in forecasting long-term growth: "[…] quantitative assessments of the impact of coal on the economy are currently lacking. Recent massive natural gas discoveries also promise to transform public and external finances in the long term but are beyond Fitch's current rating horizon".

According to announcements made by MIREM, the Natural gas sector's share in GDP could reach 13% as soon as the LNG exports start in 2018[9]. Although the scientific basis for this claim is unclear, this shows that the government's expectations for the sector are high. To our knowledge however, no institution has yet published an attempt at forecasting Mozambique's GDP for beyond 2015. This led the authors to build a GDP scenario builder to try and model long-term economic growth.

[9] "Contributo do gás natural no PIB vai crescer 11.3% dentro de seis anos" O Pais, April 25th, 2012.

1. GDP growth scenarios

Economic growth is a major driver of energy demand. This is especially true for Agriculture, Services, Construction and Industry. Our Sectoral GDP growth scenarios for Agriculture, Services, Construction, Industry, as shown in Figure1, are based on official projections until 2012, and from then on, on reasonable year-to-year growth % assumptions. Extractive industries, whose energy demand depends on the technical specificities of each project, but whose contribution to GDP depends on the added value of the production, can be modeled differently.

Extractive Industries GDP is modeled as a function of physical production (Coal, LNG, Minerals), & scenarios of international prices. Our projection of Physical production of Coal, Heavy Sands and Natural Gas is based on financial press releases by the companies, by press releases and the GoM announcements. We estimate that the growth rate of the Extractive GDP (defined here as Mining and Gas) is a function of physical production and commodities prices.

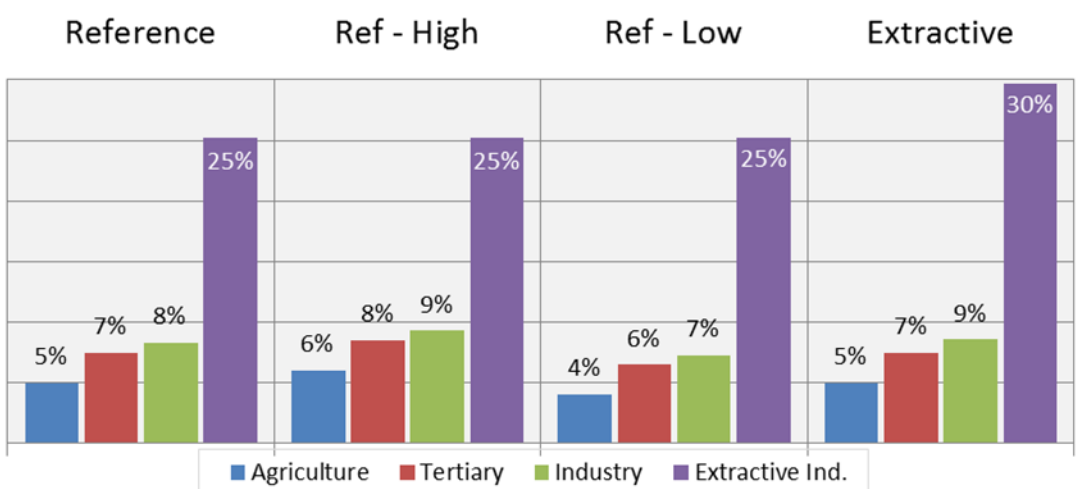

Figure 2.1 : Average Annual Sectoral GDP growth rates, for 2011 - 2030.

For this report, we have modeled the Extractive industries GDP as a factor of quantities produced, in each scenario, as well as international commodities prices. The method used in the GDP builder is conservative: it does not take into account the investment costs' participation to GDP, nor does it model price increases faster than the GDP growth. Using this method we still came up with very high growth rates for the extractive sector, considerably impacting GDP growth in the long run.

In our reference scenario, GDP growth, estimated on the basis of quantities produced, could top double digits for several years, with an annual average growth rate (AAGR) of 8,3% from 2010-2030. In the extractive scenario, this AAGR would reach 9,4% through 2030. This is in line with what happened in some countries such as Angola, Mongolia or Equatorial Guinea in recent years, when experiencing a natural resources boom, completed by a price increase on the international markets for Coal, Petroleum and Liquefied Natural Gas. Rating Agency Fitch estimated that "[…] mining's contribution to GDP is expected to increase to around 10% from 3% in the medium term, due to the rapid expansion of the coal sector[10]".

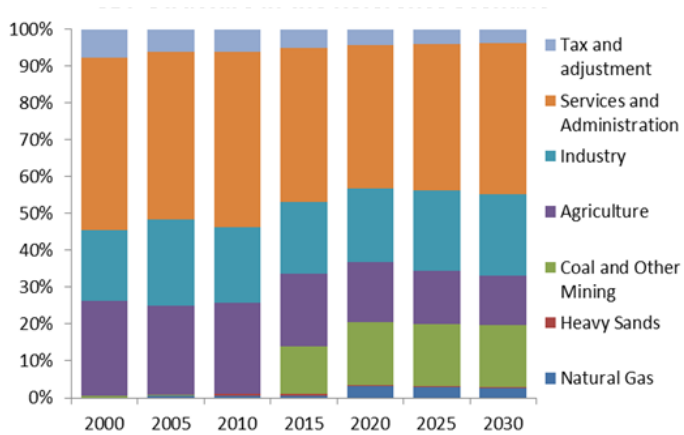

Figure 2.2: GDP structure for the Reference Scenario

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In the following decade, the structure of the Mozambican GDP is expected to experience dramatic changes, which we have tried to reflect in our economic Scenarios. For this study, 6 sectors are modeled: Households, Agriculture, Services, Industry, Mining (Coal, Heavy Sands and Other), Road Transport. Regional Exports are modeled as a Demand section. No specific GDP section is associated to Transport and households, but these sectors' demand is linked to GDP per capita. In our *Reference Scenario*, which accounts only for the projects most likely to happen, Extractive Industries (Coal, Gas, Heavy sands and other Mining), would weigh 13,4% of GDP by 2015 (vs. less than 2% in 2010), to reach 20% of GDP in 2022. In our *Extractive Scenario*, Figure 1.2, the Extractive industries sector would reach 15,6% of GDP by 2015 and reach 30% in 2022.

[10] Statement by Caryn Trokie, Fitch Ratings New York Unit, July 20th, 2012 (Reuters)

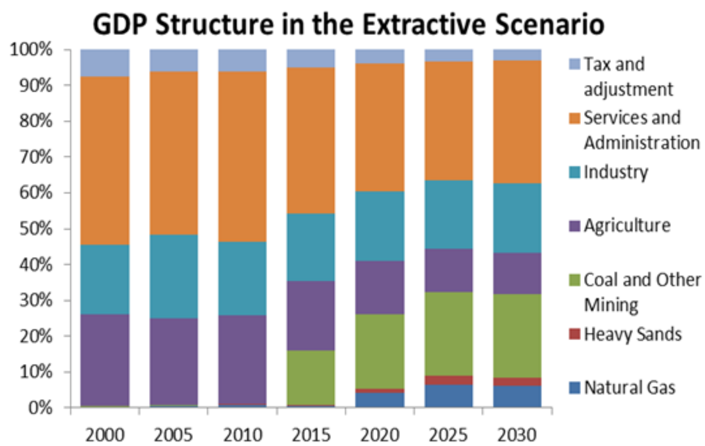

Figure 2.3: GDP structure for the Extractive Scenario

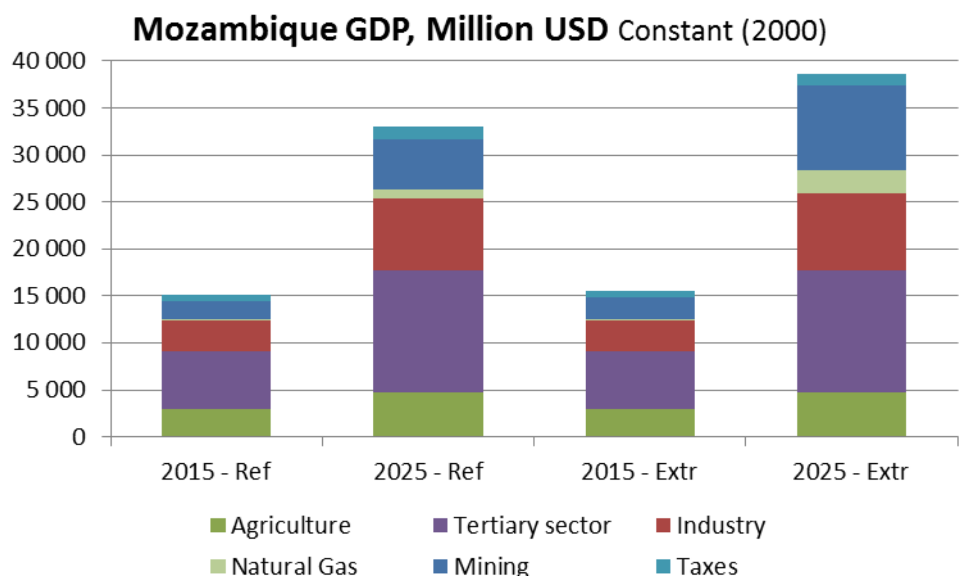

Figure 2.4: Projected sectoral GDP for Reference and Extractive scenarios

Our ***GDP builder*** is based on a simplified principle: quantities extracted * contribution to the GDP * price increase = sectoral GDP[11].

2. Impact of International Commodities Prices on Economic Growth

This report does not look explicitly at energy prices. However international commodity prices are looked at implicitly in the GDP scenarios. While it is not the aim of this study to forecast prices, we have assumed growths for LNG prices, Aluminum prices and Coal prices. This price increase reflects into their impact on GDP via our GDP builder. It is important to note that we have assumed very

[11] The contribution to the GDP is based on previous records of GDP in 2000 USD/quantities produced in physical quantities over the base year period (2000-2011)

as a conservative estimate concerning the impact of these commodities' production on GDP. The Natural Gas sector for example, might have a very different contribution to GDP from today's: for example, in 2011 SASOL paid the GoM 67 USc/GJ for the Royalty (Extra) natural gas, while as a comparison, Japan paid on average 1500 USc/GJ for its LNG imports, Figure 1.5.

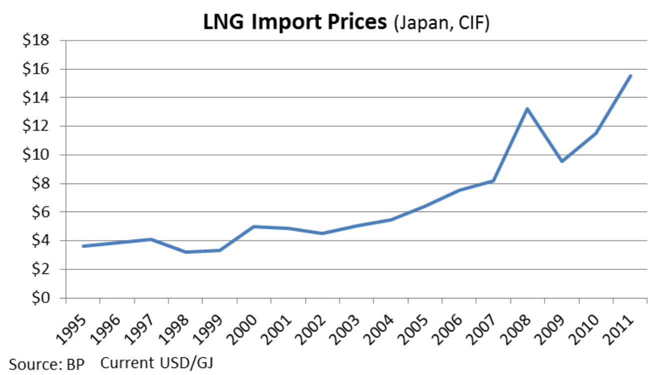

Figure 2.5: Evolution of the import price of Liquefied Natural Gas for Japan

With these assumptions, the final value of Gas exports from Mozambique could be double check (2011, constant) in our Reference scenario (20 mtpy in 2020). Therefore it is possible that our GDP assumptions for the natural Gas sector be very conservative. Still, our scenarios of growth all show that GDP could grow well above 10% for many years (Annex f. 20).

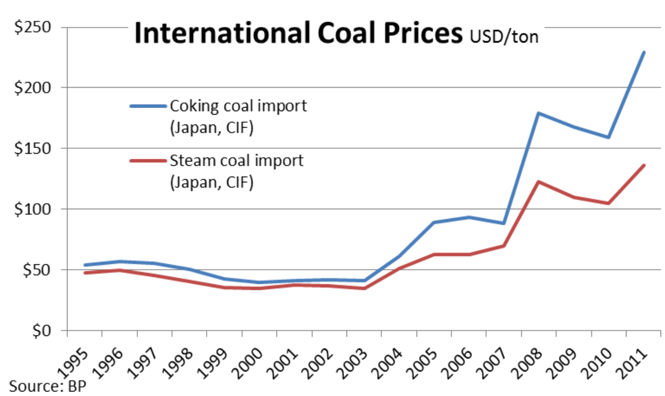

Figure 3.5: Evolution of coal international price

In summary, the impact of extractive industries on GDP deserves some more analysis. Just how will production and sales be accounted for into the GDP and what their contribution will be is yet unknown, and will surely be a challenge for the National Statistic (INE). Another question mark will be the impact of the Extractive Industries sector on the country's real socio-economic growth and subsequent impact on other sectors energy demand.

III. FINAL DEMAND PROJECTIONS BY SECTOR

Sectoral demand projections

3.Households

Future energy demand by households is categorized into 2 groups: electrified and non-electrified households. Table 2.1 shows historical and projected demand by residential sector disaggregated into different forms of energy used.

Table 3.1: Energy Demand by Households (Reference Scenario)

KTOE	2000	2005	2010	2015	2020	2025	2030	Average Annual Growth 2010-2030
Charcoal	395	602	808	1 159	1 609	2190,6	2 915	6,6%
Electricity	34	41	77	153	229	301,7	372	8,2%
Kerosene	49	32	20	25	31	38,6	49	4,6%
LPG	8	14	16	32	62	103,6	168	12,4%
Wood	3 992	4 263	4 534	4 855	5 036	5092,8	4 962	0,5%
Total	**4 478**	**4 953**	**5 455**	**6 224**	**6 966**	**7727,3**	**8 466**	**2,2%**

Biomass model

Demand for fuel wood and charcoal is modeled using a *biomass model* (Figure 2.1) that we built outside LEAP model and based on an s-curve. Total consumption is modeled using fuel price elasticity and GDP per capita, with data derived from logarithmic regression based on IEA data, whereas for the consumption of fuel wood and charcoal we use inter-fuel substitution elasticity and the annual growth in urbanization, with data derived from household surveys and census data from (INE, 2002).

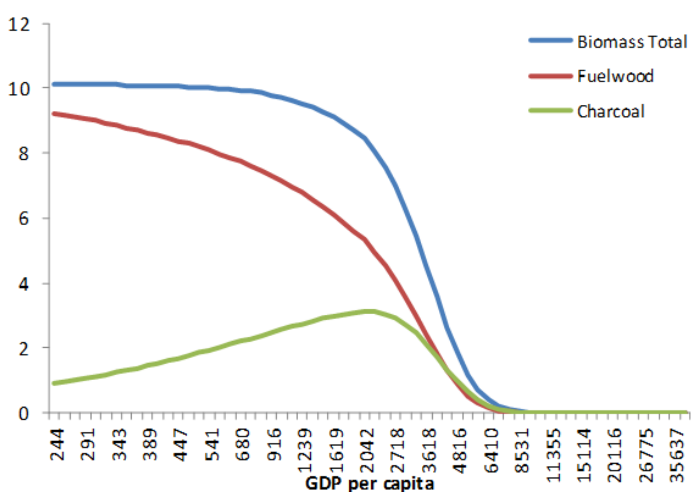

Figure 3.1: Residential biomass consumption [GJ/cap]

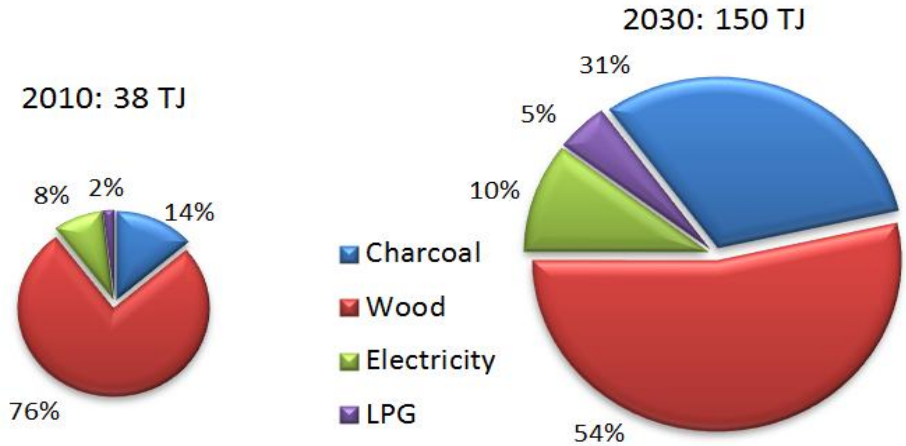

Figure 3.3: Energy consumption by electrified households, Reference scenario

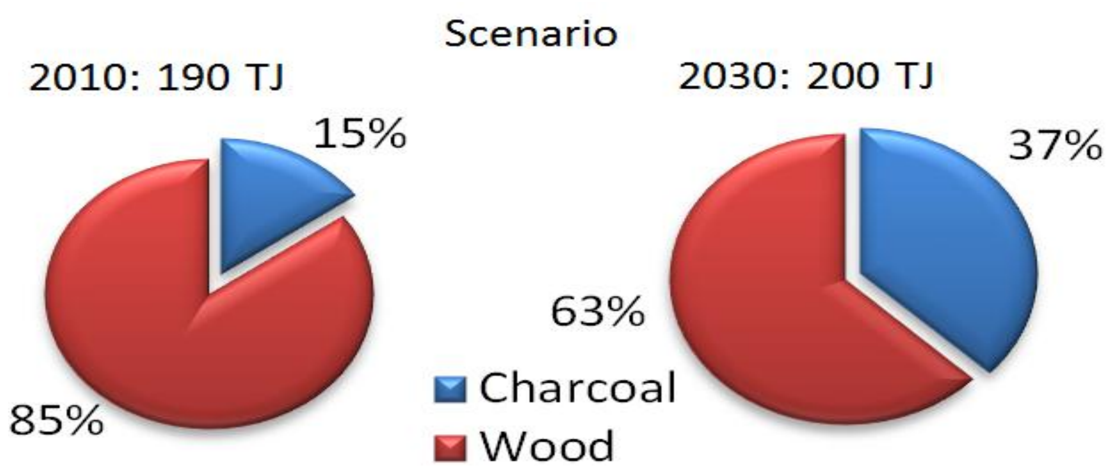

Figure 3.4: Energy consumption by non-electrified households, Reference scenario

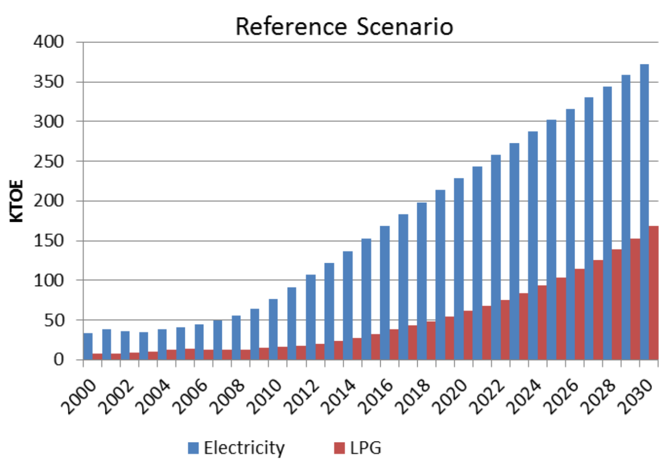

Figure 3.5: Residential Demand for Electricity and LPG

Electrification

The national power utility (EdM) has connected on average 33 thousand new clients per year from 2000-2006, and has accelerated the effort since then, with an average of 121 thousand total connections per year from 2007-2011. It has connected to the grid 112 thousand domestic clients per year on average from 2007-2011, Table 2.2. The grid is now reaching 106 districts. In the 'Strategic Vision' document, EdM and the government aim at connecting all 128 districts by end 2014[12], and connecting 100 000 new clients per year. However, our projections (Figure 2.2) show that in spite of these efforts, Mozambique might have to cope with a large share of non-electrified population for the foreseeable future.

Table 3.2 : Energy Demand by Households (Reference Scenario)

Scenario	New Households Connections	*Non-Electrified Population* (million people with no direct access to the grid)			
↓	Average/year ↓	2010	2015	2020	2025
Reference - High	147 000	19,0	18,6	18,1	17,5
Reference	120 000		18,8	19,2	20,0
Reference - Low	108 000		19,0	20,1	22,0

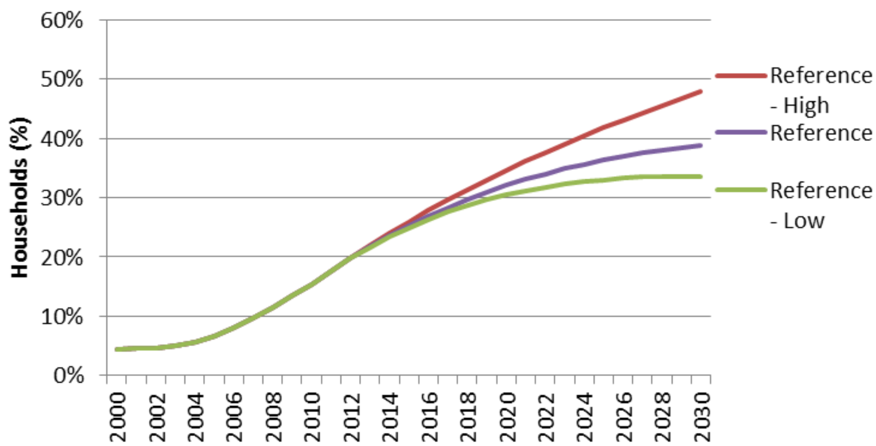

Figure 3.6: Percentage of Electrified Households

[12] "Distrito de Lalaua, em Moçambique, ligado à rede eléctrica nacional", AIM, January 5th, 2012

Depending on the calculations[13], the country currently may have between 18 and 19 million people not beneficiating of direct access to the grid. In our most optimistic scenario, Figure 2.7, *Reference - High*, which assumes i) an urbanization level of 57% by 2030 (therefore making electrification easier), ii) a lower rural population growth, iii) an average 147 thousand new domestic connections per year on average, and iv) a 2030 electrification rate of 47%, Mozambique would still have about 17,5 million people without access to the grid by 2030, about 1,5 million less than today.

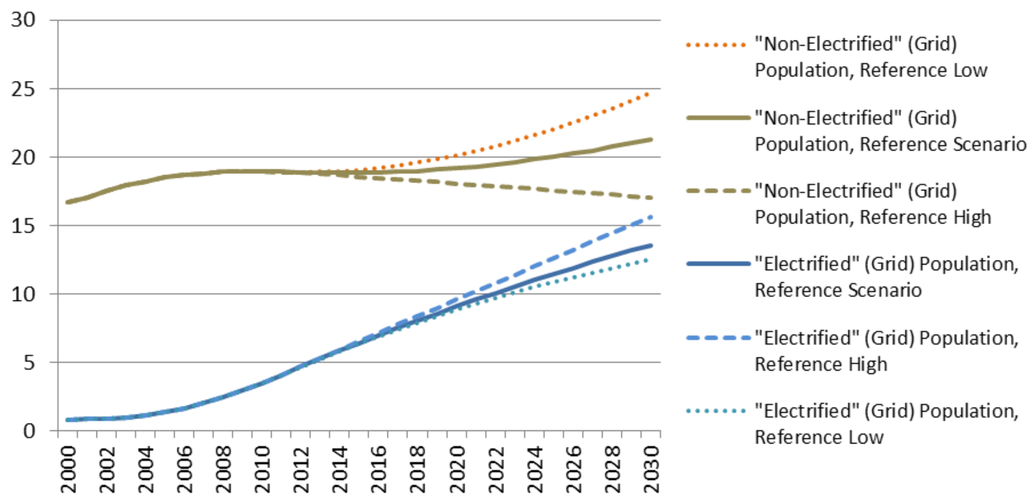

Figure 3.7: Historical and projected domestic electrification.

In our *Reference - Low* scenario, which assumes lower growth, slower urbanization and a stronger population increase, the electrification rate would be limited to 33% in 2030. Total population living away from the grid could in fact increase, even if EdM manages to connect 108 thousand new houses per year. This rhythm of new domestic connections would implicate maintaining at least its 2010 performance, which was the double of its 2003-2007 average performance.

[13] If one uses total clients divided by number of households, or only domestic clients divided by number of households, the results can vary. Also, the choice of population data, and the estimate of average number of people per household, can push the electrification percentage up or down.

LPG Access

From 2007-2010, LPG consumption had increased 8,4% a year on average (2011 data are not relevant, as imports were stopped in Q4 due to a technical problem). All our scenarios plan an acceleration of LPG consumption growth. For this report, we have modeled LPG consumption growth as a function of GDP Growth with the urban population growth as a multiplicator:

*Growth of [1+GDP GrowthRate * 1+Urban Population GrowthRate]*

The 2008 INE "MIC" survey showed that 5,9% of all Urban Households were using LPG for cooking that year. We assume that the increase of this LPG access rate follows the same trend as the general LPG demand, therefore increasing to 6,4% in 2009 and 6,9% in 2010. Using these assumptions, we have calculated that the average LPG user should consume close to one bottle of 11kg per month on average (11 bottles per year per family).

In our Reference Scenario, the LPG usage rate amongst urban households could raise from 6,9% in 2010 to 33% in 2030. This scenario would require the addition of 64 thousand new clients (assuming clients consuming a bottle per month). This usage is 38% in the Reference High Scenario (92 thousand new clients per year) and 28% in the Reference Low Scenario (52 thousand).

Table 3.3 : Households LPG consumption

	2010	2015	2020	2025	2030	Average Annual Growth
Reference - High - Demand (MT)	**18,1**	**38,1**	**75,4**	**132,6**	**224,7**	*13,4%*
Ref - High - Households Using LPG (10^3)	137	289	571	1 005	1 702	*78*
% of Urban Households consuming LPG	**6,9%**	**11,6%**	**18,7%**	**26,8%**	**38,4%**	*New clients / Year (10^3)*
Ref - High - Total Urban Households (10^3)		2500,7	3058,5	3754,4	4433,6	
Reference - Demand (MT)	**18,1**	**36,2**	**68,7**	**115,8**	**187,7**	*12,4%*
Reference - Households Using LPG (10^3)	137	274	520	877	1 422	*64*
% of Urban Households consuming LPG	**6,9%**	**11,1%**	**17,3%**	**23,9%**	**33,0%**	*New clients / Year (10^3)*
Reference - Total Urban Households (10^3)	1999,2	2472,8	3001,9	3668,9	4312,5	*4%*
Reference - Low - Demand (MT)	**18,1**	**33,9**	**61,3**	**99,3**	**156,1**	*11,4%*
Ref - Low - Households Using LPG (10^3)	137	257	464	752	1 182	*52*
% of Urban Households consuming LPG	**6,9%**	**10,7%**	**16,1%**	**21,4%**	**28,4%**	*New clients / Year (10^3)*
Ref - Low - Total Urban Households (10^3)		2408,9	2882,2	3515,3	4156,4	

4. Agriculture and fishing

In Mozambique, 79% of active population works in the agriculture sector, and 81% of output is produced by families i.e. subsistence farming. The only known electrical consumption by the sector is about 0,8 GWh, that is, less than 0,4% of EdM's distribution, and only a handful of the exploitations beneficiating from the Agro tariff were located outside of Maputo province (10 in 2010)[14]. Access to the cultivations areas is particularly difficult for EdM, as well as non-profitable.

Agriculture in Mozambique is notoriously underdeveloped. Although its share of GDP was 27,6% in 2010, the agro sector is the recipient of only 8% of loans delivered in Mozambique, and 8% only of the State budget is directed to the sector[15]. In this report, we have used the World Bank's estimate of about four thousand active tractors, but an unknown share of which may actually be used for plowing, or may be in conditions to run. The sector is characterized by low input use, relies heavily on human work and therefore, has very low yields and is very vulnerable to climate change[16] (R. Uaiene, 2009, 2011).

There is a clear link between diesel sales (M3) agro-fishing exportations, both peaking in the months of May to September. However, no specific data seems to exist on the Agriculture sector's Diesel consumption[17], and therefore we had to estimate it (at 5% of total diesel consumption). The major part of Diesel consumption linked to this sector could be the road transport of agricultural products to the markets, during harvest season. This demand is modeled within the transport sector scenarios.

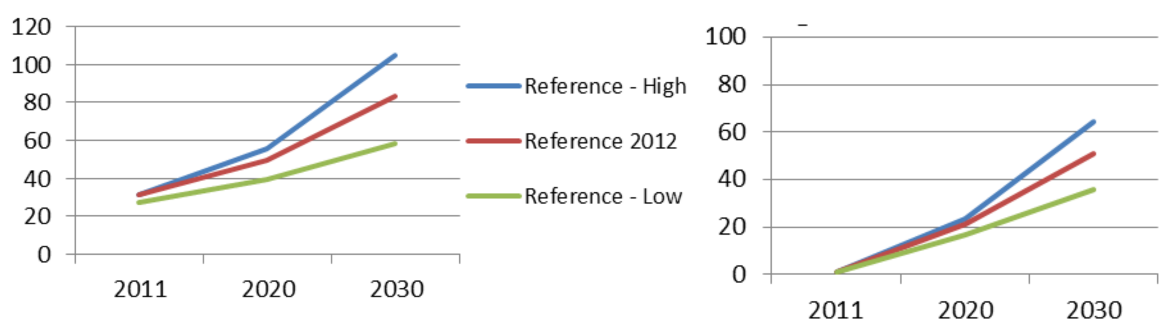

Figure 3.8: Energy demand by Agriculture: Left, Diesel (ktoe); right, Electricity (GWh)

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[14] However, it is possible that many farms or agri-business companies be using electricity but via another tariff structure.

[15] "Apenas 8% do crédito à economia vai à agricultura" O Pais, Sexta, 25 Novembro 2011.

[16] Uaiene, R.N and Arndt, C; (2009)- Farm household efficiency; Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

[17] Relatively to fisheries, only the industrial fishing's consumption of Diesel is reported, while the informal fishing sector, which probably represents the bulk of Diesel consumption, supplies itself in the regular petrol station network and therefore, goes unreported.

In neither of our scenarios, the Agro-tariff total demand would top 80 GWh, even in the *Reference - High* scenario, which requires planning of an extensive farm electrification plan. In our *Reference - High* scenario, we assume the equivalent of 10,6 thousand agricultural exploitations would be electrified by 2030 (an average of 560 per year), with access reaching an increased number of small exploitations. Currently, only 0,4 of Mozambique's 3,8 million exploitations[18] cover more than 10 ha, that is, 23 thousand exploitations. If we use our *Reference High* assumptions, 46% of these could have access to electricity by 2030, but only 22,2% in the *Reference 2012* Scenario (260 new clients per year), and 10,1% in the *Reference Low* Scenario (120 new clients per year). This is, assuming the number of exploitations remains constant. We have assumed that as the electrification effort would reach smaller exploitations, the average electricity consumption of clients in the "Agro tariff" would go down, similarly to what happened with the "Domestic tariff" in the past ten years[19].

Table 3.4 : Electrification of Agriculture sector

	2011	2020	2030	Average growth
Reference - High - Demand (MWh)	847	23 540	64 120	25,6%
Reference - High - Clients	55	3 139	10 687	32,0%
Average billing (kWh/client)	15 400	7 500	6 000	*560 new clients/y*
Reference 2012 - Demand (MWh)	847	20 990	50 840	24,0%
Reference 2012 - Clients	55	1 749	5 084	26,9%
Average billing (kWh/client)	15 400	12 000	10 000	*260 new clients/y*
Reference - Low - Demand (MWh)	847	16 660	35 820	21,8%
Reference - Low - Clients	55	1 082	2 326	21,8%
Average billing (kWh/client)	15400	15400	15400	*120 new clients/y*

In all three scenarios, the immense majority of the exploitations would remain without access to the grid (at least not under the Agro tariff). The assumptions of the Reference 2012 Scenario: 27% increase in number of clients each year, are in line with the trend observed since 2007 (+26%/y) but so far only 55 clients are billed under this category, so the sample might not yet be significant.

[18] INE, *Censo Agricola 2010*. According to INE, the country has 3 824 585 "fazendas", an increase of 25% since the 3 064 715 recorded in the first *Censo agrícola*. Out of this total, 99,6% cover less than 10 hectares, and 72% less than two. 57% of the cultivated area in the country is occupied with basic alimentation such as rice, sorghum, mil, peanuts and various types of beans. "Área de cultivo em Moçambique cresceu 47%" O Pais, Sexta, 25 Novembro 2011.

[19] The average consumption of EdM's Domestic clients has gone from 2200 kWh/year/client in the years 2000-2003 to 1100 kWh in the years 2009-2011, while the number of domestic clients was going up 17% a year on average.

5. Services

In our model we have assumed that the tertiary sector is responsible for 74% of the non-domestic, low-voltage consumption. Our calculations show a yearly average growth of 6,8% a year in the past decade. In our different scenarios, GDP growth of the tertiary sector is assumed strong. In the Reference scenarios, the services sector (including all tertiary activities) would weigh 41% of GDP in 2030, vs. 47,6% today. In the extractive scenarios, Services sector growth is roughly the same, but its share would go down to 34% by 2030.

Table 3.5 : GDP growth for Service sector.

Services Sector 2011-2030	GDP Growth	Electric demand growth
Reference - High	8,3%	8,6%
Reference 2012	7,5%	7,8%
Reference - Low	6,7%	7,0%

In 2011 EdM had 70 872 clients in the Commercial ("Geral") category and 2 397 in the 'LV-Big consumers' category. We estimate that 54 thousand of these are in the service sector, but it was not possible for this study to estimate which share of the tertiary sector organizations was comprised in this figure. It is possible that a large share of the sectorial GDP be generated without electricity. In the absence of bottom-up data, it is difficult to attribute the consumption of each category to a specific section of the services sector. For this study, we relied on an estimate. LPG demand of the Tertiary sector ('Services') was indexed on GDP growth and urbanization.

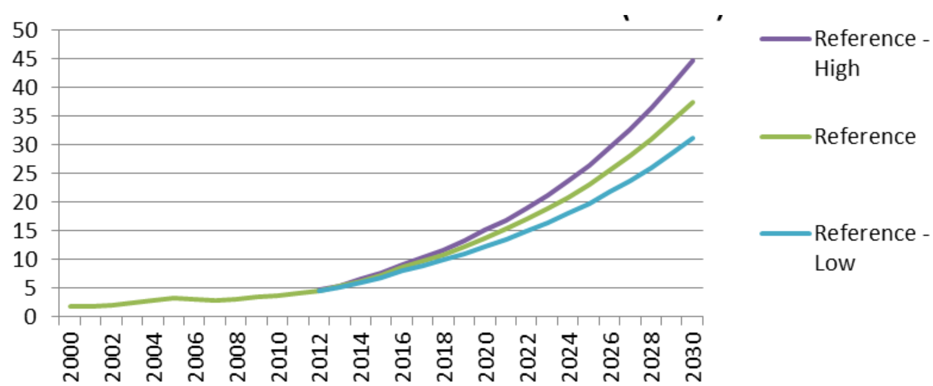

Figure 3.9: LPG demand by Services (ktoe)

Table 3.6 : Electricity demand by services.

GWh	2000	2005	2010	2015	2020	2025	2030
Reference - High				701,8	1 064,4	1 609,0	2 409,5
Reference 2012	238,5	317,2	461,6	675,6	991,1	1 442,1	2 077,8
Reference - Low				650,2	923,5	1 295,4	1 799,4

6. Industry

In 2010, 2/3rds of the Medium Voltage demand in the country came from Maputo province and city, due to the concentration of industry in this region. The only other region with some significant MV consumption was Beira (11,8%). If one includes the Heavy Sands Mine (Moma, Angoche district), the total MV-HV consumption of Nampula Province reaches 123 GWh (15% of total). EdM does not make available the consumption of its clients by activity branch, but only by tariff category. In our model, we have attributed to the industry sector 25% of the “BT-Geral” category, 25% of the “GCBT” category and 75% of the “MT & AT” consumption.

Tete (3,8%) and Lichinga (0,4%) had very little demand for Medium Voltage. This pattern of Medium Voltage concentration is due to change considerably with the development of Mining projects in the Tete, Nampula, Niassa and Gaza provinces. For this report, the largest loads of the Industrial sector such as Cement factories and metal smelters, were modeled separately.

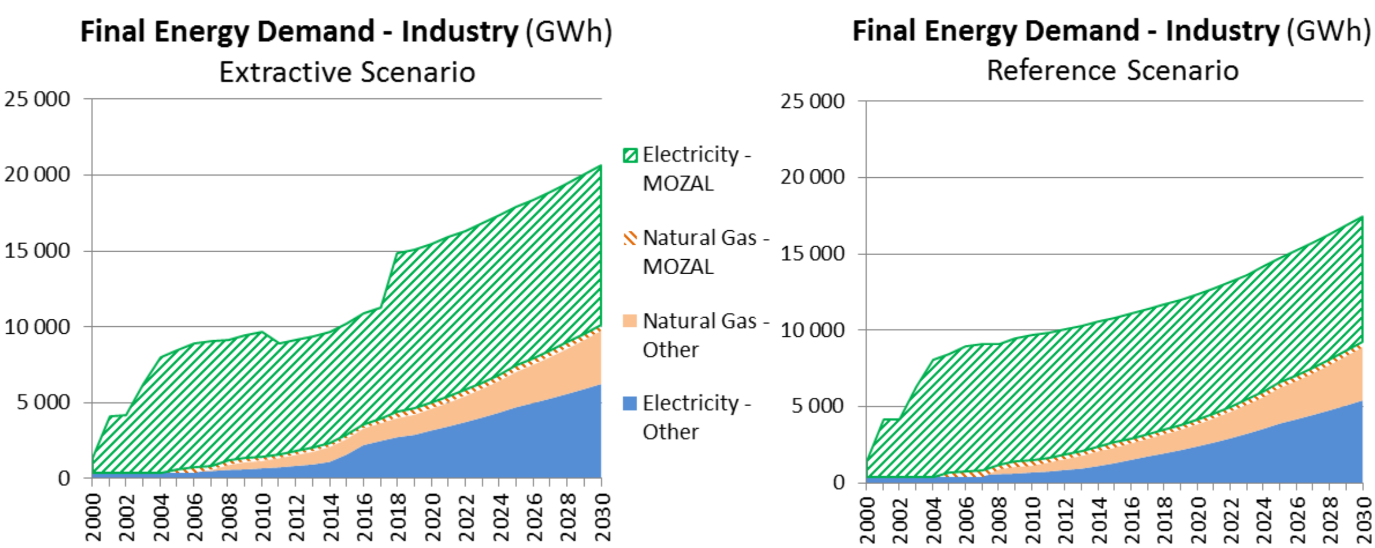

Figure 3.10: Final Energy Demand by Industry: Left, Extractive scenario; right, Reference scenario.

7. Transport

Data for the transport sector were collected from INATTER (former INAV), *Autoridade Tributaria*, and from the World Bank. No single source of data seems to be exact; therefore the authors had to proceed to reconciliation of the data in order to build a reasonable estimate.

Mozambique has a ratio of only 9 cars per 1000 habitants, Figure 2.11. However, since 2003, the GDP elasticity of car ownership was found to be 1,34, which denotes a relatively fast growth. In our most road-transport intensive scenario, the Extractive Scenario, Mozambique would have about 2,5 million light vehicles (Annex f. 23). This would represent a level of 47 cars per 1000 habitants, close to the current levels of middle-income countries such as China, Ecuador or Colombia. The current constraints on road transport, which are the weak road infrastructure and the relatively high cost of cars, need to be lifted, especially in the rural areas, in order to improve mobility.

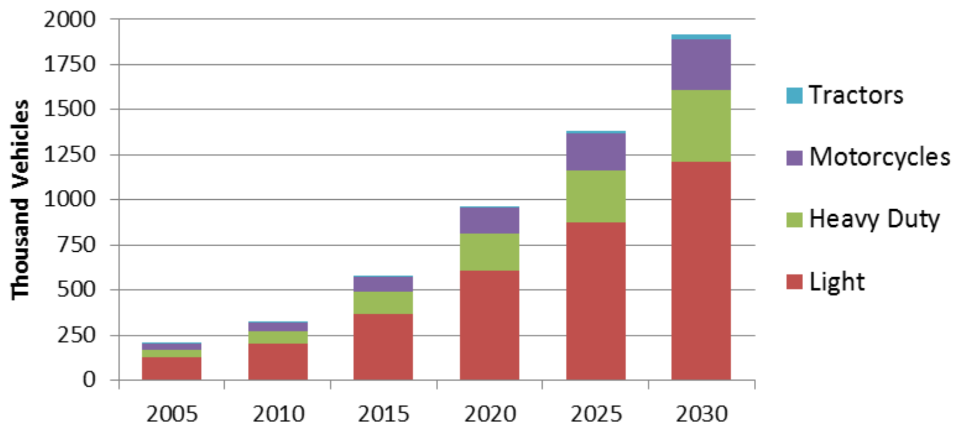

Figure 3.11: Vehicle Categories, historical and Reference scenario

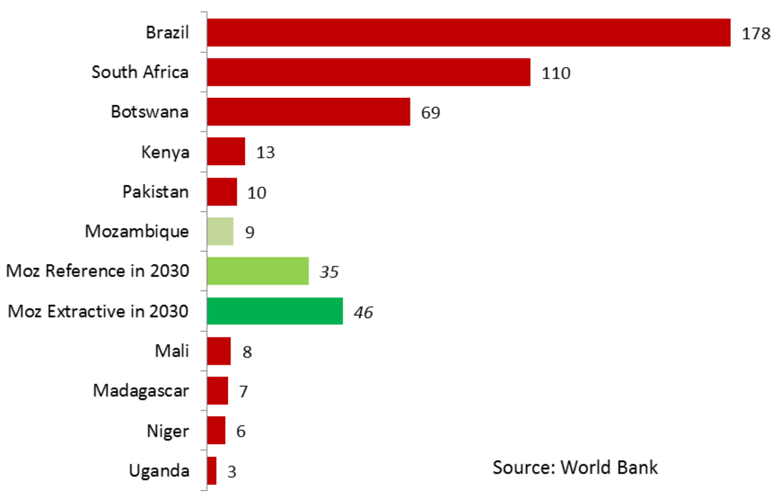

Figure 3.12: Passengers car per 1000 people in 2009, international comparison

The road transport sector will need rapidly increasing quantities of energy. We currently estimate the demand for Diesel (or equivalents) at 560 ktoe. This demand would grow at a pace of 9% a year in the Reference Scenario to top 2100 ktoe in 2025, and 12% a year in the Extractive Scenario, to top 3400 ktoe in 2025.

Gasoline demand has grown 15,5% a year since 2005 (from 96 to 228 million liters per year). As light vehicles ownership in our scenarios is indexed to GDP growth, the number of gasoline-fueled cars would keep increasing fast, and push Gasoline demand to a pace of 9% a year in the Reference Scenario, and 12% a year in the Extractive scenario. In other words Gasoline demand is on pace to be multiplied by a factor of 5 to 9 by 2030.

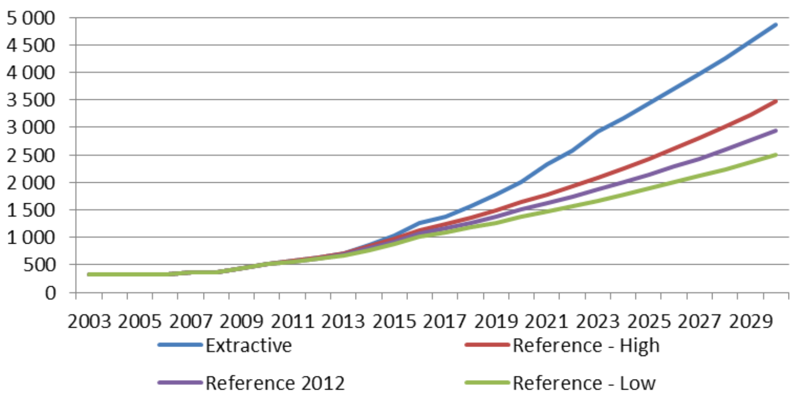

Figure 3.13: Diesel demand by Transport sector (ktoe)

Table 3.7: Fuel demand by Transport sector

Gasoline Demand For Transport: Million Litres				
Scenario ↓	2015	2020	2025	2030
Extractive	436,4	844,1	1 443,3	2 044,5
Reference 2012	383,1	620,7	874,5	1 188,7

Diesel Demand For Transport: Million Litres				
Scenario ↓	2015	2020	2025	2030
Extractive	1 198,9	2 318,9	3 965,3	5 617,0
Reference 2012	919,4	1 504,8	2 140,1	2 939,5

8. Mining

Mozambique's mineral resources are attracting major investments in the mining sector since 2007. Mining is an energy-intensive industry, and the size of the projects currently planned will change the picture of energy demand in Mozambique.

Coal Mining

We have modeled twelve projects (Table 2.8); other new projects can be added. In the Reference scenario, the projects currently at the most advanced stage are modeled. These would produce up to 72 mtpy by 2016 and then stabilize. In the Extractive scenario, total coal production in Mozambique would reach 100 mtpy by 2021 and continue to grow.

Building an estimate for consumption of the Coal mining sector as a whole is particularly difficult. The mix of Diesel vs. Electric, and the respective consumption of each, are mine-specific and are hard to model without information on each project. In the model, each major mine is modeled independently, but information on mine-specific energy consumption was not available.

Table 3.8: Coal mining projects considered in this study

SCENARIO	Project name (Coal)	Year of commission - ning	Production peak after ramp-up (mtpy)	Electricity consumption after Ramp-up (GWh)	Diesel consumption after Ramp-up (ktoe)
REF	Moatize Phase 1 Vale	2013	11	253	34
REF	Moatize Phase 2 Vale	2011	11	253	34
REF	Mucanha Vuzy Vale	2018	11	253	34
REF	Benga Rio Tinto	2012	10	230	31,5
EXTR	Benga Phase 2	2015	10	230	31,5
REF	Zambeze Rio Tinto	2021	10	230	31,5
REF	Moatize Jindal	2014	8	180	25,2
REF	Revobué Anglo American Nippon Steel	2015	5	115	15,8
REF	Moatize BHR	2012	2	55	7,4
REF	Ncondezi	2016	15	350	47
EXTR	Tete East Rio Tinto	2015	10	230	31,5
EXTR	Moatize ETA Star India	2021	10	230	31,5
EXTR	Moatize Coal India	2021	10	230	31,5
EXTR	About 90 companies licensed		tbd	tbd	tbd
EXTR	*Evate Phosphates*	*2016*	*1,8*	*504*	*5*

Table 3.9: Projected coal mining GDP

SCENARIO	Coal Mining as a % of GDP in 2015	Coal Mining as a % of GDP in 2025	2011-2030 Coal Mining GDP average annual growth %	Total coal production in 2030
REF	13 %	17 %	37 % /y	66 mtpy
EXTR	15 %	23 %	41 % /y	116 mtpy

Our original assumption is 3,5 liters of Diesel per Ton ROM, and 23 kWh per ton ROM. Our Diesel consumption assumption is based on sources indicating a one gallon per Ton ROM consumption in US open-cut coal mines. Our electricity consumption assumption is based on the output of the Power plants planned for each mine in Mozambique and the mines' respective production after ramp-up. We acknowledge that these assumptions are fragile and need to be checked.

Based on our current assumption (of 23 kWh per Coal ton ROM), all the currently planned Coal mining projects could combine for a 1 300 GWh/y demand in the *Reference 2012 Scenario*, and 2700GWh/y in the *Extractive Scenario*.

- These scenario results amount respectively to 0,6 and 1,25 times EdM's distribution in 2011

Additional coal projects in Cahora Bassa and Niassa could push up this trend even further. The rest of the mining sector (gold, uranium, precious stones, graphite, limestone, etc.) could demand between 200 and 400 GWh/y, although the estimate is also fragile, due to lack of mine-specific data.

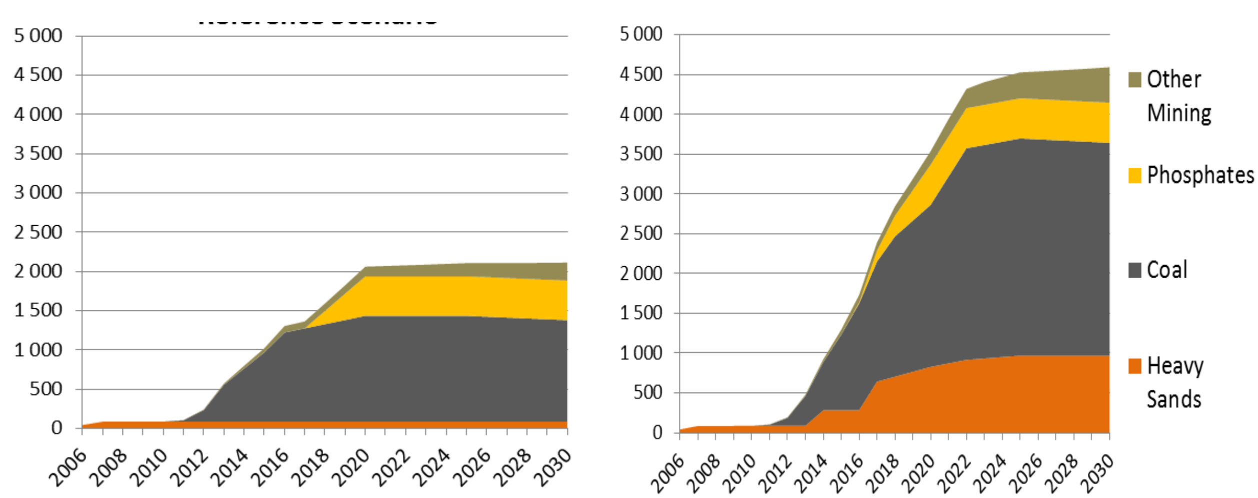

Figure 2.14: Electricity (GWh) demand by Mining: Left, Reference scenario; Right, Extractive scenario.

The only phosphates mine modeled in the Extractive scenario is Vale's Evate phosphate mine in Nampula province. With a 76 MW peak load after ramp-up, the mine could consume above 500 GWh/y. Based on our current assumption of 3,5 L Diesel per Coal ton ROM, all the current Coal mining projects could consume up to 340 KTOE of Diesel by 2025, that is, about half of the amount Mozambique consumed in 2011.

Heavy Sands

The GDP impact of the future Heavy Sands Mining projects is based on the impact that Moma Kenmare's project has had since 2007. With 95 GWh in 2010, the Moma Kenmare project[20] consumed more than 1/10th of all Medium Voltage demand in the country.

In the Extractive Scenario, the 5 projects (Figure 2.15) would produce up to 9,1 mtpy of various minerals. Heavy Sands could weigh up to 1,8% of GDP in 2030 in the Extractive Scenario. As a result, Electricity consumption of the Heavy Sands mines in the Extractive Scenario would increase to 280 GWh in 2015, 730 GWh by 2020 and 970 GWh by 2025.

Table 3.10: Heavy sand projects considered in this study

Scenario	**Heavy Sands** Project name	Production (mtpy)
Reference	Moma Kenmare	0,8
Extractive	Corridor Sands BHP Billiton	5,0
Extractive	Mutamba Rio Tinto	1,2
Extractive	Moebase e Naburi Pathfinder	1,3
Extractive	Sangage Africa Great Wall	0,8

Table 3.11: Kenmare's electricity consumption and value of exports

Kenmare's Heavy Sands Mine	2007	2008	2009	2010	2011
Electricity Consumption (GWh)	15,3	60,0	88,0	95,7	112,0
Value of Exports (M.USD)	2,9	26,0	45,3	98,1	175,4

Source: EdM, Statistical Reports; Banco de Moçambique

[20] Listed as « Clientes especiais » in EdM statistical reports. EdM supplies electricity to the mine in the terms of a specific contract with Kenmare, i.e. outside of the other tariff categories.

IV. FINAL REMARKS

In this paper we have attempted to present, for the first time, a thorough overview of the Mozambican energy sector. The analysis makes use of LEAP, the Long range Energy Alternatives Planning System – an integrated modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. Calibration of our model is based on a newly developed comprehensive database of the recent past (2000-2011) and the latest developments and plans as regards the production and transformation of energy in Mozambique. We have analyzed scenarios for 2012-2030 based on a detailed bottom-up study of energy supply and demand in all sector and including all energy forms. With the exception of natural gas exploration as such, electricity is a key issue for all existing and future large energy projects in Mozambique. The industrial and mining projects all depend critically on the availability of cheap electricity in large quantities while the other projects are engaged in the production of electricity. At the same time, access to modern energy services is still very low in Mozambique, with for many years to come about 70-80% of the population relying entirely on traditional biomass to meet their energy needs. The energy sector in Mozambique is growing rapidly and the country's energy and mineral resources can contribute to reduce absolute poverty and promote growth including the development of domestic energy infrastructure within and across regions.

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