ALUMINIUM MATERIAL FLOW AND VALUE CHAIN ANALYSIS IN THE KENYAN INDUSTRY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

This work is dedicated to my dad Watitwa, mum Khapwoya, brothers Were, Kachi, Osundwa and Wetaba, Sisters Ameyo, Lubale, Khandasi and Akhwale, and my Fiancèe Belinda Akinyi.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANG	Angola
APEM	Alumina Plant Establishment Model.
ARM	Athi River Mining.
AV	Average Value.
BPCCL	Bamburi Portland Cement Company Limited.
BUR	Burundi.
$\mathbf{C}_a$	Actual capacity.
$\mathbf{C}_d$	Designed capacity.
COMESA	Common Market for East and Southern Africa.
DC	Direct Chill.
DF	Discount Factor.
DIY	Do It Yourself.
DMI	Direct Material Input.
EAC	East African Community.
EAPCCL	East Africa Portland Cement Company Limited.
$\mathbf{E}_i$	Energy input.
EMC	Energy Management Committees.
ETH	Ethiopia.
EOL	End-of-life.
FOC	Full Operating Costs.

GDP	Gross Domestic Product.
IDF	Import Declaration Form.
IM	Industry Mean.
KAM	Kenya Association of Manufacturers.
KEBS	Kenya Bureau of Standards.
KISMA	Kenya Iron and Scrap Metal Association.
KRA	Kenya Revenue Authority.
KNBS	Kenya National Bureau of Statistics.
kg	Kilograms.
Km	Kilometres.
kWh	Kilowatt hour.
LCA	Life Cycle Analysis.
LME	London Market Exchange.
MAA	Mean Annual Average.
MCL	Mombasa Cement Limited.
MFA	Material Flow Analysis
$\mathbf{M}_i$	Material input.
MJ	Megajoules.
mt	Metric tonnes.
$\mathbf{M}_o$	Material output.
N	Targeted units.

NE Net Earnings.

NPV Net Present Value.

PAD Primary Aluminium Demand.

PBP Payback Period.

PM Product Mean.

PV Present Value.

r rate of depreciation.

R Grossing-up factor.

RWA Rwanda.

SIM Specific Industry Mean.

SOM Somalia.

SUD Sudan.

TIC Total Initial Cost.

TJ Terajoules.

TMR Total Material Requirement.

TZN Tanzania.

UGA Uganda.

UK United Kingdom.

UNCTAD United Nations Conference on Trade and Development.

USD United States Dollar.

VCA Value Chain Analysis.

ZAM Zambia.

ABSTRACT

Vision 2030 is Kenya's development blueprint aiming at making the country a newly industrialized middle income nation, and providing high quality of life for all the citizens. In support of this vision, this research work aimed at investigating the supply chain systems and demand for aluminium in Kenya. This is because aluminium has practically replaced copper in high-voltage transmission lines in Kenya. The other major uses of aluminium in Kenya include: domestic and industrial construction, packaging (aluminium foil, cans) and kitchenware. Material categories and transformation processes were identified and the material flows examined. Aluminium consumption, production and availability was determined by collecting secondary data from Kenya National Bureau of Statistics, Kenya Bureau of Standards, Ministry of Environment and Natural Resources, and Kenya Association of Manufacturers. The primary data and effects were acquired from the industry players through questionnaires that were distributed and interviews carried out in specific industries. The analysis was carried out through Material Flow Analysis and Value Chain Analysis.

Annual collective data on aluminium consumption, production, and efficiency to assist in running aluminium industry has not been available to users. Therefore there was a need to avail the data on the market in order to get a clear understanding and information on aluminium material transformation, consumption, production and use by the government and potential investors in Kenya.

The study established that from 2003 to 2007, local bauxite, imported bauxite, imported billets, coils and ingots, imported semi fabrications and castings, imported scrap and local scrap consumption increased steadily by 35% , 55% , 37.1% , 35% , 197% and 241% respectively. The year 2008 recorded a slight drop due to the 2007 political instability. Imported bauxite, unwrought aluminium and and wrought aluminium consumption was projected to increase by 53.1% , 54.9% and 32.8% respectively between the years 2009 and 2019. During the period of study, aluminium sector recorded Material Efficiency, Energy Efficiency and Capacity Utilization rate means of 80.95% , 26.68 mt/TJ and 48.84% respectively. The local industry efficiencies compared too low to the global Material Efficiency, Energy Efficiency and Capacity Utilization rate that varied between 92% to 98% , 80 mt/TJ to 92 mt/TJ and 81% to 93% respectively. Information on use of aluminium material in its primary and secondary states was provided.

The findings of the study will be useful to the private sector and government when establishing the cost of transformation, consumption and production that may lead to investing in aluminium processing plant in Kenya. Value chain analysis will provide the basis of determining the material costs that are incurred at each stage of the production cycle for this material, which will consequently facilitate the formulation of a long-term duty structure. This will form the basis for informed and supportive decisions from policy makers and during trade negotiations over tariffs with other countries. Current and potential investors will be able to forecast market trends in terms of aluminium material availability and efficiency by comparing with the

global trends.

CHAPTER 1

INTRODUCTION

1.1 Background

Aluminium deposits make up 7.3% of the earth's crust making it the third most common crustal element and the most common crustal metal on earth after iron and calcium [1]. Aluminium is a lightweight metal, resistant to atmospheric corrosion, a good conductor of electricity, and is versatile and strong when alloyed with other metals. The year 2006 saw aluminium overtake iron as the second most used material in new cars and trucks globally [2]. It has practically replaced copper in high-voltage transmission lines. The other major uses of aluminium in Kenya include: domestic and industrial construction, packaging (aluminium foil, cans) and kitchen ware (cutlery, pans) [3].

Aluminium is produced by mining bauxite, an aluminium ore, then refining it into aluminium oxide trihydrate, commonly known as alumina. The alumina is then electrolytically transformed into metallic aluminium with the use of smelters. It is approximated that for every two tonnes of alumina, one tonne of aluminium is produced [1]. The aluminium is then processed by casting, rolling, extrusion (due to its ductility and malleability) according to its application and subsequently used to make finished aluminium products. Such production requires a manufacturer to make large capital investments to produce aluminium from its raw materials. For example, Alcan Inc. report reveals that the Chinese full operating costs (FOC) for primary aluminium production is US $ 1,368 per tonne, which is above the world average by 26% [4].

A relatively large percentage, i.e, 60% of the material is imported from South Africa to Kenya in form of billets and coils while the rest is derived from locally sourced scrap [5]. The primary (new) scrap generated from used beverage cans and from other operations is melted and formed into ingots or finished products. Recycling reduces energy costs involved in making aluminium from bauxite by approximately 95% through elimination of mining, shipping, refining and processing costs [2]. By reducing the production costs, the nation will prosper through an economic development programme focussing on achieving an average Gross Domestic Product (GDP) growth rate of 10% per annum beginning in the year 2012.

Aluminium consumption is linked to world economic growth. In particular, there is a strong relationship between aluminium supply and demand in the construction, power transmission, transport and packaging industries. These industries together account for around 70% of world aluminium consumption. Information on the quantities of flows of aluminium material relating to specific forms of materials is required to shade more light. It is vital for the sustainable management of resource flows, particularly at the end-of-life stage where resources become wastes.

1.2 Problem statement

There was an increasing demand for prime aluminium and bauxite in household, packaging, construction and power transmission in Kenya. Therefore there was a need to predict the future flow and stocks of this material that will enable the country and potential investors to be in a position to develop ways of acquiring the primary and secondary material. These can only be implemented if relevant data on flow and stocks is provided. The forecast in this study determines if there is a need in establishing a processing plant that may lead to a reduction in production costs.

1.3 Objective

The general objective of this research was to investigate the supply chain systems and demand for aluminium in Kenya. The specific objectives of the research were:

i) To study the patterns of aluminium consumption and establish projections.

ii) To determine the efficiency of aluminium industry in Kenya and compare with the global practices.

iii) To relate the material flows to economic variables in order to provide further light on concepts such as resource productivity and sustainable resource management.

iv) To establish the economic viability of setting up alumina processing plant in Kenya.

CHAPTER 2

LITERATURE REVIEW

2.1 Bauxite Mining and Production

Bauxite ($Al_2O_3 \cdot H_2O$) is the aluminium ore that exists in three main variants, each containing hydrated forms of aluminium oxide. The variants depend on the crystalline structure and are known as gibbsite, bohmite, and diaspore. Gibbsite exists in trihydrate form, as opposed to monohydrate for the bohmite and diaspore, and is currently the most dorminant form being mined. Trihydrate forms contain approximately 50% alumina by weight. The largest known economic resources of bauxite occur in Australia and Guinea followed by Brazil, Jamaica and India [6].

Bauxite mining takes place in four main climatic groups. According to 1998 figures, the distribution was; 48% Tropical, 39% Mediterranean, 13% Subtropical and 0.5% Temperate. Major bauxite deposits are found in the Tropics, Caribbean and Mediterranean regions [7].

Bauxite is found in four different types of deposits; blanket, pocket, interlayered and detrital. Bauxite is extracted by open cast mining method. The topsoil is taken away and vegetation carefully preserved to await reinstatement. Front-end loaders, power shovels or hydraulic excavators mine the underlying bauxite, broken by explosives if necessary. Sometimes the bauxite is crushed and washed to remove some of the clay/sand waste and dried in rotary kilns. On the other hand it may just be crushed or dried. The ore is then loaded into trucks, railway cars or onto conveyor belts, and transported to ships or refineries for further processing.

2.1.1 Capital costs

Bauxite mining like other forms of mining is highly capital intensive. It has a very low value to weight ratio, dictating that its refining take place near the mine. This, combined with risks associated with substantial sunk costs, meant that mine developments were undertaken in conjuction with the construction of vertically integrated aluminium refineries, adding to the capital outlays involved [3].

2.1.2 Operating costs and key inputs

A typical operating cost structure of Australian mining is summarised as shown in Figure2.1. Labour was by far the largest item. Labour costs excluding contractor costs, accounted for 32% of total operating costs in 1996 - 1997. In addition, mining and other contractor's costs accounted for 11% of the total making labour related costs 42% of total costs. The next largest item accounting for 20% of the total, was fuels and electricity. The results of a survey of Australian aluminium industry showed that specific energy consumption at bauxite mines in 1998 was 46MJ/mt of bauxite [8].

2.1.3 Uses of bauxite

Bauxite finds a number of applications in industry which includes: production of alumina, abrasive, refractory, industrial chemicals, high-alumina cement, absorbant or catalyst for use by oil industry, welding coatings and fluxes and flux in making steel and ferro-alloys.

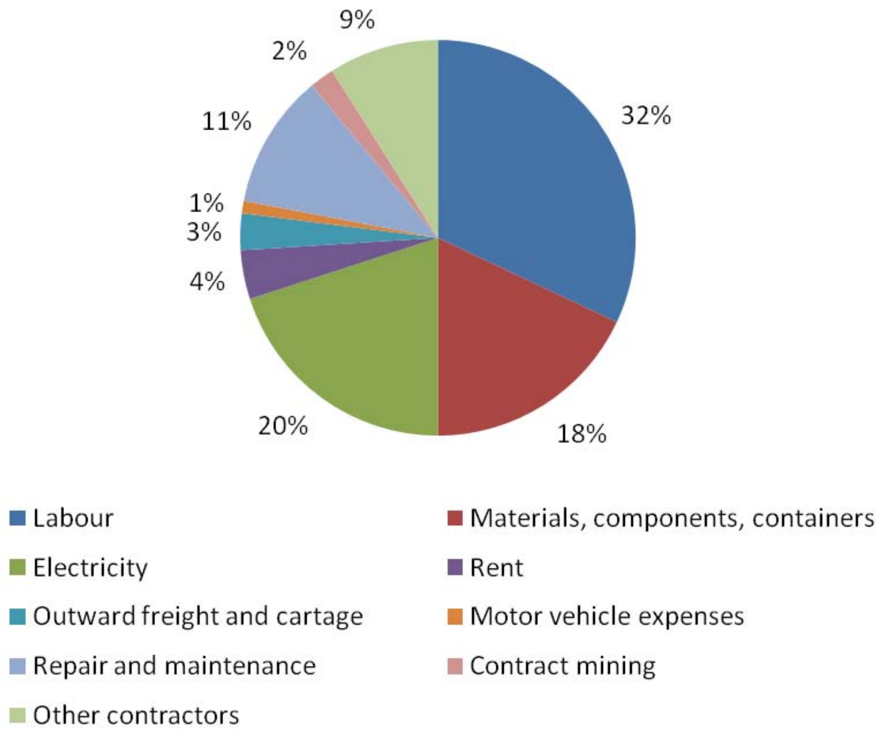


Figure 2.1: Operating costs and key inputs [8]

2.2 Alumina Refining and Production

The next in the aluminium production chain is the production of alumina. Producing alumina (Al_2O_3) from bauxite uses a process called Bayer Process in refining it into alumina. A flow chart for this process is displayed in Figure 2.2 [9].

Bauxite is first washed, ground and dissolved in caustic soda ($NaOH$), at high pressure and temperature. Bauxite becomes a liquid containing a solution of sodium aluminate ($Na_2Al_2O_4$) and undissolved bauxite residues containing iron, silicon and titanium. Gradually, these residues (red mud) sink to the bottom of the tank where they are removed. The resulting clear $Na_2Al_2O_4$ solution is fed to a precipitator to extract particles of pure alumina. These are further passed through a rotary or calciner to drive off chemically combined water. A white powder of pure Al_2O_3 is the end result [6].

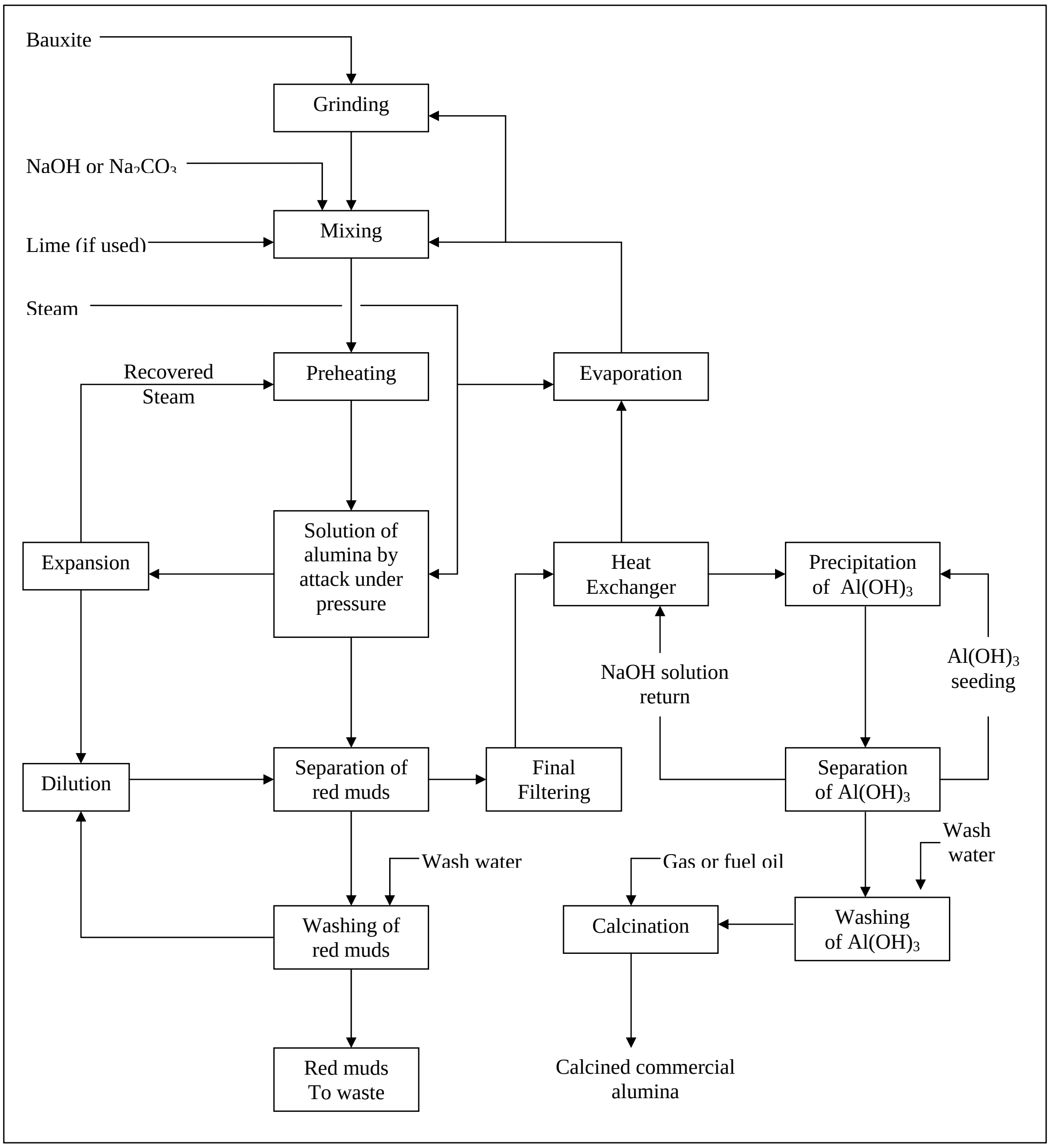


Figure 2.2: Flowsheet of the Bayer process [9]

2.2.1 Operating and investment costs

Cost of refining bauxite into alumina is ten times that of mining bauxite, that is, $USD^{1995}150/mt_{output}$. Table 2.1 shows distribution of operating costs [10]. Approximately 7.27 kWh of energy were required and 1.62 kg of CO_2 equivalent were released to refine the 1.93 kg of alumina from bauxite needed to produce one kilogram of aluminium in 2000 [11]

Table 2.1: World average operation costs for alumina refining [10]

S.No	Description	Percent of Operating cost
1	Bauxite	34
2	Labour	13
3	Electricity	3
4	Other Energy	22
5	Caustic soda	13
6	Other operating costs	15

With regard to operating costs, 59% are related to energy costs and bauxite material costs [12].

2.3 Aluminium Smelting

Alumina is insoluble in all ordinary chemical reagents at room temperature. Its melting point is high, above $2000^0 C$. Charles Martin Hall in the United States and Paul Lewis Toussaint Heroult in France independently developed and patented a commercially successful process for alumina reduction in 1886, commonly referred to as the Halt-Heroult process that is still in use [1]. The Halt-Heroult process takes place in a molten cell or pot. The cell consists of two electrodes (an anode and cathode) and contains molten bath of cryolite/sodium aluminium fluoride (Na_3AlF_3) which serves as an electrolyte and solvent for alumina. The electrodes comprises of pre-baked carbon anodes and carbon cathodes that serves as a melt container. An electric current is passed through the electrolyte at low voltage, but very high current, which reduces the alumina, to form liquid aluminium and oxygen gas. The oxygen gas reacts with the carbon anode made of petroleum coke and pitch to form carbon dioxide. Molten aluminium collects at the cathode in the bottom of the cell and is removed by siphon [7, 11].

2.3.1 Electricity Consumption

Being a very energy intensive industry, lowering the consumption for the smelting process is important for the industry, knowing that approximately 96% of electricity consumption for producing primary aluminium is related to this process (approximately 3% for alumina and 0.6% for bauxite mining) [10].

Electricity consumption from smelting plants differs somewhat in different regions, due to different technology mixes. Electricity consumption by region is as shown in Table 2.2 for 2002 [7].

Table 2.2: Electricity consumption for primary aluminium production in different regions [7]

S.No	**Region**	MWh_{el}/t_{output}
1	Africa	14.6
2	Americas	15.2
3	Asia	15.4
4	Europe	15.4
5	Oceania	14.5

2.3.2 Carbon Anode Energy Requirements

Anode blocks are typically baked in a neutral gas-fired furnace for several weeks. Quality anodes depend upon careful baking controls to gradually raise the temperature to about 1,250 ^oC. Volatile hydrocarbons from the pitch are gradually released during the baking process. Theoretically, these volatile compounds could provide sufficient heat for anode baking and no additional energy would be required. However, in practice, volatile organic compounds account for 46% of the energy input to the prebake ovens. The remaining 54% of the energy needed comes from fuel. Only about 30% of the input energy goes into making the anode, 24% is lost from oven surfaces, 29% goes up the stack and 17% is lost in other ways.

Approximately 0.61 kWh of energy were required and 0.12 kg of CO_2 equivalent were released in the manufacturing of the 0.45 kg of carbon needed to produce one kilogram of aluminium in 2000.

The total energy associated with primary aluminium production from bauxite ore was approximately 23.78 kWh per kg of aluminium in 2000. This consisted of:

- 8.20 kWh per kg of aluminium from raw materials and
- 15.58 kWh per kg of aluminium for electrolytic reduction.

2.3.3 Production and Consumption of Refined Aluminium

The largest alumina producers in ranked order are: Australia, China, United States, Jamaica and Brazil. Together, these countries' aluminium production contributed 60% of world alumina supply in 2002. The recent growth in Asian alumina production is mainly due to rapid growth in the Chinese industry [13]. World Aluminium reserves (in thousand metric tonnes) shown in table 2.3 gives the rest of the world a direction on how to utilize the available resources. From Tables 2.4 and 2.5, the world production of refined aluminium (in thousand metric tonnes) was greater than the world consumption of refined aluminium (in thousand metric tonnes) for respective periods, indicating a surplus [14].

Table 2.3: World Bauxite Mine Production, Reserves, and Reserve Base in metric tonnes [13, 14]

S.No.	Country	Mine Production			
		2005	2006	Reserves	Reserve Base
1.	Australia.	60,000	61,400	5,800,000	7,900,000
2.	Brazil.	19,800	21,000	1,900,000	2,500,000
3.	China.	18,000	20,000	700,000	2,300,000
4.	Greece	2,450	2,000	600,000	650,000
5.	Guinea.	15,000	15,200	7,400,000	8,600,000
6.	Guyana	1,500	1,500	700,000	900,000
7.	India.	12,000	13,000	770,000	1,400,000
8.	Jamaica	14,100	14,900	2,000,000	2,500,000
9.	Kazakhstan	4,800	4,900	350,000	360,000
10.	Russia.	6,400	7,200	200,000	250,000
11.	Suriname	4,580	4,800	580,000	600,000
12.	Venezuela	5,900	6,000	320,000	350,000
13.	Other Countries.	4,620	4,820	3,400,000	4,000,000
	World Total.	169,000	177,000	24,980,000	31,960,000

Table 2.4: World Production of Refined Aluminium in metric tonnes [13, 14]

YEAR	UNITED STATES	CANADA	FRANCE	NORWAY	GERMANY	AUSTR ALIA	UK	INDIA	CHINA	RUSSIA	WORLD TOTAL
2005	2,480	2,894	442	1,376	662	1,903	368	942	7,806	3,647	31,895
2004	2,517	2,592	451	1,322	668	1,895	360	861	6,689	3,594	29,992
2003	2,704	2,792	443	1,192	661	1,857	343	799	5,547	3,478	28,001
2002	2,705	2,709	463	1,095	653	1,836	344	671	4,321	3,348	26,076
2001	2,637	2,583	461	1,068	652	1,784	341	624	3,371	3,302	24,436
2000	3,668	2,373	441	1,026	644	1,762	305	649	2,794	3,247	24,418
1999	3,779	2,390	455	1,020	634	1,719	270	621	2,598	3,146	23,710
1998	3,713	2,374	424	996	612	1,626	258	545	2,335	3,005	22,654
1997	3,603	2,327	399	919	572	1,490	248	547	2,035	2,906	21,798
1996	3,577	2,283	380	862	577	1,372	240	531	1,771	2,874	20,846

Table 2.5: World Consumption of Refined Aluminium in metric tonnes [13, 14]

YEAR	UNITED STATES	CANADA	SPAIN	FRANCE	GERMANY	ITALY	UK	JAPAN	CHINA	RUSSIA	WORLD TOTAL
2005	6114	803	624	719	1773	977	353	2276	7119	1020	31,622
2004	5800	760	603	749	1795	987	439	2319	6043	1020	29,888
2003	5667	736	596	754	1916	956	302	2235	5178	802	27,605
2002	5509	747	533	762	1690	850	428	2010	4115	990	25,370
2001	5230	743	508	746	1580	756	433	2014	3492	786	23,721
2000	6161	800	526	782	1491	780	576	2225	3499	748	25,059
1999	6158	777	494	774	1439	735	597	2112	2925	563	23,312
1998	5814	721	436	734	1519	675	579	2082	2425	489	21,825
1997	5390	644	430	724	1558	654	583	2434	2260	469	21,797
1996	5348	614	360	672	1355	585	600	2386	2135	444	20,650

Generally, mining of bauxite and the conversion of bauxite into alumina, is a weight loosing process and is therefore recommended to be located near the source of the raw material to minimize transportation. Although the smelting process is also a reduction process, transportation costs are no longer the major locational determinant. Rather, the principal locational cost is electricity while other costs are carbon electrodes, labour and capital costs. Figure 2.3 shows the net weight of material of obtained from each process of aluminium production from the raw material (bauxite).

2.4 Future primary aluminium demand

Primary aluminium demand is expected to increase in the years to come, for the world in general as well as for the different regions. In order to make projections about this future demand, macroeconomic relationships between aluminium consumption and national income are utilized. Primary aluminium demand (PAD) is econometrically estimated as a simple logarithmic function of GDP for individual

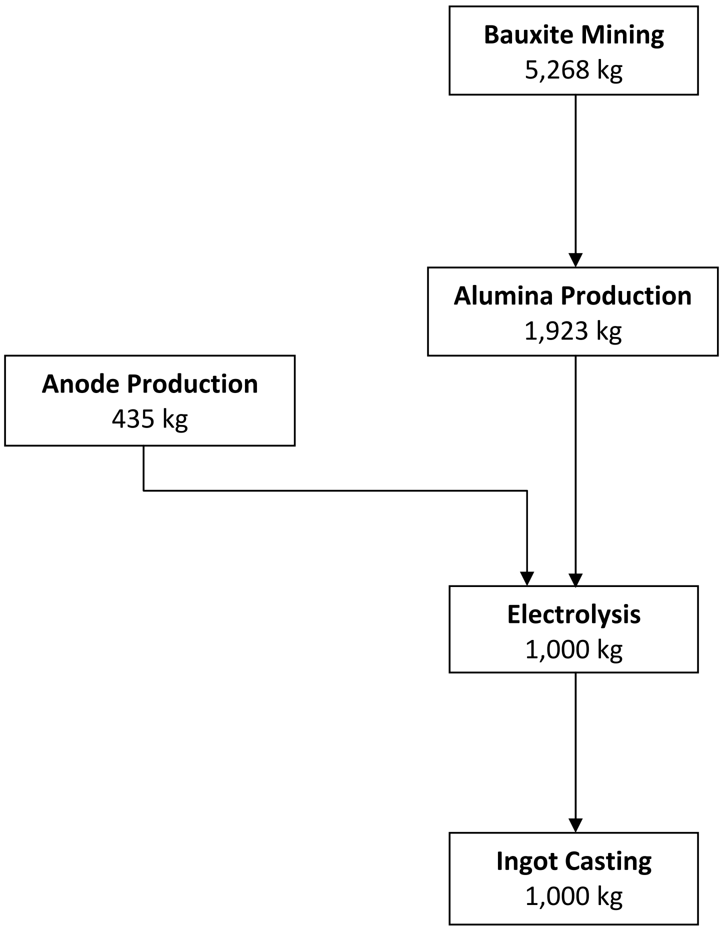


Figure 2.3: Weight flow diagram for primary aluminium production [11]

regions, attempting to capture the effect of the "market saturation" with rising income [15]. Equation 2.1 shows the relationship between GDP and PAD

$$PAD = \alpha + \beta \ln GDP \tag{2.1}$$

α and β are found by regression. GDP projections for different regions are provided by UNCTAD [16], while the path to 2050 technical report provides the same for China and India [17]. India and China are examined on their own due to their large populations and potential growth. Figure 2.4 shows projected PAD for different regions as well as the world total.

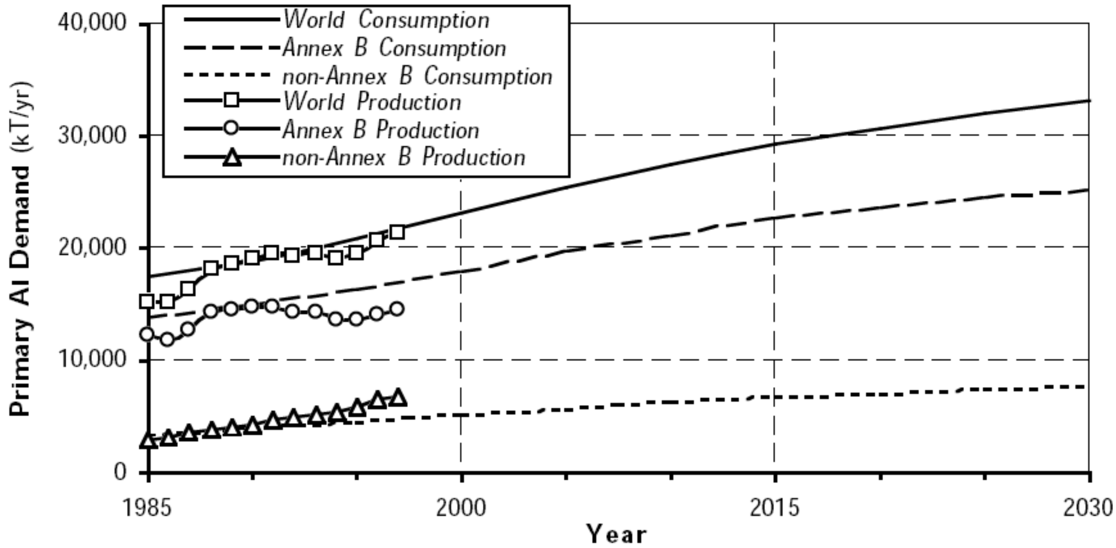


Figure 2.4: Projections of future primary aluminium demand (*See text for explanation for annex B and non-annex B*) [15]

The demand curves in Figure 2.4 are all increasing, and world PAD is estimated to nearly double in the next fifty years. The PAD is divided into two regions, i.e Annex B and Non-Annex B. Annex B included countries like USA, Japan, Canada that produced primary aluminium from imported bauxite while Non-Annex B included countries like China, India, Guinea, Brazil, et cetera, that produced primary aluminium from bauxite from locally mined bauxite. Europe will experience the largest demand, followed by North America and China. However, looking at growth rates, both Europe and China will experience substantially higher growth than North America, which actually has the lowest growth of all regions. The region of Middle

East and Africa has the highest growth of all, followed by India and China. PAD in 2050 is displayed in Table 2.6 for all regions relative to the 2000 level, showing that developing countries will have the strongest growth.

Some regions have fairly equal growth rates over the entire period, while others, like China, increase more rapidly in the beginning. It might be due to higher saturation concerning aluminium demand, and a sign of PAD growing in pace with the economy for Europe and North America (when measured as annual percentage increase), while for China PAD growth will be higher than economic growth in the beginning, and eventually slow down as the market becomes more saturated. The less developed countries will be able to have strong PAD growth for a longer period than the western economies, as an expanding economy is more materials intensive than a more developed and service oriented economy.

Table 2.6: Growth in PAD as from 2000 to 2050 [15]

Region	***PAD Growth***
Middle East and Africa	403 %
India	346 %
China	257 %
Africa	236 %
Latin America	222 %
South Asia	198 %
Other Pacific Asia	185 %
Europe	173 %
Oceania and Japan	139 %
North America	135 %
World Total	*187 %*

2.5 Material Flow Analysis

The core of industrial ecology as an emerging scientific field is the study of the industrial metabolism. Understanding the structure, quantity and quality of the industrial metabolism requires analysis of material flows from resource extraction to final waste disposal. This entails determining and quantifying the types of material flows and cycles, e.g., the amount of physical input into an economy, material accumulation in the economy, and outputs to other economies or to nature. Material flow analysis (MFA) is a development tool, which examines how materials and energy flow into, through, and out of a system. The principle behind MFA is the first law of thermodynamics on the conservation of matter: that matter, i.e., mass or energy, is neither created nor destroyed by any physical transformation (production or consumption) processes. This material balance principle provides a logical basis for physical bookkeeping of the economy-environment relationship and for the consistent and comprehensive recording of inputs, outputs and material accumulation. There are different types of MFA models, in which the target of the analysis can be a selected substance (e.g., a chemically defined element or compound such as carbon dioxide), a material (e.g., natural or technically transformed matter that is used for commercial or non-commercial purposes such as iron and steel), a product (such as a fuel cell), or an economy. In life cycle assessment (LCA), the MFA methodology targets one product in a specific or average life cycle. MFA when used at a national level provides an aggregate overview, in mass, of annual material inputs and outputs of an economy, including inputs to and output from the national environment and the physical amounts of imports and exports. The net stock change or net accumulation is equal to the difference between inputs and outputs. MFA methods are gaining in popularity as a means to apply a systems view to many types of decisions: from product development and design, to business management, and to public policy. Generally two basic types of MFA can be distinguished [18]. The first type starts with specific problems related to selected substances [19, 20]. Examples of this type of MFA include studies on heavy metals, nitrogen, carbon and chlorinated substances. The second type starts with the question on whether the volume and structure of the throughput of selected sectors or regions are sustainable. This type of MFA aims at dematerialization and the restructuring of the industrial or societal metabolism and increase of resource productivity. Examples of this second type MFA include studies on the construction and chemical sectors, studies of cities, regions or national economies that analyze selected material flows or the total material throughput. The first type of MFA is normally applied to control the flow of hazardous substances such as heavy metals. Findings from this type of MFA have a significant influence on governmental policy as well as industries themselves. The second type of MFA is useful in providing material flow accounts for regular use in official statistics, deriving indicators for progress towards sustainability and supporting policy debate on goals and targets. These environmental pressure indicators include total material requirement (TMR) and direct material input (DMI). These material flow indicators are appearing more frequently in official outputs of many institutions and organisations such as Eurostat, the European Environment Agency and the United Nations [21].

The aluminium time series MFA found that the ultimate demand for aluminium has grown fairly steadily over the past 40 years [22]. In terms of sources of the flows, currently around 60-80% of the goods containing aluminium in use in the UK also come from imports. The significance of imported goods in meeting domestic needs does not mean low domestic production. Around half of the upstream production (i.e, aluminium products and in producing goods containing the metal) in the supply chain is exported. Unlike the developments over time in the iron and steel supply chain, the upstream aluminium supply chain has seen an increase in production as well as in imports and exports over the past two decades in UK. The aluminium supply chain depends on imported aluminium products to fulfil 40-50% of demands in downstream goods manufacturing. On the other hand, 60-70% of goods containing aluminium produced in the UK are exported. Accompanying these dynamic material flows are stocks of different material categories including both manufacturing and industrial stocks and stocks of products in use, together with prompt and EOL scrap arising from used goods. In early studies, it is indicated that about 700,000 tonnes per year of prompt and EOL aluminium scrap was released from used goods. As in the case of iron and steel, about 70-80% of this scrap is recovered, either reused/recycled domestically or exported. Less than 30% is lost from the economy, of which 80% ends up in landfill. Over the past 40 years, UK has seen a growing output from the aluminium recycling industry. Secondary unwrought aluminium production has remained fairly stable, currently accounting for 40-50% of total unwrought aluminium output in the UK [22].

The mineral industry in Kenya was noted chiefly for its production of flourspar, salt, and soda ash. Other industrial minerals produced in recent years included diatomite, feldspar, gypsum, lime, silica sand, and vermiculite. Building materials produced included cement, coral, granite, limestone, marble, and shale. Kenya produced small amounts of gold, iron ore, lead, secondary aluminium, and steel. The country also produced carbon dioxide gas, gemstones, and refined petroleum products. According to the production of mineral commodities data available, it was estimated that secondary aluminium produced in the years 2000 up to 2004 was 2004 mt per year [23]. Information on the consumption of this metal has not been highlighted in the reports provided. Therefore, it created a need to avail this data for planning and investment purposes.

2.6 Value Chain Analysis

In its most common application, supply chain at firm level is a strategic management or cost accounting tool used to diagnose and enhance a company's competitive advantage. The analysis does this through a breakdown of an organization' strategic activities (so called value activities) and an examination of their costs and the streamlining and coordination of the linkages of those activities within the value chain. This exercise can enhance the efficiency of a company's internal operations and aid decisions concerning investments and expansions [24]. Competitive advantage stems not only from the value activities in themselves, but also from the way they are related to each other through linkages within the value chain. Undertaking value chain analysis at the industry level, examining linkages at the level of an industry or a whole supply chain helps companies make strategic decisions, such as if and how to expand current activities, where to focus capital investments, and identification of suitable suppliers and buyers.

The two concepts of a chain of activities/actors in production and of economic competitiveness strike the basic levels with certain aspects of environmental management that have a clear link between economic competitiveness and environmental performance through resource productivity improvements. Due to a lack of adequate data, clear resource efficiency trends are hard to establish, and the results should be treated with caution. No data exist on material inputs into aluminium production, other than the basic formula describing the conversion of bauxite into primary aluminium. Given that the conversion of bauxite to alumina is fixed by stoichiometry, primary material efficiency gains must be negligible. Primary aluminium production is substantially more energy intensive than secondary production. Both kinds of production have improved their energy efficiency, with primary aluminium production increasing its relative output from 16.6 to 18.2 tonnes per Terajoules (TJ) energy consumed between 1980 and 2001, and secondary production from 115 to 128 tonnes per TJ between 1988 and 2001. For aluminium production as a whole (combining primary and secondary aluminium production), there have therefore been overall efficiency gains. Energy efficiency increased by 47% between 1988 and 2001, to produce 46 tonnes of aluminium per TJ energy consumed in 2001. As aluminium output grew by 45% to almost 1.2 million metric tonnes (mt), total energy consumption was up 15 percent to 25,000 TJ in 2001.

This analysis demonstrated the sensitivity of the industry, in terms of levels of energy efficiency and absolute energy use, to the relative proportions of primary and secondary aluminium production. According to the data analyzed, primary smelting uses about seven times as much energy as refining and re-melting activities. The significant change in energy efficiency are positive, as is the growth in the industry; however, the total increase in energy consumption is less desirable from an environmental point of view. Economic labour productivity, value added per worker, has fluctuated quite widely, in what appears to be a gradual upward trend in UK. Value added per worker was about £35,000 in 2001. However, material labour productivity shows constant and dramatic improvements over the whole time period studied. Between 1980 and 2001, material output per worker almost tripled, to 58 tonnes of aluminium products per worker in 2001. Even though UK production of aluminium semifabrication (semis) and castings more than doubled between 1980 and 2001, the associated employment declined by 56% in the same time period, to 12,000 employees in 2001.

In contrast to the energy efficiency indicators, resource productivity indicators show productivity declines over the period studied. It was not possible to create a material productivity indicator of the form 'value added per unit of material input' for the aluminium industry, as no data on materials consumed were available. Data on outputs of semis and castings were therefore used to formulate a proxy material productivity indicator. This indicator showed wide fluctuations in what appeared to be a downward trend: the value added, in real terms, per tonne of aluminium output decreased by 56% to £600 in 2001. Despite growth in output, value added by the industry also declined in absolute terms: the value added by the UK aluminium industry decreased by 46% , to £416 million, between 1980 and 2001.

In addition, energy productivity indicator showed a steady decline in value added per unit of energy consumed since 1995 in UK. As with the iron and steel industry, the reduction in resource productivity in the aluminium industry directly reflected a reduction in employment, lower aluminium prices and increased material labour productivity in the industry. For both steel and aluminium, the resource efficiency indicators demonstrated significant improvement in UK, whereas resource productivity indicators, employing monetary output variables, demonstrated declines. This provided further support for the conclusion above that resource productivity may not be a particularly meaningful indicator at the sector level. Again, this was in contrast to the national level, where the indicator gave useful insights into the productivity of natural resource use [22].

The work undertaken paired the material flow analysis with a value chain analysis in providing an avenue for successful linkage of the physical and economic dimensions of material flows. Both material flow and value chain analysis can handle large systems; both have an explicit focus on the different stages of a production chain and the transformations through the chain, in material or financial terms. In this analysis, individual firms from Nairobi, Thika and Mombasa were sampled in order to give a clear relationship between the inputs and the outputs. This included;- East African Cables Ltd (Nairobi), Booth Manufacturing (Thika), Kaluworks, Mabati Rolling Mills (Mombasa).

CHAPTER 3

MATERIAL FLOW ANALYSIS

3.1 Introduction

Aluminium is the third most abundant element after oxygen and silicon, accounting for 8% of the earth 's crust [25]. In this section, the supply chain systems for aluminium in Kenya was explained. Material categories and transformation processes were elaborated and the material flows examined.

This study aimed to understand the stocks and flows of aluminium in the Kenyan economy by carrying out a material flow analysis (MFA). The MFA was employed to reveal past and present patterns of production, transformation and consumption of these metals in Kenya. The purpose of tracking the flow of aluminium from point of entry into the economy to its point of final disposal by mass balance principle was to identify:

- the quantities of the basic metal itself
- the quantities of the major components and products into which the metal was incorporated
- the flow of the metal through the economic sectors which own the metal for consumption or production purpose and which produce positive, zero or negative value material as waste

- the industrial sectors within which the metal was physically located

3.2 Material categories

3.2.1 Bauxite

The aluminium ore most commonly used for the extraction process is bauxite, which is impure since it contains appreciable amounts of iron compounds. Naturally occuring aluminium compounds, known as alumino-silicates, are very stable and the extraction of metallic aluminium is a very complex series of industrial processes [1]. When aluminium silicate minerals are subjected to tropical weathering, aluminium hydroxide minerals may be formed. Rock that contains high concentrations of aluminium hydroxide minerals is called bauxite. It is the raw material for almost all productions of alumina.

In Kenya Bauxite is mainly utilised in cement industry as a strengthening element of the building material. The cement industries include Bamburi Portland Cement Company Ltd (BPCCL), Athi River Mining (ARM), and East African Portland Cement Company Ltd (EAPCCL). The above three companies are operating at a capacity of 3.9 million tonnes per year, but they are all upgrading their capacity. Mombasa Cement Limited (MCL) is currently under construction at Athi River and is about to resume its operation that will increase the current capacity by 700 000 tonnes per year. In addition an Indian giant Cemtech Ltd is in the process of establishing a cement plant in Pokot Central district on the Kenya-Uganda (Ortum-

Sebit/Chebichoi area) border. This may come in at least three years time and increase the capacity by 1.2 million tonnes.

3.2.2 Alumina

Bauxite is turned into alumina (Al_2O_3) in the well-established Bayer process (as discussed in the previous chapter). 100 tonnes of bauxite produces about 40 - 50 tonnes of alumina. Normally this process is carried out close to the mine site, but there are plants in Europe where the alumina is produced at the aluminium smelter site. In Kenya, this material category does not exist due to unavailability of the processing plant.

3.2.3 Ingots, billets and slabs: (Unwrought aluminium)

Aluminium ingots, billets and slabs can be produced either by the electrolytic reduction of alumina or by secondary smelters. Molten unwrought aluminium can be cast into ingot or larger blocks known as sows which are destined for remelting. More usually the molten aluminium from the electrolytic cells is transferred to a holding furnace typically with a capacity of up to 50 tonnes of metal. There it is alloyed with a variety of elements such as iron, silicon, magnesium and copper. The alloy is then cast into extrusion billets or rolling slabs using a semi-continuous process known as direct chill (DC) casting. These products can be sent directly to casting houses and wrought processing factories for fabrication into semi-finished products such as extruded, rolled and sheet, plate and foil. In Kenya, this process does not exist but aluminium ingots, billets and slabs are imported, which undergo further operations to make them wrought products. Further operations carried out on this category include: rolling, extrusion, casting and forging.

3.2.4 Semi-fabrication and castings

Semi-fabrications and castings consist of all the finished aluminium that leaves the aluminium producers in the form of alloy castings, rolled products, extrusions, powders, et cetera. Aluminium and its alloys are generally divided into two broad classes; castings and wrought (machanically worked) products. Wrought aluminium and its alloys are specified into nine series of European standards and are classified by chemical composition in an internationally agreed four digit system [26]. Typical wrought products are extruded products such as bars, sections and tubes, rolled products such as plates, sheets, wires, strips and circles. Wrought and cast products can be processed from primary unwrought aluminium. They can also be produced from recycled scraps directly. Despite good statistics on the production of different aluminium fabrication and castings categories, care must be taken to avoid double counting. For example, both aluminium extrusion and forgings are semi-fabrications, but forgings are sometimes produced from extruded bars. If the metal is counted in the supply chain as an aluminium extrusion, it should not then be counted again as an aluminium forging. Extrusion is the category that is carried out by most companies in Kenya. Some of the companies carrying out major semi-fabrications and castings include East African Cables Ltd, Kaluworks Ltd, Booth

Extrusions, Mabati Rolling Mills, Narcol Aluminium Ltd, Cannon Aluminium Ltd, Hebatulla Ltd, et cetera.

3.2.5 New goods

These are all physical products that are manufactured/fabricated to be used in the economy by private, corporate or government consumers. They typically contain a variety of components made of various pure and composite materials. The category of aluminium contained in new goods accounts only for the aluminium that is embodied in all the different new goods that are about to enter the use phase in Kenya. Most of these material are received in form of construction, transport and engineering tools/materials such as machine brackets, hoppers, guards, guides et cetera.

3.2.6 Aluminium prompt and end-of-life scrap

Aluminium industry in Kenya only differentiates between two types of scrap: new and old. New scrap is a combination of home (these are cuttings, turnings, salt slag and dross from aluminium production) and prompt scrap (it is generated at manufacturing sites that produce new goods containing aluminium). Much prompt industrial scrap is similar in principle to internal scrap from the semi-fabrication stage. It may be off-cuts of sheets and extrusion, or damaged products, which are easily identifiable by type of alloy and are relatively uncontaminated. Most prompt scrap, together with the scrap from semi-fabricators that do not have their own remelting facilities, is suitable for returning to semi-fabricators or to specialist remelting operations.

Other forms of new industrial scrap are machine turnings, swarf and other material from the milling, boring or cutting of metals. This scrap may be of mixed alloy composition and will almost certainly be contaminated with oils, other metals, paint, dirt etc. It is normally collected by merchants or supplied directly to secondary smelters for processing. EOL or old scrap is generated when the material is recovered from used and/or dismantled products. Only the latter category is locally available in increasing quantities but the quality of such scrap progressively worsens unless cleaning treatment is used [27].

3.3 Forecasting

Forecasting is the art and science of predicting future events. It is an input for operation decisions on process design, capacity planning and inventory. Inventory decisions resulting in purchasing actions tend to be short-range in nature and deal with specific products. Forecasting can be classified into four basic types: qualitative, time-series analysis, causal relationships and simulation. Forecasting is used for many purposes in marketing, including sales planning, new-product introduction, design of marketing programs, pricing decisions, advertising and distribution planning.

In selecting forecasting model, it will depend on the following,

- Time horizon to forecast
- Data availability
- Accuracy required
- Size of forecasting budget
- Availability of qualified personnel

In summary, there are different types of decisions in operations and different forecasting requirements, as shown in Table 3.1

In time-series analysis, the idea that data relating to the past demand is used to predict future demand. Past data may include several components, such as trend, seasonal or cyclical influences. Under time-series analysis we have the following techniques:

Simple moving average: A time period containing a number of data points is averaged by dividing the sum of the point values by the number of points. Each, therefore, has equal influence.

Weighted moving average: Specific points may be weighted more or less than the others, as seen fit by experience.

Exponential smoothing: Recent data are weighted more with weighting declining exponentially as data become older.

Regression analysis: Fits a straight line to past data generally relating the data value to time. Most common fitting technique is least squares.

Box Jenkins technique: Very complicated but apparently the most accurate statistical technique available. Relates a class of statistical models to data and fits the model to the time-series by using Bayesian posterior distributions.

Shiskin time-series: Developed by Julius Shiskin of the Census Bureau. An effective method to decompose a time-series into seasonals, trends and irregular. It needs at least three years of history. Very good in identifying turning points, for example, in company sales.

Trend projection: Fits a mathematical trend line to the data points and projects it into the future.

Causal forecasting assumes that demand is related to some underlying factor(s) in the environment using linear regression technique, econometric models, input/output models and leading indicators. For example, sales may be affected by advertising, quality and competitors.

Simulation models are dynamic models, usually computer-based that allows the forecaster to run through a range of assumptions about the condition of the forecast. Depending on the variables in the model, the forecaster may ask such question as, what would happen to my forecast if the price is increased by 10% ?. What effect would a mild national recession have on my forecast?. On the other hand, qualitative techniques are subjective or judgemental and based on estimates and opinions. Qualitative technique applies the use of grass roots, market research, panel consensus, historical analogy and Delphi method analysis [28].

Table 3.1: Forecasting uses and methods

Use	Time Horizon	Accuracy Required	Number of Forecasts	Management Level	Forecasting Method
Process design	Long	Medium	Single or few	Top	Qualitative or causal
Capacity planning facilities	Long	Medium	Single or few	Top	Qualitative and causal
Aggregate planning	Medium	High	Few	Middle	Causal and time-series
Scheduling	Short	Highest	Many	Lower	Time-series
Inventory management	Short	Highest	Many	Lower	Time-series
program					
Pricing decisions	Short	High	Many	Middle	Time-series
New-product introduction	Medium	Medium	Single	Top	Qualitative and causal
Cost estimating	Short	High	Many	Lower	Time-series
Capital budgeting	Medium	High	Few	Top	Causal and time-series

CHAPTER 4

VALUE CHAIN ANALYSIS

4.1 Introduction

This chapter will expand on the concept of the value chain and look at how it has been applied in other areas of study, and introduce the methodology of value chain analysis that was used in this report.

4.2 Definitions

4.2.1 The simple value chain

A value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use. In this chain, there are ranges of activities within each link of the chain. Although often depicted as a vertical chain, intra-chain linkages are most often two-way. For example, specialised design agencies not only influence the nature of the production process and marketing, but are in turn influenced by the constraints in these downstream links in the chain (Figure 4.1). Simple value chain captures the spine (central activities) of the chain. For example, consider Figure 4.1, where the main link is connecting from design to production to marketing and finally ending with consumption and recycling.

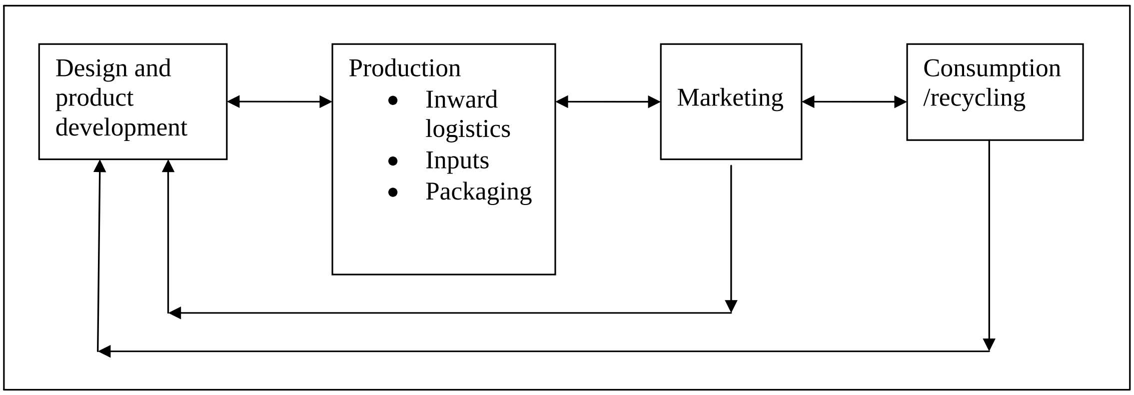


Figure 4.1: Four links in a simple value chain [29]

4.2.2 The extended value chain

An extended value chain tends to have many more links and service activities than a simple chain, for example, the case of the furniture industry (Figure 4.2). This involves the provision of seed inputs, chemicals, equipment and water for the forestry sector. Cut logs pass to the sawmill sector which gets its primary inputs from the machinery sector. Sawn timber moves to the furniture manufactures who, in turn, obtain inputs from the machinery, adhesives and paint industries and also draw on design and branding skills from the service sector. Depending on which market is served, the furniture then passes through various intermediary stages until it reaches the final customer, who after use, consigns the furniture for recycling.

4.2.3 One or many value chains

In addition to the manifold links in a value chain, typically intermediary producers in a particular value chain may feed into a number of different value chains (Figure

4.3). In some cases, these alternative value chains may absorb only a small share of their output; in other cases, there may be an equal spread of customers. But the share of sales at a particular point in time may not capture the process. The dynamics of a particular market or technology may mean that a relatively small (or large) customer/supplier may become a relatively large/small customer/supplier in the future [29].

4.3 Importance of value chain analysis

There are three main sets of reasons why value chain analysis is important in this era of rapid globalisation [30]. They are:

- with the growing division of labour and the global dispersion of the production of components, systemic competitiveness has become increasingly important.
- efficiency in production is a necessary condition for competition on global markets.
- entry into global markets which allows for sustained income growth, that is, making the best of globalisation, requires an understanding of dynamic factors within the whole value chain.

In addition, value chain analysis plays a role at a firm level when the firm is pursuing an upgrading strategy and at industry or national level when the governnment has a strategy of supporting or upgrading particular industries [31], for example:

- process upgrading: increasing the efficiency of internal processes such that these are significantly better than those of competitors in individual link or between links in the chain (for example, lower scrap levels by considering the material efficiency, more frequent, smaller and on-time deliveries)
- product upgrading: introducing new products or improving old products faster than competitors. This involves changing new product development processes both within individual links in the value chain and in the relationship between different chain links.
- functional upgrading: increasing value added by changing the mix of activities conducted within the firm (for example, taking responsibility for, or outsourcing accounting, logistics, and quality functions) or moving the focus of activities to different links in the value chain (for example from manufacturing to design)
- chain upgrading: moving to a new value chain (for example, Athi River Mining moved from industrial minerals, to sodium silicate, to hydrated lime and now to fertilisers)

4.4 Origins and applications

Concepts of 'value chains' can be traced to different sources and applications. The term is used often rather loosely, referring not only to flows of money between parties but also flows of products and information. However, the work of Michael

Porter [24] has had a key influence on value chain thinking and helped establish a common framework and vocabulary for its study, primarily within business and management science [29].

Value chain analysis, as it is most commonly applied, is a strategic management or cost accounting tool used to diagnose and enhance a company's competitive advantage. The analysis does this through a breakdown of an organisation's strategic activities (so called value activities), an examination of their costs, and the streamlining and coordination of the linkages of those activities within the 'value chain'. This exercise can enhance the efficiency of a company's internal operations; and aid decisions concerning investments and expansions.

The concept has also been applied to studies of international trade from a political framework of development and underdevelopment, with a focus on the different actors in a chain and their differential capacities for wealth appropriation within the chain. Both types of applications of VCA however are concerned with identifying ways in which incomes or profits can be sustained over time.

4.5 Resource productivity and efficiency

Resource productivity indicates the economic output per material or energy input need to be created while efficiency defines how well the process utilizes the resources provided. Economic activity is associated with resource flows related to the extraction, production, consumption/use, and disposal of materials and products. Many current environmental problems are rooted in the size of society's material throughput, suggesting that a decoupling of economic growth and resource flows is needed to reduce environmental impacts while improving quality of life.

Such a decoupling hinges on improvements in resource productivity and efficiency, defined broadly as doing more with less. Decoupling can be either relative or absolute. Relative decoupling means that the productivity improvements - fewer inputs required per unit of output - have been realised but total inputs continue to increase as output increases. Absolute decoupling refers to the situation in which there is an overall reduction in required inputs, whether through significant productivity improvements or through a decrease in outputs, or a combination of the two.

Resource productivity and efficiency trends in the aluminium industry are to be examined, using both time series data on material and energy inputs and outputs for measures of material and energy efficiency, and time series data on material and energy flows in combination with data on economic output to create measures of material and energy productivity.

4.6 Value chain mapping

Value chain analysis applied in this study, was required to give a clear recognition that the stocks and flows of aluminium had associated economic values. As materials are transformed and passed along a chain of production, fabrication, use/consumption and reuse or disposal, the value of the materials is either enhanced or reduced. All the various material flows of aluminium to be investigated in this study have associated economic values.

One concern of this study was to identify and map the magnitude of these changes in material values throughout the Kenyan economy, as well as to identify the processes which hold the greatest value-creating or value-diminishing potential. In this study, input/output, geographic aspect and governance, which are the three main elements in value chain analysis were considered as below.

4.7 Chain of value adding activities

Value chain is a sequence of value adding economic activities and that it can be conceptualised in three dimensions: input-output structure, geographic spread and pattern of direct or indirect control (governance) [32].

4.7.1 Input-output structure

In this sense, a chain is a set of products and services linked together in a sequence of value-adding economic activities. A product is first designed, then raw materials purchased and production takes place, and finally the product is distributed through wholesalers and retailers. At each stage, services such as transport or finance may be needed to keep the process going.

4.7.2 Geographic spread

Some chains are truly global, with activities taking place in many countries on different continents. Others are more limited, involving only a few locations in different parts of the world. A US constructor may, for example contract with a Guinea Bauxite refiner to supply unwrought aluminium to aluminium production plant in Canada. The finished Aluminium semi fabrications will then be shipped directly to the US constructor. It is also possible to identify national, regional or local value chains. These operate in the same way as the global chains, but their geographic 'reach' is more limited.

4.7.3 Pattern of control: direct or indirect

In these dimensions, different actors can influence/control over the activities making up the chain. The actors in a chain directly control their own activities and are directly or indirectly controlled by other actors. A retailer, for example, controls the way he sells, but may be limited (indirectly controlled) by the range of goods available from wholesalers and producers. The pattern of direct and indirect control in a value chain is called its governance.

Governance ensured that interactions between various firms along the value chain exhibited some reflection of organisation rather than being simply random. Value chains are governed when parameters requiring product, process, and logistic qualification are set which will have consequences up or down the value chain encompassing bundles of activities, actors, roles and functions [33]. Governance can be considered in three main forms that includes: legislative, judicial and executive [34].

4.7.3.1 Legislative governance

In legislative governance, the standards are set for suppliers in relation to on-time deliveries, frequency of deliveries and quality. For example, conformance to international standards on quality (ISO9000), environmental (ISO14000), labour (SA8000) and hazard analysis and critical control point (HACCP). The definition of these various sets of rules as defined in the basis of participation in value chains sets the parameters governing the value chain.

4.7.3.2 Judicial governance

Judicial governance plays a major role when there is need to audit perfomance and to check compliance with rules set, that is, coordinating the conformance to the set parameters.

4.7.3.3 Executive governance

Executive governance provides assistance to value chain participants in meeting these operating rules, that is, managing the various subordinate links in the value chain. This may be direct (helping a supplier achieve quality standards for example) or indirect (forcing a first-tier supplier to assist a second-tier supplier, or introducing a supplier to a service sector firm which can assist it in meeting the standards required) [33].

When the market governs a value chain, most transactions take place between buyers and sellers dealing at arms length. The value chain for most aluminium products in Kenya such as cement, electric cables, engineering machine elements, kitchenware are good examples of market driven chains. For example, cement industry in Kenya produces standard pozzolana portland cement (PPC) and ordinary portland cement (OPC) that is internationally recognized and accepted. Therefore, the buyers and sellers do not need to collaborate on cement definition since it is a standard product. Buyers simply place orders for a given quantity of particular quality.

In power transmission industry, cables are manufactured as per the international specifications that are checked for conformance by the government. Specific cables are made as per the size, quality and materials type that are defined in the international standards.

During aluminium smelting and its products production, toxic gases such as CO_2 are produced and disposed into air. To protect the workers and the environment from these harsh conditions, environmental, labour, safety and healthy standards regulated by the government are observed by the industry.

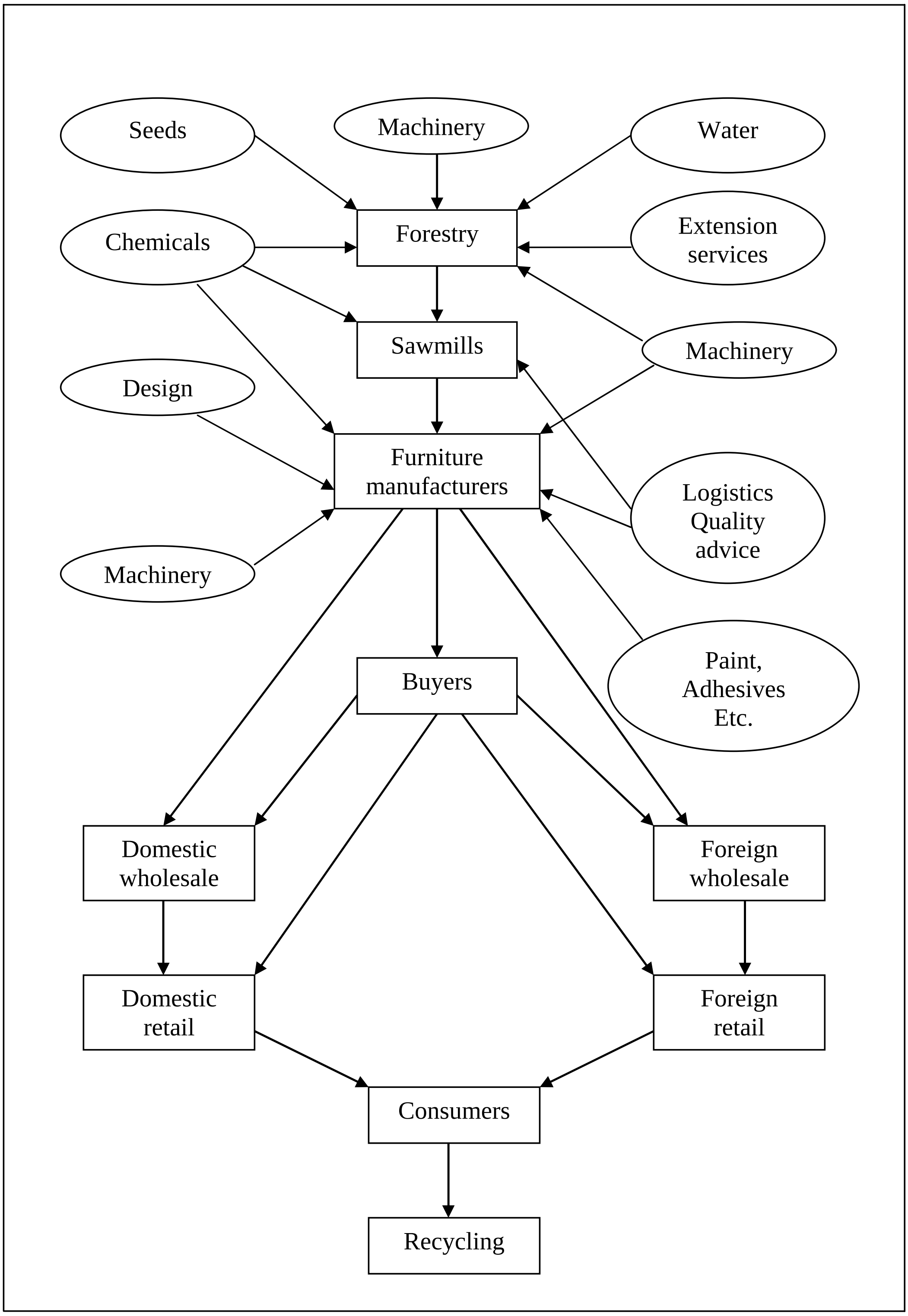


Figure 4.2: The extended value chain [29]

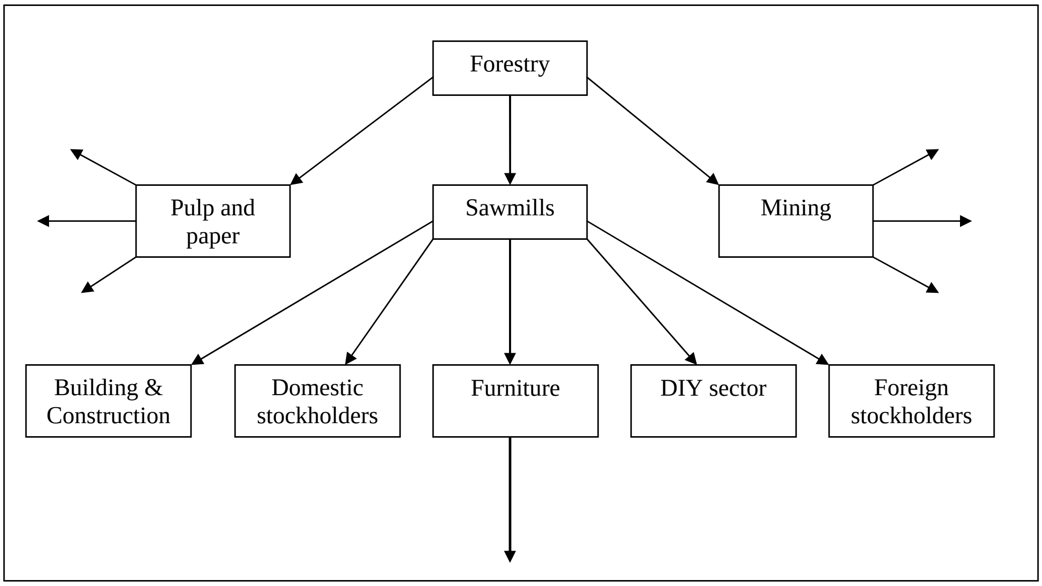


Figure 4.3: One or many value chains [29]

CHAPTER 5

METHODOLOGY

5.1 Introduction

This work involved study of MFA and VCA of aluminium industry in Kenya. To achieve the objectives in the study, survey was carried out after developing a questionnaire and a model for alumina plant establishment.

5.2 Material Flow Analysis

The system model for aluminium in Kenya was developed as shown in Figure 5.1. The aluminium material flow process starts at bauxite utilization, for example in cement sector as one of the primary raw materials, that is partially imported and partially sourced locally from Tanzania. Alumina production process from bauxite does not exist in Kenya. The continuous flow process starts at billets, ingots, slabs and refining/resmelting stages. This proceeds up to the end of life scrap that is disposed locally or exported.

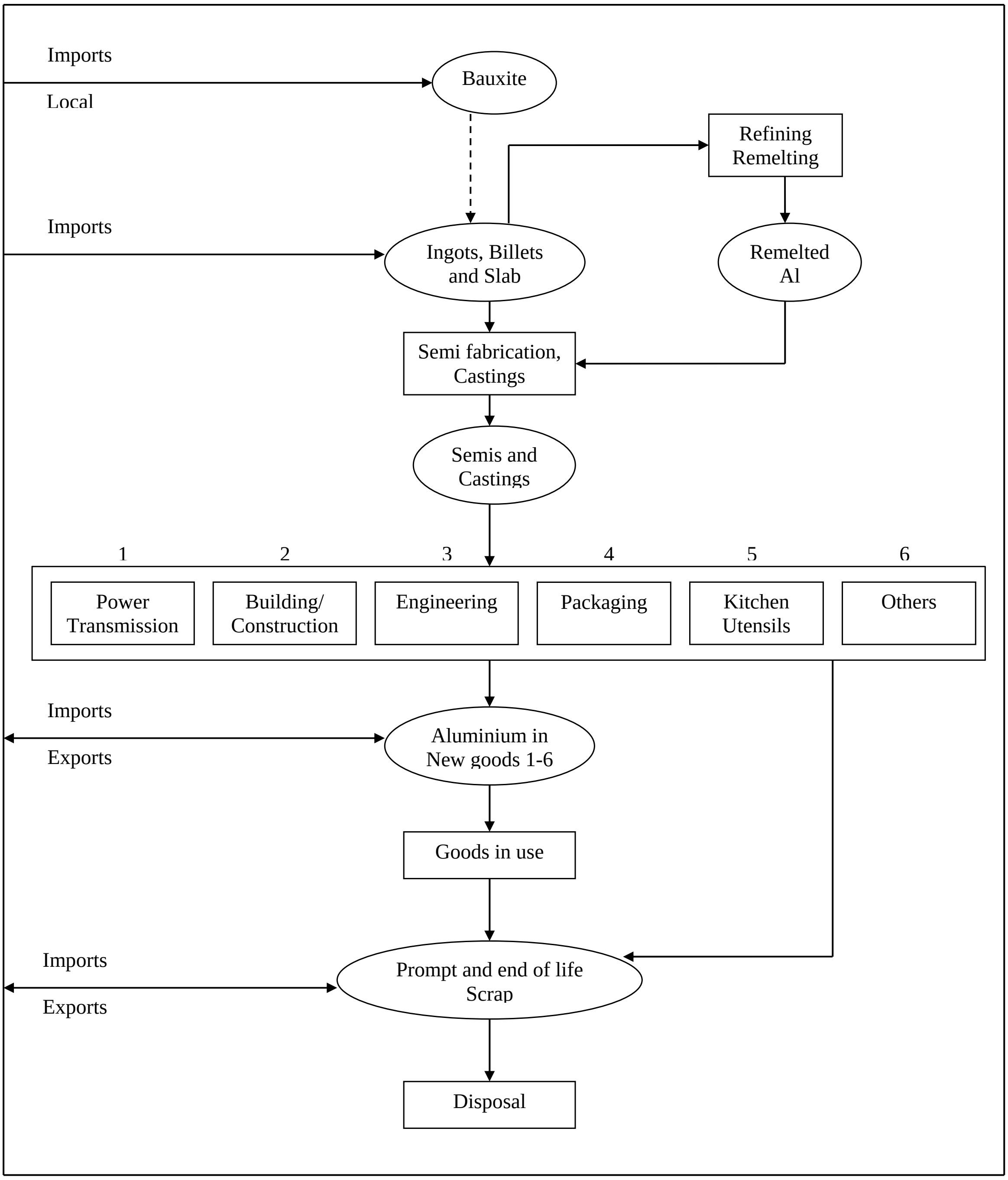


Figure 5.1: System overview of Kenyan industry aluminium flows

5.3 Value Chain Analysis

Value chain analysis was done based on resource efficiency. Resource efficiency was measured as a basic ratio between material output, (M_o) and material input (M_i), such as useful material output per total material input:

$$(M_o/M_i) = material\ efficiency \tag{5.1}$$

or some other physical ratio of interest for the issue being studied, such as useful output per unit input of energy, (E_i)

$$(M_o/E_i) = energy\ efficiency \tag{5.2}$$

or it can also be measured as a ratio of actual capacity, C, per unit designed capacity

$$(C_a/C_d) = capacity\ utilization\ rate \tag{5.3}$$

The analysis shed light on broad resource productivity trends in the aluminium industry over the last five years. Specifically, it addressed the following questions:

- Is the aluminium industry improving its material efficiency (M_o/M_i), that is, is it creating more useful output with fewer material inputs?.
- Is the aluminium industry improving its energy efficiency, that is, is it creating more useful output with less use of energy (M_o/E_i)?.

- Is the aluminium industry improving its capacity utilization rate, that is, is it creating more value with designed capacity of the plant (C_a/C_d)?.

5.4 Value Chain Mapping

Value chain analysis applied in this study, was required to give a clear recognition that the stocks and flows of aluminium had associated economic values. As materials are transformed and passed along a chain of production, fabrication, use/consumption and reuse or disposal, the value of the materials is either enhanced or reduced. All the various material flows of aluminium to be investigated in this study have associated economic values.

One concern of this study was to identify and map the magnitude of these changes in material values throughout the Kenyan economy, as well as to identify the processes which hold the greatest value-creating or value-diminishing potential. In this study, input/output, geographic aspect and governance, which are the three main elements in value chain analysis were considered as below.

As a first step in mapping the value chain, a diagrammatic overview of the industry shown in Figure 5.2 was created, with respect to flows of principal materials through the productive chain and their values depending on the quality of the material, which was a function of the specific mixture of required inputs and production processes. In the Kenyan boundaries, there are five main material categories of aluminium that were considered as the inputs of the chain, that is, bauxite, billets, coils, ingots, semi-fabrication and castings, new goods containing aluminium and scrap. The output elements in the chain considered included: construction material, power cables, packaging material, kitchenware, engineering tools and others.

This study concentrated mainly at raw material and production stages. The values considered at this stage included: material efficiency, energy efficiency and capacity utilization.

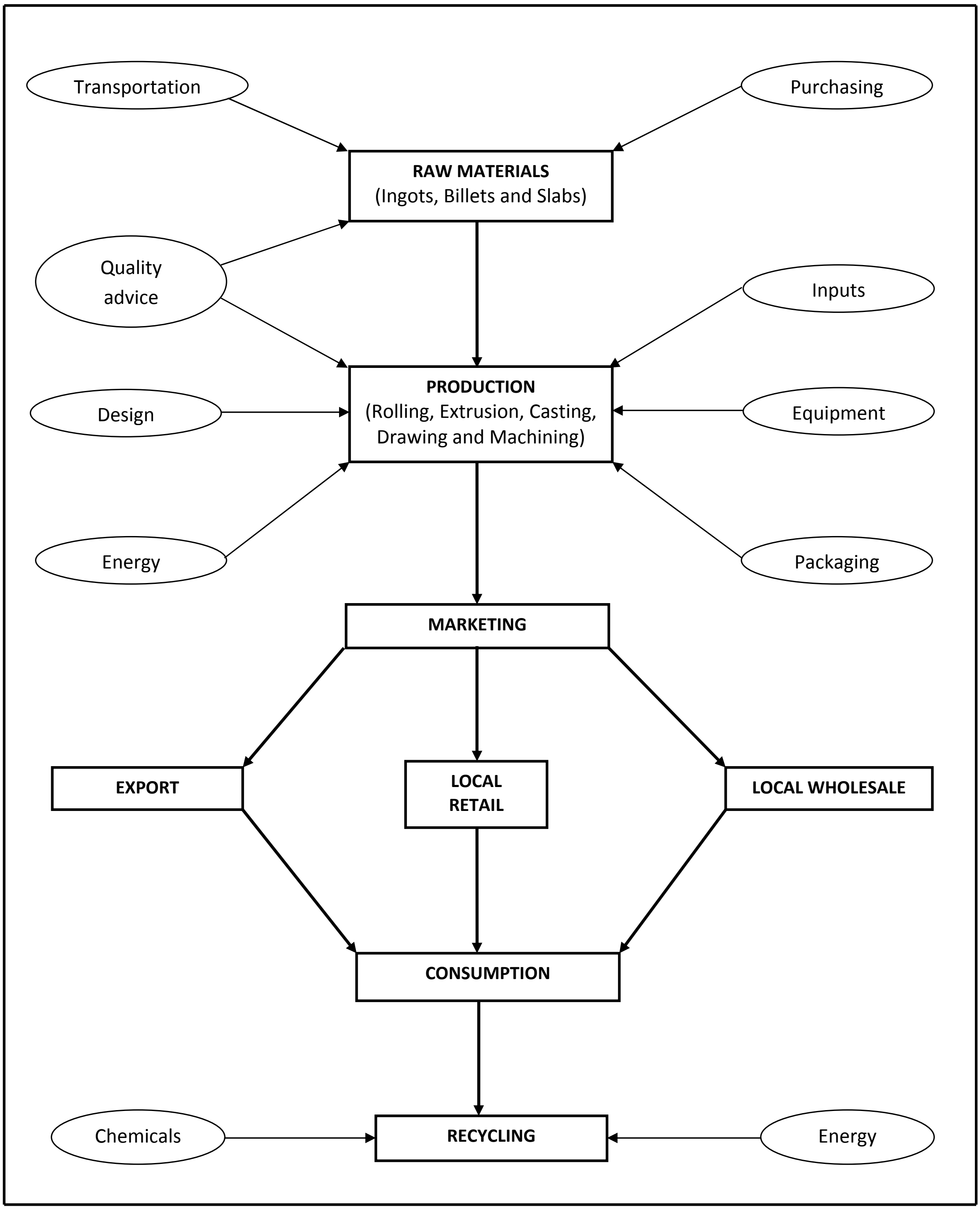


Figure 5.2: Aluminium Value Chain in the Kenyan industry, *Source: Own diagram based on the extended Value Chain, IDRC, 2000*

5.5 Data Collection Surveys

In this study, a valid and reliable questionnaire was very important. Two aspects of validity were considered: content validity and face validity [35]. Content validity refers to whether the items are adequate for determining what they were supposed to measure and whether they constitute a representative sample of the behavior domain under investigation. Face validity refers to the extent which the questions, on the face thereof,measured the construct it was supposed to achieve (e.g. usage of data analysis tools, implementation of data analysis programs) [35].

In the study collection of domestic aluminium material statistics was done by appraising the information requirements of Government and private industries of Kenya.

Specific questions about production, consumption and shipments of aluminium material were structured in the questionnaire to provide useful collective data.

5.5.1 Questionnaire

5.5.1.1 Introduction

The organization of the questionnaire is shown in Table 5.1

Table 5.1: Items in the Questionnaire

Serial no	Item	Rationale.
1	Introduction	Outlines the nature of the study, general structure of the questionnaire and the parties to be involved in the study.
2	Benefits of the study	Outlines the benefits of the study
3	Confidentiality	Affirmation of confidentiality
4	Filling questionnaire	Gives information as to who should ideally respond to the questionnaire
5	Follow-up interviews	Requests for an opportunity to participate in the follow-up case study
6	Contact person	Gives the contacts of the researcher

5.5.1.2 General Company Information

General Company Information gave the details of the company and the person who was responding to the questionnaire

5.5.1.3 Key Terms

Defined the aluminium material terminologies used in the questionnaire for easy understanding and filling of the questionnaire.

5.5.1.4 Raw Material Preparation and Processing

This sections outlined the processes through which aluminium raw material undergoes before using it on the production lines, and which products are produced after processing. The type of scrap materials used/produced from the production lines was also identified in this section. Finally, it asked for and reasons if the company had wishes to upgrade or downgrade their plant in the next five years.

5.5.1.5 Approximate Energy Consumed, Material Consumption and Cost

This part contained several sections that did address a number of aspects in the study.

- Quantities (Metric tons) of raw materials consumed; provided the past consumption, and required for forecasting.
- Sources of raw materials: was used in determining which country of origin has

penetrated into the Kenyan market.

- Cost of raw materials: provided the value of the material at each level in the chain.

- Estimated quantity of products produced: required in computing the material and energy efficiencies of the plant

- Approximate energy consumed: was utilized in energy productivity and efficiency computations.

- Estimated quantity of products on local market: required in determining what quantity the local industry was adding to the country and the regional market.

- Estimated percentage quantity of products on local market: provided the percentage of the final products added to the local and regional market.

- Estimated quantity of products on international market: required in determining what quantity the local industry was adding to the international market.

- Estimated percentage quantity of products on international market: provided the percentage of the final products added to the international market.

5.5.1.6 Research Interest

Requested for an opportunity to carry out a case study in the organization. In addition it gave room for any other relevant comments to be made in relation to the study by the person responding to the questionnaire on behalf of the organization.

5.5.2 Visits and Interviews

The questionnaires were delivered in person to 35 industry players of aluminium material in Kenya. A number of aspects were addressed as displayed in the previous section. Most companies responded positively on case study aspect, but 6 of them were sampled out (manufacturing) for the purposes of interviews. Interviews were carried out in different departments which included stores, production and sales. Another important visit was made to KNBS, where enough information was retrieved from the annual statistical publications like the 'Statistical Abstract' and 'Economic Survey'. Primary details on aluminium material importation and exportation from KRA did not succeed since there was neither chance for attachment nor interviews at the institution. Therefore most of the information to be analyzed was acquired from the aluminium industry players.

5.5.3 Survey Data Responses and Processing

Survey data response was done through a number of means that included; sending back through the address provided in the questionnaire and collecting personally from the companies as some of the the pending issues were discussed in details. Out of 35 targeted companies, 20 responded fully, seven partially, while the rest that did not respond. To produce reliable aggregated data, efficient procedure for handling instances of nonresponse was utilized. Periodic visits to KAM were made to gather hints on missing data that assisted in estimating of the nonresponse. The data acquired was processed by using mathematical equations and data analysis programs that included; matlab and microsoft excel.

5.5.4 Estimation for Nonresponse

When efforts to obtain a response to a survey fail, it becomes necessary to employ estimation or imputation techniques to account for missing data [36]. The technique was considered effective since the response rate was relatively high. In this study, two techniques were considered in analysis; that is, the "Grossing-up factor" procedure and the "Stratified two-stage random" procedure [37]. The final results were based on "Stratified two-stage random" procedure because it was more precise and small error terms resulted

5.5.4.1 The "Grossing-up factor" Procedure

This procedure sums up all those units, which have responded, denoted by "n". The sum of all the units targeted is taken to be "N".

Then the grossing-up factor is given as:

$$N/n = R \tag{5.4}$$

(This is the reciprocal of the sampling response fraction)

For a given characteristic, e.g. total industrial output (Y) which may be the subject of interest. Since only a sub-set of the total industries has responded then the total output of those firms may be represented by $\hat{Y}$.

that is

$$\hat{Y} = R\sum_{i=1}^{n} y_i \tag{5.5}$$

where y_i is the output of i^{th} firm.

Hence the estimate of the expected output from all firms can be expressed as;

$$Y = R\hat{Y} \equiv R\sum_{i=1}^{n} y_i \tag{5.6}$$

5.5.4.2 The "Stratified two-stage random sampling" Procedure

This technique entails the aggregation of all those units which responded in the first stage, and a sample of those units covered in the second stage among those which had not responded at the first level. This is expressed as shown below;

Mean amount $\hat{Y}$ is given by;

$$\hat{Y} = \frac{1}{n}\{n_1\bar{y}_1 + n_2^1\bar{y}_2\} \tag{5.7}$$

Where,

$\hat{Y}$	Estimate of Mean of the targeted amount
N	Total units targeted.
n	sampled units from (N).
n_1	Units that responded in the first stage.
n_2	Units that did not respond in the first stage.
n_2^1	Units that responded out of n_2 in the second stage.

$\bar{y}_1$ mean of n_1 units.

$\bar{y}_2$ mean of n_2^1 units.

E Sum of targeted amount.

and

$$E(\hat{Y}) = N\bar{y} \tag{5.8}$$

5.6 Forecasting

Forecasting was applied in this study in predicting the future demand and cost of aluminium material in Kenya. Considering the forecasting uses and methods as discussed in chapter 3, time-series technique was preferred appropriate in the study using trend projection analysis.

CHAPTER 6

ALUMINA PLANT ESTABLISHMENT MODEL

6.1 Introduction

Establishment of Alumina Plant viability in Kenya was based on past production processing and consumption of aluminium material for the studied period. This was highly recommended since most of the raw material utilized in this sector was imported. Before implimentation of this new investment in the country, specific requirements were to be met in relation to plant establishment.

6.2 Essential factors to be considered

From the past aluminium processing and consumption, the following factors should provide the required background information that is to assist in establishment for alumina plant model in Kenya.

- Energy and energy efficiency,
- Primary aluminium consumption and
- Capacity utilization rate.

6.2.1 Energy and energy efficiency

Electricity is the major operating cost in aluminium plants. For the past decade, Kenya has experienced interrupted power supply and quality of power which has led to relatively high costs of production and lower productivity in manufacturing sector. Therefore there is need for the aluminium plants to continuously identify means of reducing their costs of production with special emphasis on energy conservation and other relatively cheaper sources of power.

There are three main sources of energy in Kenya. These are wood fuel, petroleum and electricity, accounting for 68% , 22% and 9% of total budget in Kenya respectively. The country faces several challenges in improving electricity generation and distribution to meet the increasing industrial and residential demand. Some of the major challenges include reducing the cost of electricity and upgrading of the national electricity grid to provide constant high quality power especially to industrial consumers [38].

Energy efficiency in aluminium sector in Kenya can be improved for example by understanding the importance of energy conservation. This could be facilitated by setting up energy management committees (EMC). The membership of such committees should be drawn from various sections of the plant, who have additional responsibility of energy conservation, other than related to maintenance and production. EMC generates the energy management plan, identification and execution of energy conservation projects in the plant. EMC also monitors the energy performance of equipments and plant on continuous basis and preparing energy consumption status reports for review by different levels of management.

6.2.2 Primary aluminium consumption

The past estimated consumption of all aluminium material categories was considered in alumina plant establishment. The future consumption of aluminium material for the next 10 years was predicted based on the past trends. The increase in consumption indicated an improvement/need of aluminium material categories in Kenya, therefore creating a need of coming up with an alumina processing plant.

6.2.3 Capacity utilization rate

Capacity utilization rate was utilized to determine if most aluminium processing plants were operating below the designed capacities. It gave a clear indication that most plants were operating below the required levels, therefore there was no need to upgrade the plants, but to factor in the unutilized capacity, in order to increase there productivity. It will affect the aluminium sector by raising the consumption of these material, that will increase the demand of the raw material.

6.3 A Typical Alumina Smelting Plant in Kenya

The primary aluminium industry comprises three main processes; mining, smelting and refining. Mining of bauxite and the conversion of bauxite into alumina is a weight losing process and is therefore locating the plant near the source of the raw material would considerably minimize transportation costs. The principle factor in considering the selection of the smelting site is cost of electricity, while other major costs are in provision of carbon electrodes, labour and capital. While all these costs can vary with location , the most significant variations are in electricity and labour [39].

Therefore, based on above factors, there was need to propose establishment of the primary aluminium plant in Kenya which will start the flow process from the imported Alumina material.

6.4 Size range consideration of Alumina Smelting Plant in Kenya

A 'typical' example of a smelter plant capacity is of 60,000 - 100,000 mt per annum with the possibility of expanding to up to 500,000 mt per annum capacity [40]. Most of the smelter plants in India and China are operating between 100,000 mt and 500,000 mt per annum, but with plans to upgrade up to 1 million mt per annum.

For example an Alumina smelter plant of capacity 250,000 mt per annum in Norway is estimated to have an initial set up cost of USD 3.5 Billions including a USD 500 Million gas power plant for the production of electricity. The future prices of alumina and aluminium per mt were assumed to be USD 250 and USD 1,750 respectively on average [41].

In Bahrain, a similar plant of 12,000 mt capacity was proposed to be established at a total investment cost of USD 8 million, with the net earnings varying between 20% to 25% [42]

To estimate the size of an Alumina smelter plant in Kenya, the projected quantity of aluminium was utilized, that is, the total consumption of imported billets, coils, and ingots, semi-fabrications and castings. The regional export market share in terms of these raw materials was to be established in order to have a regional consumption required.

6.5 Model Development

6.5.1 Introduction

The main aim of Alumina Plant Establishment Model (APEM), was to check if the proposed plant was viable or not viable.

6.5.2 Profitability Estimation

In deciding whether the Alumina plant project should be implemented, there was need to determine if profit (s) would be made. This was done by calculating the Net Present Value (NPV) as shown in Appendix B. The NPV was used to determine effects discounted to the same period of time. By using the discount rate (DR), it was reflected that future benefits and costs were not valuated the same way as today. If the DR was correct, then the NPV only needed to be positive for the project to be viable. This is defined by the equation 6.4

6.5.3 Main elements of the model

In this model, there were several elements which were considered under the five main inputs. This included:

- Energy costs

- Production costs

    (i) alumina

    (ii) carbon electrode

    (iii) cathode

    (iv) labour

    (v) running and maintenance costs

- Capital Investment cost/Initial set-up costs

    (i) construction investment (machinery and equipment installation)

    (ii) land

    (iii) excavation

    (iv) cleaning and technology

    (v) coal power plant for producing electricity

The key inputs which were used in the NPV model analysis included:

- Interest rate
- Capital investment cost / Total investment cost
- Net earnings
- Time period of cash flow.

Modelling was done based on the equations below to determine the viability of the investment in Kenya.

$$DF = (1 + r)^{-n} \tag{6.1}$$

$$PV = NE(DF) \tag{6.2}$$

$$SPV = \{\sum_{i=1}^{10}(PV)_i\} \tag{6.3}$$

$$NPV = SPV - CIC \tag{6.4}$$

For

- NPV $<$ 0 ; The project is not viable and
- NPV $\geq$ 0 ; The project is viable

Payback period was given by

$$PBP = SPV[n] \leq CIC \tag{6.5}$$

where,

DF discounting factor

r rate of depreciation

n estimated time of investment.

PV present value

NE net earnings.

SPV sum of present value

CIC capital investment cost.

NPV net present value

PBP payback period

6.5.4 Materials requirements model

Material requirements model was done to determine the ratios of the materials and energy required in alumina smelting plant. It was done based on the capacity of the plant to be established, since for every 1 mt of aluminium to be produced, 1.9 mt of alumina is required. From alumina quantity, the aluminium fluoride, anodes, coke, pitch, import aluminium, alloying elements, fuel oil and power were determined in ratio form.

CHAPTER 7

RESULTS AND DISCUSSION

7.1 Introduction

The results from these work were grouped into two main sections namely: past and future flows of aluminium material in Kenya. The past flows included quantity, approximate cost, market share and efficiencies of aluminium material in Kenya. The future flows included: the projected quantity and cost, factors which may affect the future growth and establishment of alumina processing plant in Kenya.

7.2 Quantity of Aluminium Material

Aluminium mills and related industries in Kenya depend on imports of billets, coils and ingots for production of items such as circles for deep drawing, iron sheets, semi fabrication and castings. The sector has generally recorded an increase in consumption of the aluminium raw materials as from 2003 to 2007, then slightly dropped in 2008. Local sourced scrap recorded the highest percentage increase of 241.0% followed by 197.0% imported scrap, 83.3% local sourced bauxite, 55.0% billets, ingots and coils, 37.1% imported semi fabrication and castings, as imported bauxite recorded the least increase of 35.0% as observed in Figure 7.1. The slight drop in 2008 for the raw materials was attributed to internal and external shocks which included; poor transport and communication logistics, 2007 post election violence, high cost of fuel prices, continued political bickering and global financial crisis.

Bauxite consumption was observed growing for the period studied as cement production increased due to the high demand in construction sector. Currently, Kenyan market is producing 3.5 million mt per year, which is expected to rise to 6.25 million mt per year by the year 2012. Kenya is estimated to be registering growth of up to 11% in cement demand, largely driven by homebuilders, followed by Tanzania and Uganda with a 10% and 9% growth respectively. The global per capita consumption averages 389 kg. Kenya has a per capita consumption of 57 kg that compares relatively low to 420 kg in Egypt and 600 kg in Turkey. The rest of East Africa ranges from 42 kg in Tanzania to 20 kg in Burundi [43].

For the period studied, the country experienced remarkable overall sustained economic growth with the GDP growth rate reaching 7.1% in 2007, the highest growth rate over the period. During the period of 2007 and 2008, manufacturing sector growth declined from 6.5% to 3.8% [27]. The annual quantities are shown in Table 7.1 and Figure 7.1.

Imported semis and castings, billets, coils and ingots recorded the second and third most consumed material categories in Kenya due to the following reasons:

- high demand in wall panels, roofing, partitioning, windows, doors, awnings and canopies,
- rural electrification program by the government that targeted distributing

power to rural areas.

Aluminium scrap recorded the lowest consumption rates in this industry due to:

- low recycling rates (particularly for disposable packaging, kitchenware and construction products).
- illegal flow/trading of aluminium scrap across the Kenyan boundaries.

There is little information on scrap generation and collection at regional/country level, and also for many countries little is known regarding sectoral consumption as well as the rate of recycling [44].

Generally, in the near future it appears that urbanization in the developing countries will continue creating a large market for almost every sector of the aluminum industry, especially infrastructure building. Market growth and distribution will vary with different patterns of geography and social development; the aluminum industry must be part of the transformation and keep pace with market developments to benefit.

Table 7.1: Quantity of Aluminium Material (metric tonnes), *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*

Serial. no.	Raw material	2003	2004	2005	2006	2007	2008
		Metric tonnes					
1	Locally sourced bauxite	13,480	17,890	20,340	23,100	24,570	22,000
2	Imported bauxite	24,680	28,750	30,150	32,170	33,530	30,340
3	Imported Billets, coils and Ingots	6,562	7,877	9,342	9,632	10,215	9,400
4	Imported Semis and Castings	8,288	8,128	6,764	8,771	11,362	10,200
5	Imported scrap (Prompt & Home)	175	201	350	381	520	407
6	Local scrap (Prompt & Home)	1,126	1,440	1,941	2,140	3,841	2,489

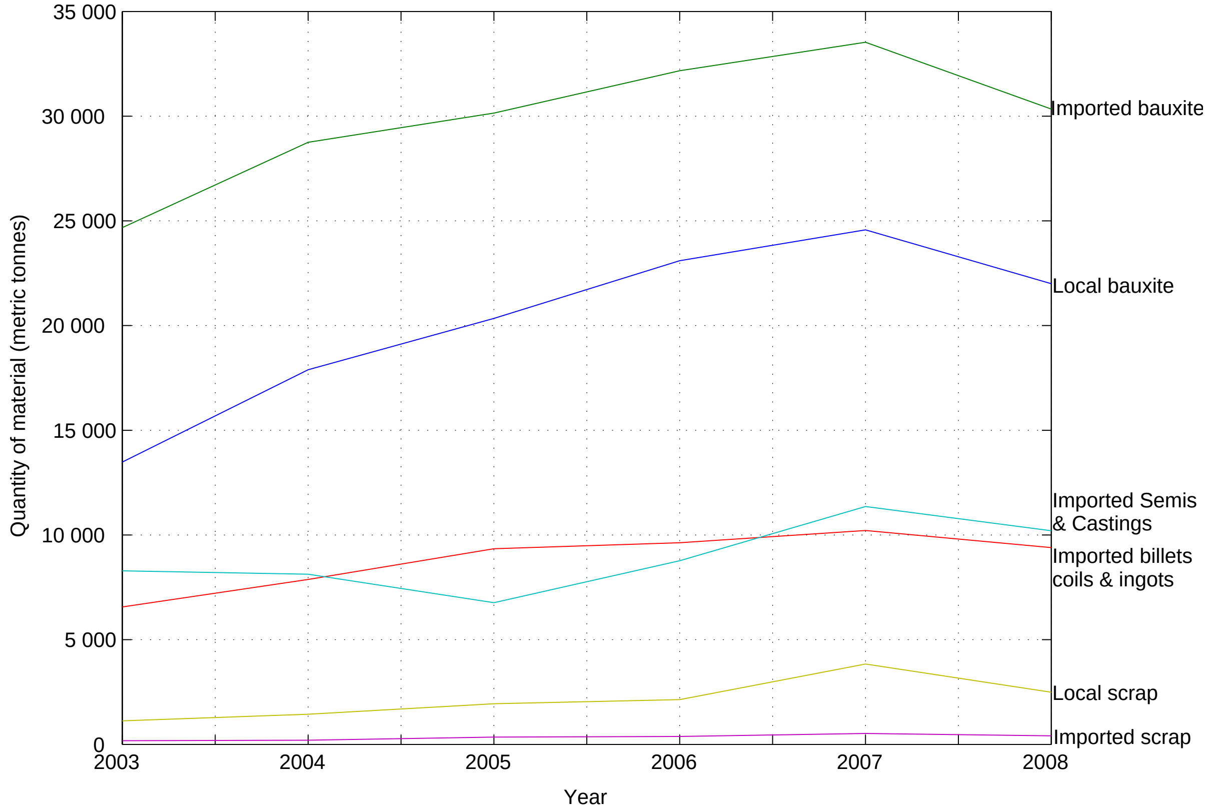


Figure 7.1: Quantity of aluminium material, *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*

7.3 Approximate Cost of Aluminium Material

Apart from local sourced bauxite and local scrap prices, the rest of these materials are controlled by London Market Exchange (LME). In addition to the prices quoted at LME, there are some more charges as per the government policies, which include 2.75% Import Declaration Fee (IDF), 0.33% Insurance, 5 to 10 USD / mt port charge, 0.6% service charge, 0.5% handling charge and 1.17% loading charge. There is also 26 USD / mt charged for transportation. From the past trend, imported billets, coils and ingots (wrought aluminium) recorded 59% increase in price, followed by 30.8% local bauxite, 30.4% imported scrap, 25% imported bauxite, 16.7% local scrap and finally 14.0% imported semi fabrication and castings. However 2008 was affected by increase in prices of the raw materials which was due to high crude oil prices and global financial crisis. The approximate costs of these materials is shown in Table 7.2 and Figure 7.2.

According to the Customs and Exercise Act, Chapter 76 [45], aluminium material categories are subjected to import duty as shown in Table 7.3. The specific import duties reflect an additional charge to the LME prices on every material category in aluminium sector.

Tables 7.1 and 7.2, shows a direct proportional relationship, i.e, an increase in aluminium consumption, led to an increase in its prices as expected. Apart from demand in consumption, increase in factor costs (energy, fuel labour and alumina) and decrease in capacity and lower production levels led to price increases and upward consumption trends.

Between 2003 and mid 2008, continued cost pressures drove the cash cost of alumina production strongly upward. Influence from the effects of the global economic crisis led to some input costs easing slightly at the end of 2008. American Market Exchange estimates average global production costs were approximately 54% higher in 2008 than estimated for the base year 2003 [46].

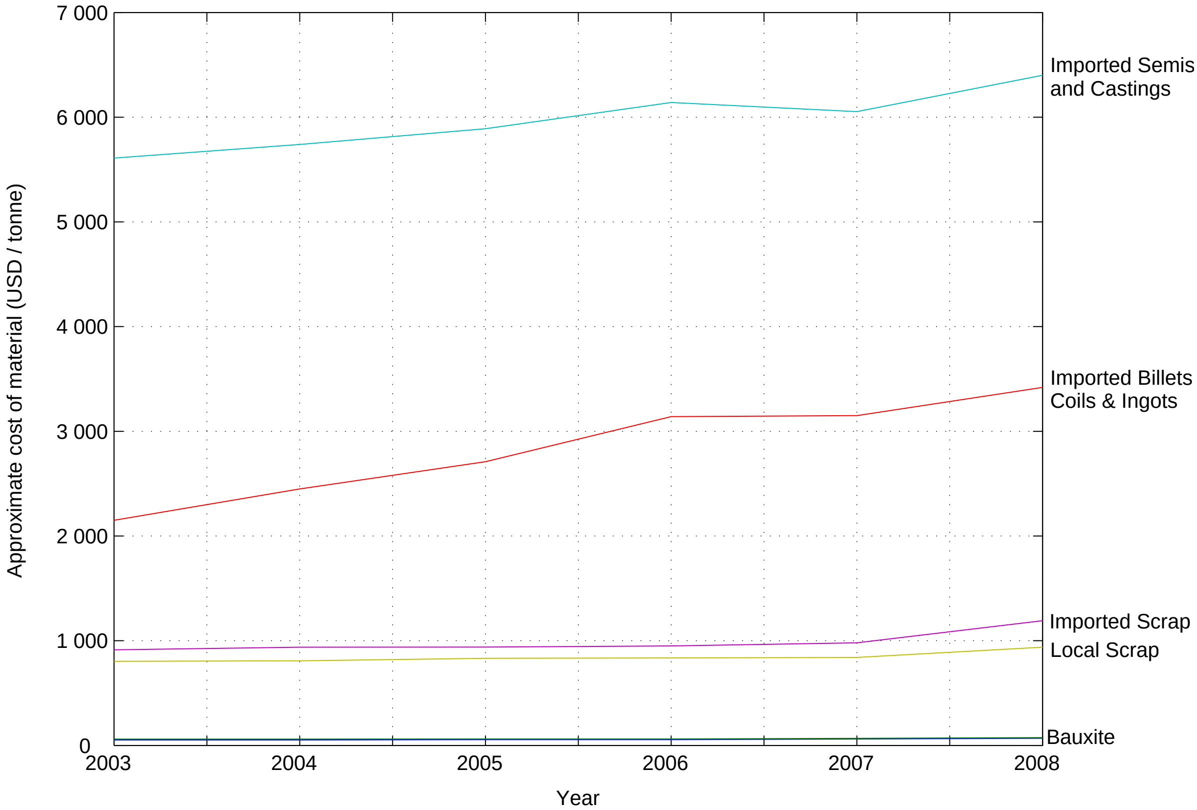


Figure 7.2: Approximate cost of aluminium material, *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*

Table 7.2: Approximate Cost of Aluminium Material, *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*

Serial. no.	Raw material	2003	2004	2005	2006	2007	2008
		USD / tonne					
1	Locally sourced bauxite	52.0	52.0	55.0	56.0	61.0	68.0
2	Imported bauxite	60.0	60.0	62.0	62.0	67.0	75.0
3	Imported Billets, Coils and Ingots	2,150.0	2,450.0	2,710.0	3,140.0	3,150.0	3,420.0
4	Imported Semis and Castings	5,610.0	5,740.0	5,890.0	6,140.0	6,053.0	6,400.0
5	Imported scrap (Prompt & Home)	913.0	938.0	940.0	950.0	980.0	1,191.0
6	Local scrap (Prompt & Home)	804.0	808.0	832.0	836.0	840.0	938.0

Table 7.3: Import duty on aluminium material and products, *Source: Customs and Exercise Act-Kenya*

S.No	Tariff Description	Import Duty in Percent	Unit of Quantity
1	Unwrought Aluminium	5	kg
2	Aluminium scrap and waste	15	kg
3	Aluminium bars, rods and profiles	25	kg
4	Aluminium wire	10	kg
5	Aluminium plates, sheets and strip	15	kg
6	Aluminium foil	15	kg
7	Aluminium tube or pipe fittings	15	kg
8	Aluminium Doors, Windows and Frames	25	kg
9	Aluminium kitchenware	25	kg

7.4 Market share of aluminium products

7.4.1 Export

Aluminium sector exports approximately 20% per annum of aluminium products which include cement, iron sheets, semi fabrication, castings, kitchen ware, packaging, electric cables, engineering tools, circles, coils, et cetera. This study shows that the export markets are mostly Common Market for East and Southern Africa (COMESA) countries (Uganda, Tanzania, Rwanda, Somalia, Ethiopia, Sudan, Burundi, Angola and Zambia), Ghana, Nigeria and South Africa. Some companies in the sector have been able to supply high quality aluminium products (Aluminium-Zinc coated sheets) to countries like Germany and United States of America (USA) [47]. The percentage of exports to destination countries is shown in Table 7.4 and Figure 7.3.

Uganda had the highest mean of 18.3% in amounts of imported Kenyan aluminium products, which varied from 17% to 20% between the years 2006 to 2008. Although this country had the highest mean, it is still too low in terms of the fraction of what is produced in total. However, with anticipated economic growth, Uganda is expected to improve its infrastructure in order to accommodate the current and future changes in population and technology, that will lead to increase in consumption of aluminium products in future.

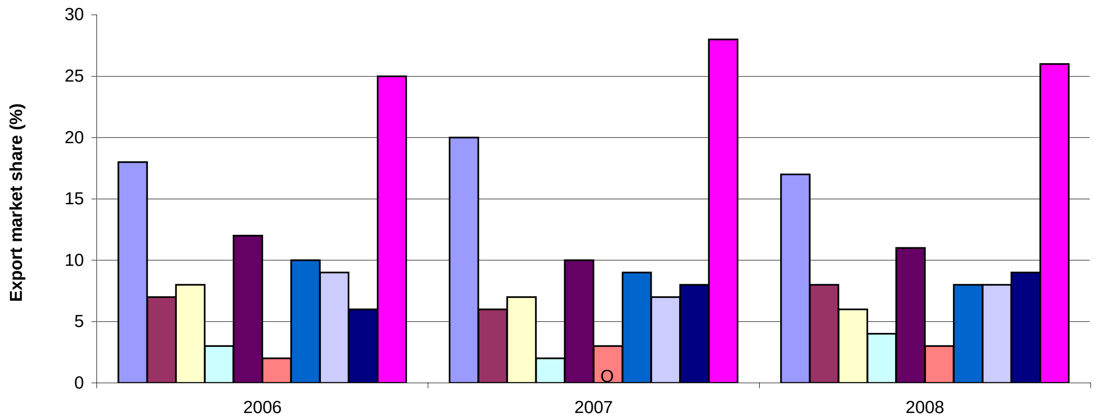
Uganda is currently faced with an acute shortage of electricity supply which is affecting industrial and commercial sector. To address this problem, short, medium and long term measures were proposed. An Investment of the order of USD 4.43 billion is required for the entire power sector. From the budget, USD 95 million will be used in transmission line construction that will utilise aluminium cables. The project will lead to attaining a rural electrification target of 10% from 1% coverage by the year 2010.

Figure 7.4 clearly shows that there is a continuous increase in cement consumption in Tanzania and Uganda [48]. Since Kenya is increasing its production capacity by upgrading the existing plants or investing in new ones, then the market share of Tanzania and Uganda is expected to go up. Local cement production rose from 2,615,100 mt in 2007 to 2,829,600 mt in 2008, an 8.2% increase. Importation of cement on the other hand dropped by 56% from 42,500 mt in 2007 to 18,700 mt in 2008, while the exports to Uganda and Tanzania rose by 21.8% to 626,500 mt in 2008 [27].

Domestic exports for aluminium ware were observed to have an increasing trend from the year 2004 to 2007. The export rose from 1,643 mt in 2004 to 1,924 mt in 2005, a 17.1% increase. The year 2006 recorded 2,127 mt export that translated to 10.6 percent while 2007 had the highest export of 3,481 mt that gave an increase of 63.7% [49]. Based on this data, export market share is expected to increase in future as the consumption levels go up.

Table 7.4: Export market shares of aluminium products, *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*

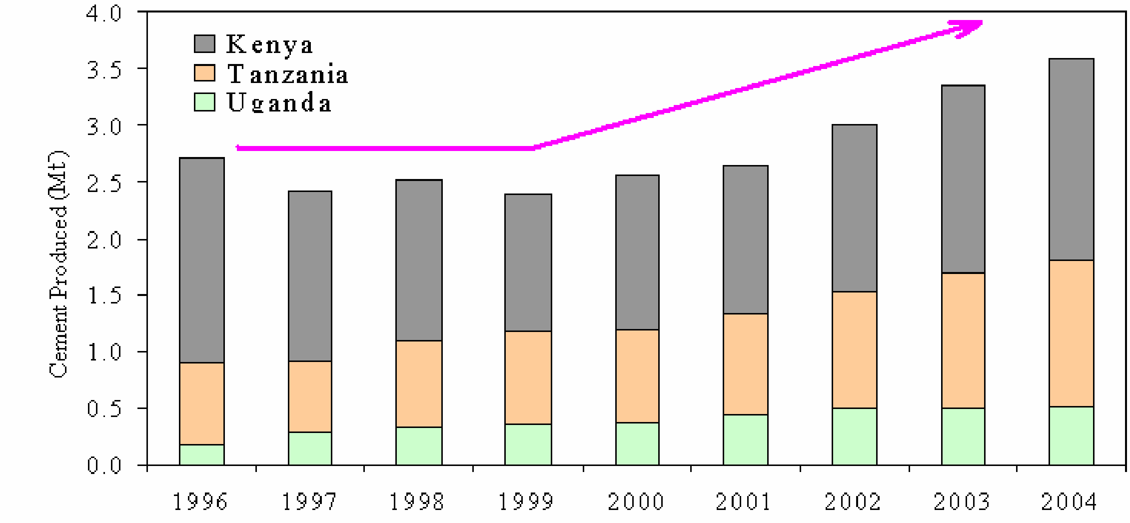
Year	Percentage									
	UGA	TZN	RWA	SOM	ETH	SUD	BUR	ANG	ZAM	Others
2006	18.0	7.0	8.0	3.0	12.0	2.0	10.0	9.0	6.0	25.0
2007	20.0	6.0	7.0	2.0	10.0	3.0	9.0	7.0	8.0	28.0
2008	17.0	8.0	6.0	4.0	11.0	3.0	8.0	8.0	9.0	26.0
Mean	18.3	7.0	7.0	3.0	11.0	2.7	9.0	8.0	7.7	26.3



	2006	2007	2008
Uganda	18	20	17
Tanzania	7	6	8
Rwanda	8	7	6
Somalia	3	2	4
Ethiopia	12	10	11
Sudan	2	3	3
Burundi	10	9	8
Angola	9	7	8
Zambia	6	8	9
Others	25	28	26

Year

Figure 7.3: Percentage export market share of aluminium products, *Source: Survey data 2009 and Statistical Abstract 2008, KNBS*



	1996	1997	1998	1999	2000	2001	2002	2003	2004
Kenya	1.816	1.506	1.426	1.204	1.367	1.319	1.463	1.658	1.789
Tanzania	0.726	0.621	0.778	0.833	0.833	0.9	1.026	1.186	1.281
Uganda	0.175	0.29	0.321	0.347	0.367	0.43	0.507	0.507	0.52

Figure 7.4: Trends of cement consumption in East Africa [48]

Table 7.5: Aluminium ware domestic exports [49]

Year	2004	2005	2006	2007
Quantity (metric tonnes)	1,643	1,924	2,127	3,481

7.4.2 Local market share of aluminium material

From Table 7.6, local market is fed with approximately 80% aluminium products of its total production. From the year 2003 to 2007, there was relatively little change of aluminium products on Kenyan market, but between 2007 and 2008, there was a sharp increase in demand of these products. The increase is attributed to 2007 post election violence that hindered delivery of these products to the destined countries, which in turn reduced the export market share. There was also reconstruction, after most of the infrastructures were demolished in 2007 post election violence. The sector recorded a growth of 8.3% in 2008 compared to 6.9% in 2007. This growth was largely supported by increased capital investments in roads and housing, where government expenditure on housing rose from Ksh 3.1 billion to 4.1 billion in 2008, while disbursement of funds by Kenya Roads Board rose from Ksh 15.4 billion in 2007 to Ksh 19.0 billion in 2008. [27]. In total

- 502Km of roads were maintained,
- 1,411.8 Km of roads were rehabilitated,
- 808.8 Km of roads were constructed.

The study shows, between 2003 and 2008, construction and power cables material recorded the highest percentage mean of 90.50% and 89.67% respectively. This is due to expansion of infrastructure (Roads and rural electrification) in order to meet the demand of the increasing population. The construction of houses goes hand in hand with power cabling, hence recording almost the same demand. Estimated percentage share market of the products is shown in Table 7.6 and Figure 7.5.

The continuous expansion in road network, housing, energy investment and growth in population are the future contributors of increase in the aluminium products consumption in Kenya. This will lead to increase in future consumption of aluminium materials. The future changes should be counter checked by investing in aluminium sector.

Table 7.6: Estimated aluminium goods on local market, *Source: Survey data 2009*

Serial no.	Product	Percentage						
		2003	2004	2005	2006	2007	2008	PM
1	Powers cables	88.0	90.0	89.0	87.0	88.0	94.0	89.67
2	Kitchen ware	78.0	79.0	79.0	80.0	80.0	84.0	80.00
3	Engineering tools	70.0	71.0	73.0	74.0	74.0	74.0	73.33
4	Construction	88.0	89.0	90.0	91.0	90.0	95.0	90.50
5	Packaging	80.0	79.0	81.0	80.0	80.0	83.0	80.50
6	Others	76.0	77.0	79.0	78.0	78.0	81.0	78.17

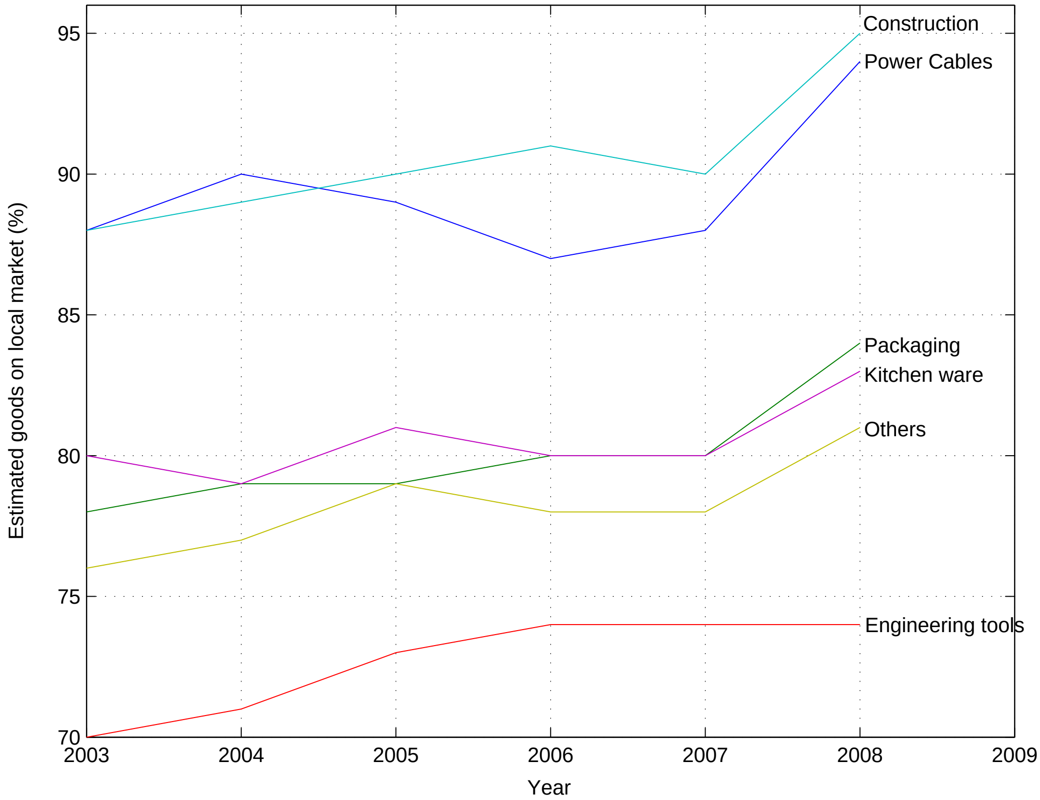


Figure 7.5: Estimated aluminium goods on local market, *Source: Survey data 2009*

7.5 Efficiencies

7.5.1 Material efficiency

Material efficiency in this sector varies with the type of production processes undergone until a final product is achieved. From the study, power cables recorded 95.08% material efficiency mean, followed by 85.00% cement, 76.62% packaging, 74.24% kitchenware and 73.82% engineering tools.

Cables sub-sector had the highest material efficiency, which varied from 94.5% to 95.55% with a mean of 95.08% . Although this was the highest level recorded in Aluminium sector, it can be improved further, so that the sector achieves minimal material wastage. Rolling and extrusion processes are applied in power cables production, where minimum material is lost through feeding, joining and surface finishing. Material efficiency in this sub-sector has not had a relatively big change, because of continual usage of machines that are beyond their operation life. However, with anticipated upgrading of the plants, the sub-sector is expected to minimize material wastage to almost 1% .

Cement industry was ranked the second in terms of material efficiency, that varied between 82% to 87% with a mean of 85% . In cement production, there are minor losses along production system and calcining which removes almost all the moisture content in the materials. There are losses of raw materials and finished products in form of dust to the atmosphere, that lower the final value of efficiency. However this is expected to improve since the industry has embarked on the following;

- environmental conservation, by reducing the amount of dust that is allowed into the atmosphere.
- conserving the natural resources that include bauxite, limestone, et cetera.
- improving the collection and recycling of waste, e.g making the pavement blocks .

Packaging industry had a material efficiency varying between 75% and 78.5% with a mean of 76.62% . This industry has relatively more processes of material preparation as compared to cable and cement sub-sectors. Most of the packaging products are made as per the customers profile needs, which involves relatively more material wastage in attaining the required package. However, this sub-sector can reduce material wastage by producing by-products from the off-cut material.

Engineering tools and kitchen ware recorded the lowest means of 72.82% and 74.24% respectively. This is because they undergo almost the same processing which depends on the final product to be attained. Most of the production process in this sub-sector require relatively more material removal and leaving some material on the semi-finished product for surface finishing allowance. Utilization of unskilled machine operators contribute to material wastage in the two sub-sectors. However the sub-sector are set to improve in future by the anticipated change of technology that will eliminate unskilled labour through automation, and finally reducing the material wastage.

In summary, the improvement of material efficiency in aluminium sector in Kenya, depends on utilization of advanced technology.The efficiencies are as shown in Table 7.7 and Figure 7.6.

Table 7.7: Material efficiency, *Source: Survey data 2009*

Industry	2003	2004	2005	2006	2007	2008	IM
Cables	95.40	94.50	95.00	95.55	95.00	95.50	95.08
Cement	82.50	82.00	84.00	85.50	87.00	87.00	85.00
Kitchen ware	73.00	73.50	72.00	74.55	76.40	76.00	74.24
Packaging	75.20	76.35	75.00	77.40	77.25	78.50	76.62
Engineering tools	73.00	74.00	72.00	75.00	74.00	75.00	73.82
MAA	79.82	80.07	79.60	81.60	81.93	82.40	

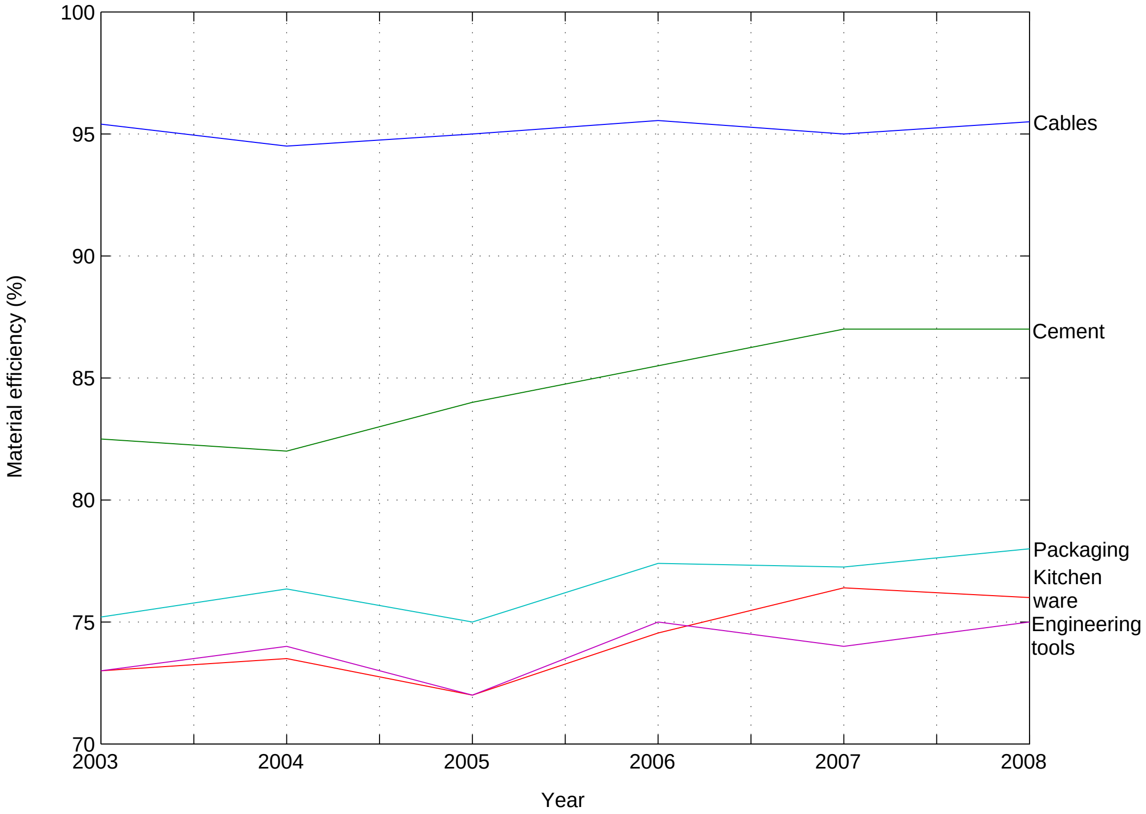


Figure 7.6: Material efficiency, *Source: Survey data 2009*

7.5.2 Energy efficiency

In Kenya this sector has faced a lot of challenges in terms of power prices and supply. This has led to higher costs of production, making the industry face competition from imports, mainly originating from India, Asia and USA. Despite unconducive local manufacturing environment, the market for aluminium products still exists and is increasing in demands within the region, since the neighbouring countries do not have a well-developed aluminium industry compared to Kenya. The energy efficiency average value (AV) for the studied period was found to be 26.68 mt/TJ. This compared relatively low with the energy efficiency in UK, where one TJ energy produced 128 mt of aluminium in 2001 [1].

Cement industry was ranked the second last, with the efficiency varying from 21.2 mt/TJ to 27 mt/TJ, with a mean of 24.55 mt/TJ. This efficiency was below the sector average, indicating the sub-sector was efficiently lower than most other sub-sectors in aluminium sector. Cement production undergoes a series of processes which includes: quarry operations (drilling, blasting, excavating, handling, loading, hauling, crushing, stock piling and storing), grinding, preheating, calcining, cooling and milling, that are energy consuming processes. If some of the processes like grinding raw materials to the proper-size is not achieved, then optimal fuel efficiency will not be achieved. The materials are also processed at high temperatures exceeding 1482.2^0C that require a lot of energy to achieve these temperatures. In Kenya most cement plants utilize semi-dry process (pyroprocessing:- raw mix of supplied to the system as moist pellets) which requires relatively more fuel than dry (utilizing preheater and precalciners that enhance fuel efficiency further and allow for high production rates) process. However, a mean of 24.55 mt/TJ is still too low as compared to the global efficiency of 88.8 mt/TJ. With most of the local plants investing in coal, coke and tyres as their main source of fuel, this figure is expected to improve and meet the global standards.

Aluminium cables sub-sector was ranked second among the five aluminium material sub-sectors, with its efficiency ranging from 24.8 mt/TJ to 32 mt/TJ, and a mean of 28.97 mt/TJ. This sub-sector had the best material efficiency which contributed to a relatively high energy efficiency. However, with the projected growth in rural electrification and investment in geo-thermal energy, the sub-sector will attain a stable power supply, leading to high energy efficiency.

Kitchen ware sub-sector recorded the highest energy efficiency which ranged between 26.4 mt/TJ and 34 mt/TJ, with a mean of 30.22 mt/TJ. This range is too low compared to the global range of 37 mt/TJ and 46 mt/TJ. However, consumption has been growing gradually since 2003 and it is expected to improve with the growth in economy.

Packaging sub-sector was ranked third, with the efficiency varying between 23.5 mt/TJ and 28.8 mt/TJ, with the mean of 26.8 mt/TJ. This sub-sector recorded an efficiency that was almost same as the sector average, but it is still low as compared to the global efficiency of 45 mt/TJ. However, with the increasing demand in packed foods which are exported and consumed locally, most firms have to improve on their energy efficiency which will in turn boost their production capacities.

This efficiency faced a number of challenges since 2006 that included:

- high oil prices that were occasioned by speculative demand, unstable geo-political situation in some oil-producing countries.
- increased demand, particularly in Asia and Latin America
- decline of Hydro-electricity generation from 3,591.5 GWh in 2007 to 3,271.8 GWh in 2008 due to inadequate rainfall experienced in most parts of the country [27].
- supply disruption and temporary closures during the post election skirmishes.

Generally, this measure of performance can be improved in Kenya by investing in advanced equipment and systems that can minimize energy losses during production. Energy efficiency can also be improved by optimizing the production processes (e.g. forging, extrusion, rolling)that are utilized in aluminium production. The specific annual variations per given firm are as shown in Table 7.8 and Figure 7.7

Table 7.8: Energy efficiency, *Source: Survey data 2009*

Serial no.	Industry	2003	2004	2005	2006	2007	2008	IM
		Metric tonnes per TJ						
1	Cement	21.20	22.20	26.30	27.00	24.80	25.80	24.55
2	Cables	24.80	28.30	31.20	32.00	28.50	29.00	28.97
3	Kitchen ware	26.40	28.90	32.10	34.00	29.70	30.20	30.22
4	Engineering tools	22.50	22.80	23.00	23.10	22.70	23.00	22.85
5	Packaging	23.50	25.80	28.30	28.80	26.80	27.60	26.80
	MAA	23.68	25.60	28.18	28.98	26.50	27.12	

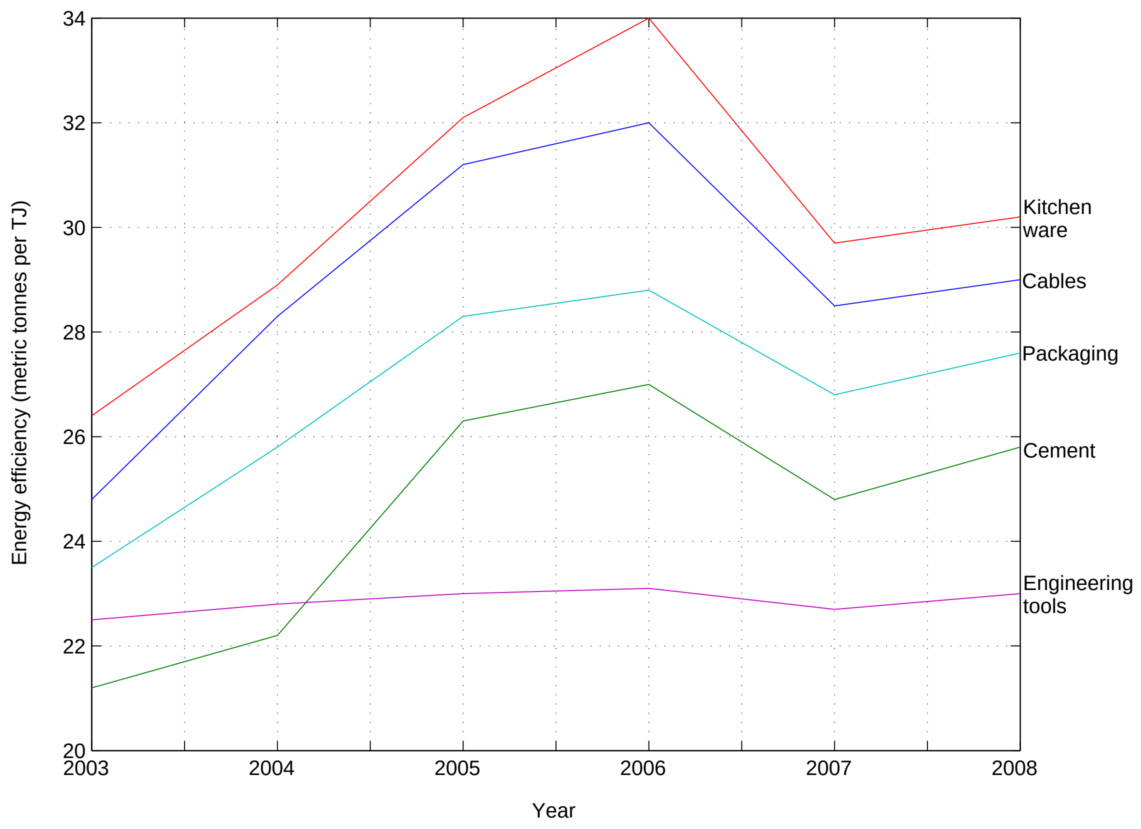


Figure 7.7: Energy efficiency, *Source: Survey data 2009*

7.5.3 Capacity utilization rate

In this study, capacity utilization rate is expressed in terms of percentage fraction of the designed capacity during production in aluminium sector. In Kenya, most of industries in this sector recorded an actual capacity utilization of below 70% , but did not go below 32% due to a number of problems arising from;

- importation from countries that are given subsidies by their governments (example, tax free power and water in Eastern Europe, China, India and South Africa)
- high cost and poor provision of power in the country
- damage and delay in shipment of imported raw materials

Cement sub-sector had the highest capacity utilization, with the rate varying between 42.2% to 69.4% with a mean of 57.12% . This still compares too low with the global rates which are varying between 81.3% to 93.8% . However, with the slower rate compared to demand growth, the sub-sector is expected to attain higher average capacity utilization rates. The key drivers for cement demand in the country are real estates, infrastructure projects and industrial expansion projects.

Cables sub-sector recorded the third highest capacity utilization rate varying between 34.6% and 58.9% with a mean of 48.72% . Figure 7.8 shows that the estimated capacity utilization of cables has been improving gradually over the studied period. With the growing demand in rural electrification and high demand by the regional market, this rate is expected to improve much more.

Packaging sub-sector was ranked second in terms of capacity utilization, with the rate varying between 44.2% and 54.3% with a mean of 51.33% . This indicated a mean above the sector average of 48.84% . The sub-sector mostly served the local market. By targeting regional markets, there will be an increase in production that will require the producers to reduce the unutilized capacity.

Kitchen ware sub-sector had a capacity utilization rate ranging between 34.2% and 54.6% with a mean of 45.4% . This is still low compared to the global levels of 78% to 82% . However, due to the rising population locally and regionally, this sub-sector is expected to improve in terms of capacity utilization.

Engineering tools sub-sector had the lowest capacity utilization rate among the sub-sectors studied. This varied between 32% and 46.7% with a mean of 41.65% . This was attained by having an average of a number of firms engaged in different types of engineering that were not standardized across. In some instances, imports had captured some of the market share of the sub-sector, resulting in low capacity utilization.

The AV for capacity utilization for the period studied in Kenya was found to be 48.84% as shown in Table 7.9 and Figure 7.8. Eleven companies in 2000 operated 23 primary aluminium facilities in the U.S.A which had a production capacity of approximately 4,280,600 mt and produced 3,668,000 mt giving an approximate capacity utilization rate of 86% [11].

Table 7.9: Capacity utilization in percent, *Source: Survey data 2009*

Industry	2003	2004	2005	2006	2007	2008	IM
Cables	34.60	39.40	48.40	54.40	58.90	56.60	48.72
Cement	42.20	48.00	54.40	61.70	69.40	67.00	57.12
Kitchen ware	35.30	34.20	47.10	48.80	54.60	52.40	45.40
Packaging	44.20	49.70	54.0	53.70	54.30	52.10	51.33
Engineering tools	32.00	39.50	44.60	44.80	46.70	42.30	41.65
MAA	37.66	42.16	49.70	52.68	56.78	54.08	

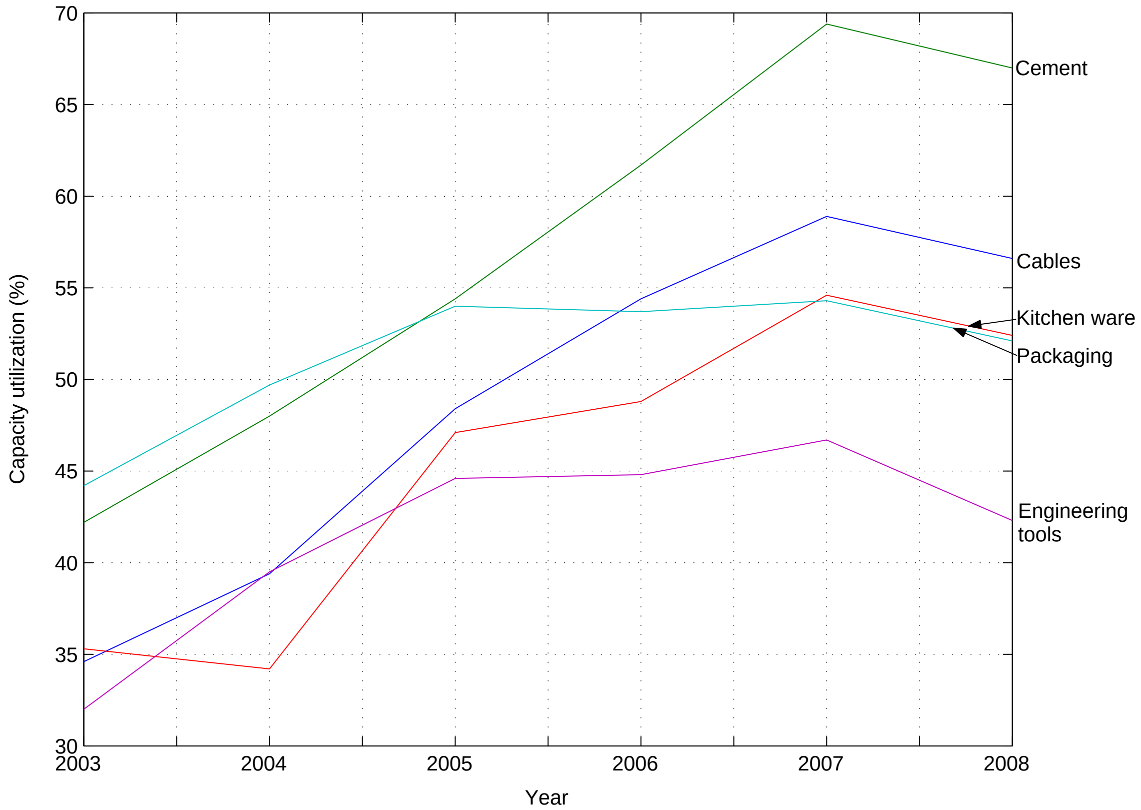


Figure 7.8: Capacity utilization, *Source: Survey data 2009*

7.6 Future trends of aluminium material in Kenya

7.6.1 Introduction

In this study, future consumption of aluminium material in Kenya was predicted using the quantities consumed in the past. Computer programs were utilized in larger sets of data to translate them into coordinates on a line or curve. In this study, the Microsoft Excel spread sheet was applied using the trend function, that is, the trend finds points that lie along the best line of fit and fall into unknown category. The trend was used to extrapolate the future data based on the tendencies exhibited by known data as shown in Figure 7.9. The **TREND** function takes the form =**TREND**(*known y's,known x's,new x's,const*).

The first two arguments represent the known values of dependent and independent variables. To calculate the trend-line data points that best fit our known data, the third, fourth, fifth, sixth and seventh arguments were omitted from the function. The results array was the same size as the *known x's*.

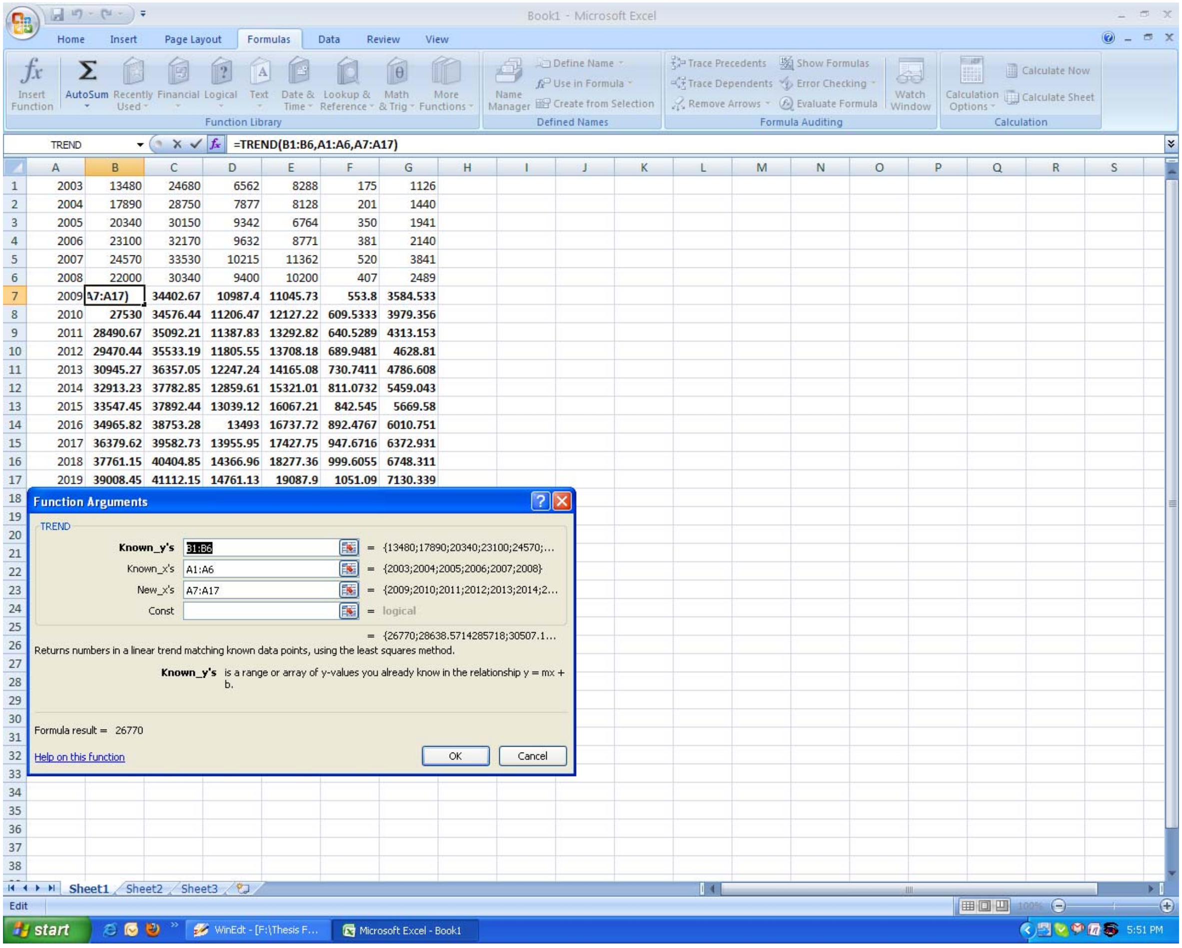


Figure 7.9: Projections data sheet for aluminium materials consumption, *Source: Survey data 2009*

7.6.2 Projected Quantity of Aluminium Material

7.6.2.1 Bauxite (Local and Imported)

Bauxite is among the raw materials used on commercial scale in Kenya in the production of cement. The study shows that the projected consumption of local bauxite is to increase by 69.8% and imported one to increase by 40.3% . Most of the companies utilizing the local bauxite are to switch to imported bauxite because of higher percentage concentration of Al_2O_3:- 57% as compared to local one:- 48% to 54% . This is expected to give a combined increase in consumption of imported bauxite from 37,652 mt to 68,159 mt between the years 2009 to 2019 translating to a percentage increase of 53.1%.

Future consumption of bauxite is expected to be more than the current level, due to increase in production capacity. This is as a result of two cement producing companies joining the market. Mombasa Cement Limited is expected to boost the capacity this year by adding 700 000 mt per annum, while Cemtech Limited is to resume its operations after 33 months. Cemtech intends to have an initial production of 600 000 mt, after which it will be upgraded to 1 million mt per annum. The existing companies are to increase the capacity more, following their upgrading program expected in the next 2 years.

7.6.2.2 Imported unwrought and wrought aluminium

The study shows that the consumption of unwrought aluminium (billets, coils and ingots) was projected to increase by 54.9% between the years 2009 and 2019 as shown in Table 7.10.

The changing pattern of the global market shows that primary aluminium production is projected to reach 60 million mt by the year 2020 [50–52]. The consumption of wrought aluminium (semi fabrication and casting) was projected to increase by 32.8% between 2009 and 2019. See Figure 7.10

7.6.3 Projected Approximate Cost of Aluminium Material

The past trends showed an increase in aluminium material prices that is being reflected in the projected prices. This has been experienced globally due to a number of production challenges the industry is facing.

From Table 7.11, semi-fabrication and castings prices range between USD 6,660.2 - 7,469 per mt during the projected period, giving a percentage increase of 12.1% . Imported billets, coils and ingots prices gave the highest percentage change of 54.7% between the years 2009 and 2019 as shown in Figure 7.11.

The approximate aluminium prices were as per London Market Exchange prices plus the Kenyan Government taxes based on 6 months to 1 year buyer contract type. During the second quarter of the 2008/2009 calendar year, LME three-month contract type aluminium prices ranged between USD 2,828 - 3,150 per mt before

Table 7.10: Projected quantity of Aluminium Material, *Source: Survey data 2009*

Serial. no.	Raw material	2009	2011	2013	2015	2017	2019
		Metric tonnes					
1	Locally sourced bauxite	26,770	30,507	34,244	37,981	41,719	45,456
2	Imported bauxite	34,846	37,652	40,458	43,263	46,069	48,874
3	Imported Billets, coils and Ingots	10,937	12,137	13,337	14,436	15736	16,936
4	Imported Semis and Castings	10,077	10,739	11,401	12,063	12,725	13,387
5	Imported scrap (Prompt & Home)	401	436	472	507	543	578
6	Local scrap (Prompt & Home)	2,594	2,840	3,087	3,333	3,579	3,825

closing at USD 3,114 at the end of June 2008. Primary aluminium material prices are expected to remain high due to supply uncertainties, increasing energy and raw material prices [53].

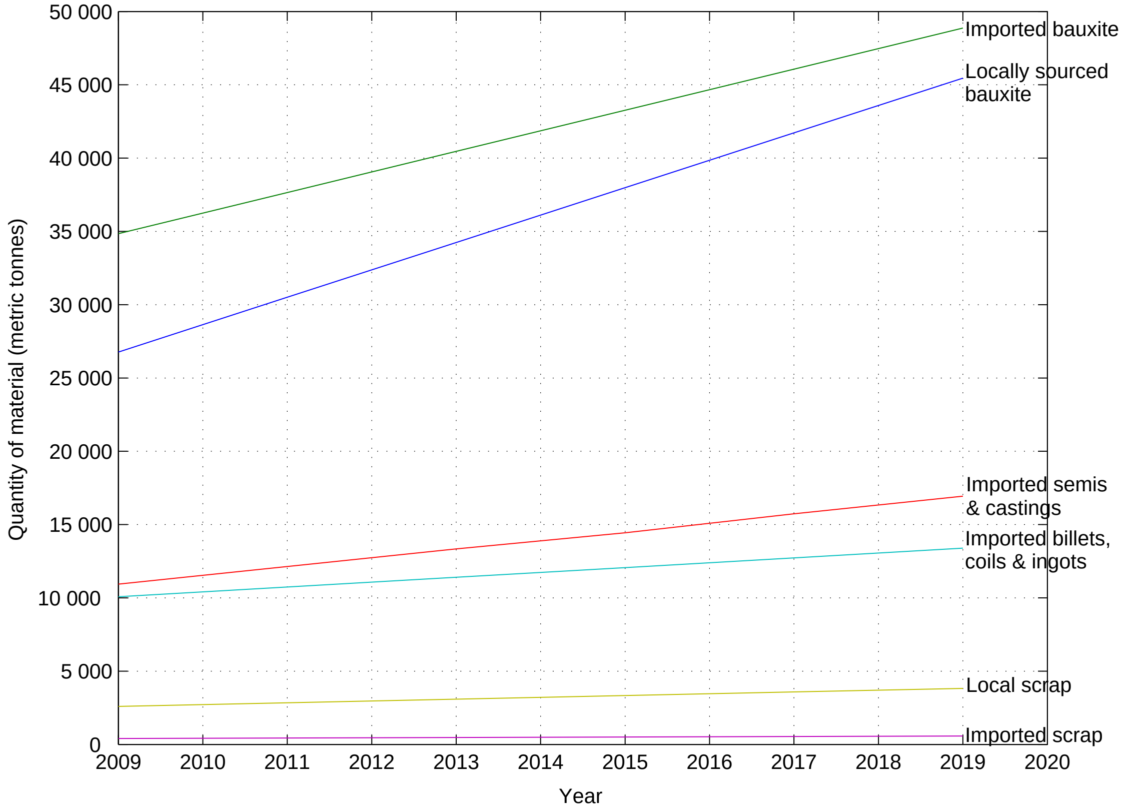


Figure 7.10: Predicted quantity of aluminium material, *Source: Survey data 2009*

Table 7.11: Projected approximate Cost of Aluminium Material, *Source: Survey data 2009*

Serial. no.	Raw material	2009	2011	2013	2015	2017	2019
		USD / tonne					
1	Locally sourced bauxite	68.1	74.3	80.5	86.6	92.8	99.0
2	Imported bauxite	74.4	80.2	85.9	91.7	97.4	103.2
3	Imported Billets, Coils and Ingots	3,508.2	3,891.9	4,275.7	4,659.4	5,043.2	5,426.9
4	Imported Semis and Castings	6,660.2	6,582.0	6,803.7	7,025.5	7,247.2	7,469.0
5	Imported scrap (Prompt & Home)	1,101.4	1,167.8	1,234.1	1,300.5	1,366.8	1,433.2
6	Local scrap (Prompt & Home)	897.2	928.1	959.1	990.0	1,021.0	1,052.0

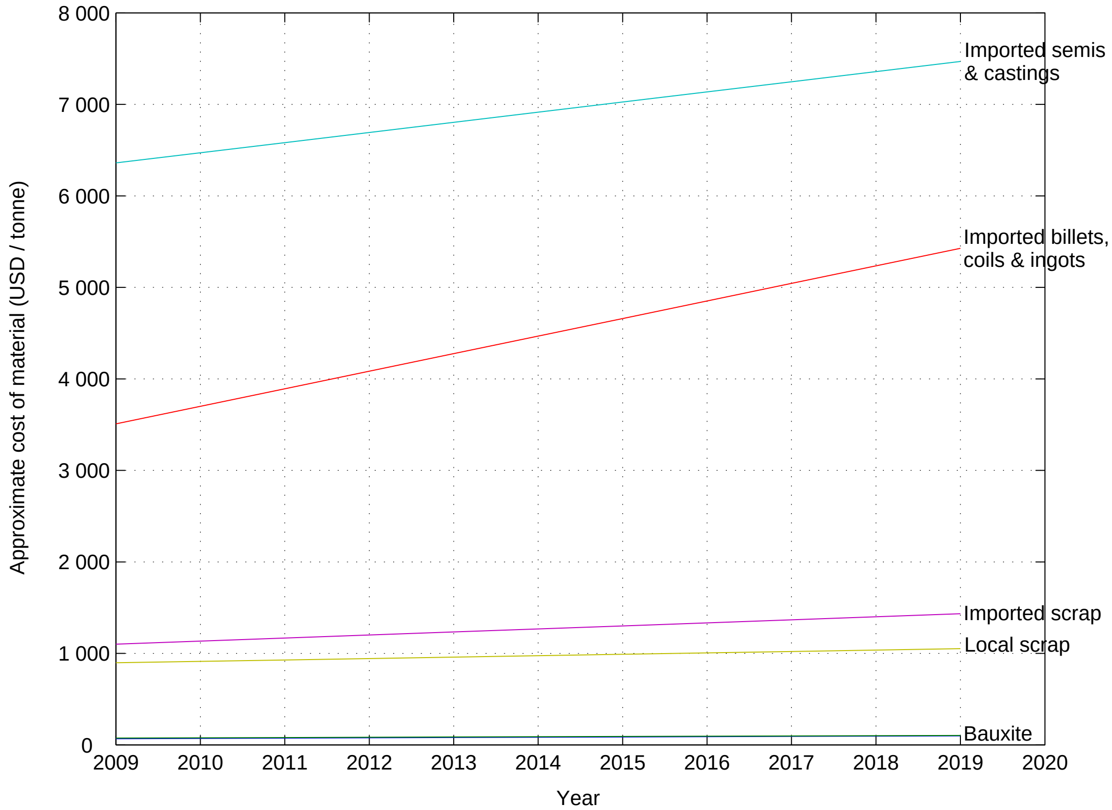


Figure 7.11: Predicted approximate cost of aluminium material, *Source: Survey data 2009*

7.6.4 Other factors which may affect the future growth (Consumption and Cost)

Apart from the past trends of consumption and prices that were used in the future projections, growth of aluminium in Kenya depends on a number of factors which includes:

- population growth
- regional developments
- power prices and availability
- petroleum prices
- political events
- labour and taxation

The above factors will affect the aluminium raw material consumption and prices, and finished products indirectly or directly.

7.6.4.1 Population Growth

Kenya's population has increased rapidly during the past half century from 8 million in 1960 to approximately 37 million in the year 2007. With a current growth rate of 2.8% per year, the country's population is projected to reach 51 million by the year 2025 [54]. The population was observed to grow from the year 2004 to 2008 as shown in Table 7.12.

Table 7.12: Population Growth in Kenya [27]

Year	2004	2005	2006	2007	2008
Population (million)	34.2	35.1	36.1	37.2	38.3

The above trend was assumed to continue even in the period projected for aluminium consumption and prices till the year 2019. Therefore the effect on aluminium projections will be constant, i.e, the ratio of past population growth to past aluminium material trends and the future population growth to projected aluminium trends will change with almost the same rates.

7.6.4.2 Developments in the region and Taxation

The process of creating a free trade area and customs union between Kenya, Tanzania, Uganda, Rwanda and Burundi, will lead to establishment of a full common market between these countries. The integration is set to improve the economic growth of the member countries.

Tanzania had an economic growth of 7.4% in the year 2008 compared with 7.1% in the year 2007. Rwanda recorded the economic growth of 11.2% mainly due to good perfomance in agriculture, growth in the industry sector with improvement in electricity supply.

With the projected economic growth in East African countries of above 10% by the year 2013, the consumption of aluminium material is expected to increase while the prices to relatively go down.

East African integration has proposed a common External Tariffs that applied to goods imported into the EAC. The following are some of the proposals made in respect of these tariffs that are common to all EAC countries.

- exemption of import duty on all industrial spare parts to be managed through the duty remission scheme.
- import duty exemption on equipment used in oil, gas or geothermal exploration and developments.

All the above exemptions will lead to enough supply and availability of petroleum and power within the region at relatively low costs. Hence a reduction in the cost of production in the aluminium sector by cutting down the transport, fuel and power costs.

7.6.4.3 Power prices and availability

Electric power supply in Kenya falls far below the demand currently. This calls for private sector investment in power generation for sale to the national grid. The current peak electric power demand is estimated at 1,180 MW and it is projected to grow at 7% annually over the next 10 years to reach 2,263 MW by the year 2018.

This demand growth is driven by an accelerated consumer connection policy and anticipated robust economic perfomance. The government's policy is to connect at least 1 million new consumers in the next five years. To meet the projected demand in electricity, the installed generating capacity will have to be raised from 1,180 MW to 1,860 MW by 2013 and to 2,600 MW by 2018 [55].

The projected growth rate in demand will require corresponding increases in associated supply and distribution infrastructure which affects aluminium sector directly. To achieve the above target, the government of Kenya is in the process of setting the following:

- establishing Geothermal Development Company (GDC) which is to undertake geothermal resource assessment activities.
- commissioning a feasibility study and establishment of a 300 MW coal power plant in Mombasa [56].
- carrying out coal exploration in the Mui Basin in Mwingi district, which covers an area of 400 km^2
- investing in wind energy for industrial and domestic use in Marsabit, Ngong' and the Coastal region.

By meeting the above targets, the high power prices that are due to use of alternative power supplies like diesel generators, will be reduced and meet the increasing demand. This will in turn reduce the costs of production and increase productivity of aluminium sector.

7.6.4.4 Petroleum prices

Petroleum fuels are the most important source of commercial energy in Kenya, and are mainly used in the transport, commercial and industrial sectors. The past trends of petroleum prices in Kenya have been unstable and increased suddenly due to high demand and declined supply. This is because Kenya imports its fuels from Middle East countries which are OPEC (Organization of the Petroleum Exporting Countries) members. OPEC was founded to unify and coordinate members petroleum policies. OPEC is effective in determining production capacities and prices of the crude oil.

Petroleum prices are likely to increase in the future due to rising international demand, declining supply and increasing production costs. Since this is a major cost in Aluminium production, this sector will be forced to invest into relatively cheaper energy sources. Otherwise there will be increase in cost of production and low productivity that will increase the cost of aluminium material and lower the consumption due to decline in supply.

7.6.4.5 Political events

The economic growth momentum that started in the year 2003 was restrained by a number of internal and external factors in the year 2008. These factors included the 2008 post election disruptions, the high fuel and food prices among others. combined, these factors slowed the economic growth from 7.1% in the year 2007 to 1.7% in the year 2008. The manufacturing sector growth rose by 3.8% in in the year 2008, the lowest in the last five years, compared to a revised growth of 6.5% registered in the year 2007 [27].

Though the post election crisis was experienced only in the first quarter of 2008, the spill-over effects were manifest throughout 2008 resulting to substantial declines in growth of most sectors of the economy. The decline was due to low levels of productivity and the high cost of production which was as a result of the depreciation of the Kenya shilling.

However, the building and construction sub-sector indicated an improvement in the year 2008. This is because cement consumption increased by 7% from 2,061.4 thousand mt recorded in the year 2007 to 2,205.8 thousand mt in the year 2008.

In future, the political instability is expected to lower the aluminium sector's productivity and increase the cost of production, that will reduce its consumption and increase the prices of the material.

7.7 Establishing Alumina Processing Plant in Kenya

Kenya is the logistical hub for the East African region. Through its strategic geographical location, Kenya has emerged as a significant player in regional trade, investment, infrastructure development and general economic growth.

The Kenyan government plays an important role towards improving aluminium manufacturing sector. To begin with, there are a number of economic measures that were considered towards viability of establishing alumina processing plant in Kenya that included:

- Energy and Energy efficiency,
- Primary aluminium consumption and
- Capacity utilization rate.

The above mentioned economic factors play a major role in improving efficiencies and productivity in order to increase revenues and capital available for alumina industry investment. It also gives investors confidence in the market and encourages them to invest more capital.

7.7.1 Primary aluminium consumption, Energy and Energy efficiency in Kenya

The study established that in 2009, the projected consumption of primary aluminium (Imported billets, coils, ingots, semi-fabrication and castings) in Kenya would be 21,014 mt. Assuming the total energy associated with primary aluminium production to be approximately 23.78 kWh, then the total energy required to give the projected consumption in Kenya will be 499.713 MWh. In 2019, the projected consumption was estimated to be 30,323 mt that would require 721.081 MWh for its production. Since Kenya is strategically placed in East African region (Kenya, Tanzania, Uganda, Rwanda and Burundi), it implies that the consumption is likely to be tripled, making it convenient to set up an primary aluminium smelting plant of at least 60,000 mt per annum initially, and upgrade it after 10 years.

The current installed power capacity in Kenya is 1,296 MW, with an effective capacity of 1,204 MW. The current system peak demand is 1,071 MW, while the annual energy demand is about 6,500 GWh. Kenya's demand for power is increasing 8% annually, which has put a strain on the national grid. The energy capacity tends to be interfered with due to frequent droughts and major climate variability [27].

The energy efficiency average value (AV) for the studied period was found to be 26.68 mt/TJ. This compared poorly with the energy efficiency in UK, where one TJ energy produced 128 tonnes of aluminium in 2001 [1]. Therefore there is need to improve on these efficiency in order to increase the production that will in turn increase the income and reduce production costs.

7.7.2 Capacity utilization rate

Kenyan industries in aluminium sector had an actual capacity utilization ranging from 32% and 67% . This was due to a number of factors as discussed previously. An AV for capacity utilization rate for the period studied in Kenya was 48.84% . Eleven companies in 2000 operated 23 primary aluminium facilities in the U.S.A which had a production capacity of approximately 4,280,600 mt and produced 3,668,000 mt. These facilities operated at approximately 86% capacity in 2000 [11]. Kenyan industries were found to be operating at much lower capacity utilization rates than Indian, Chinese and American plants.

In reference to Figure 7.12 and the economic measures discussed above, it is appropriate for the government to invest in establishing alumina smelting plant. The process flow should start from alumina importation and smelting up to ingot casting, and join the existing process that starts from ingot, billets and coils importation. To achieve these fully, the government should upgrade the existing energy capacity to at least 3,000 MW, by focusing on geothermal power generation that has a potential of 7,000 MW. There should also be fast tracking the implementation of the 300 MW capacity coal power plant at the Coast to cushion the country from impending current power rationing. Capacity utilization rate and energy can be dealt with during the production period.

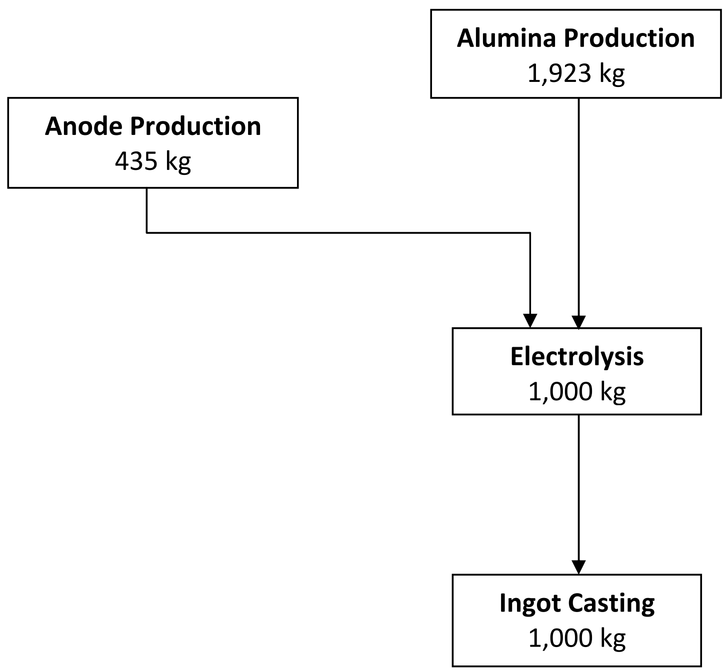


Figure 7.12: Proposed Weight flow diagram for primary aluminium production in Kenya, *Source: Own diagram based on Life Cycle Assessment of Aluminium Production, technical report*

7.7.3 Proposed Alumina Plant in Kenya

From the above three economic measures, the main components required to set up a 60,000 mt alumina plant were verified using the established model (APEM). In the a number of inputs such as depreciation rate, TIC, net earnings and time period and period of cash flow were considered as Appendix B. The model executed payback period, project viability and raw materials requirements as output. The viability of the project was executed as shown in Figure 7.13. The generated values of NPV key inputs were as shown in Table 7.13. The NE from this table were considered varying between 22.5% and 22.6% of the TIC. The rate of depreciation, **r** was selected based on the following variables;

- the assets cost basis
- estimated life expectancy of the asset and
- payback period

7.7.4 Proposed Alumina Plant material requirement in Kenya

The material requirements for the Kenyan alumina plant were determined based on the following.

- final primary aluminium required backward material quantities calculation.
- existing global aluminium production material ratios.

With the quantity of primary aluminium as the key input, the material quantities were generated as shown in Figure 7.13 for a 60,000 mt aluminium plant.

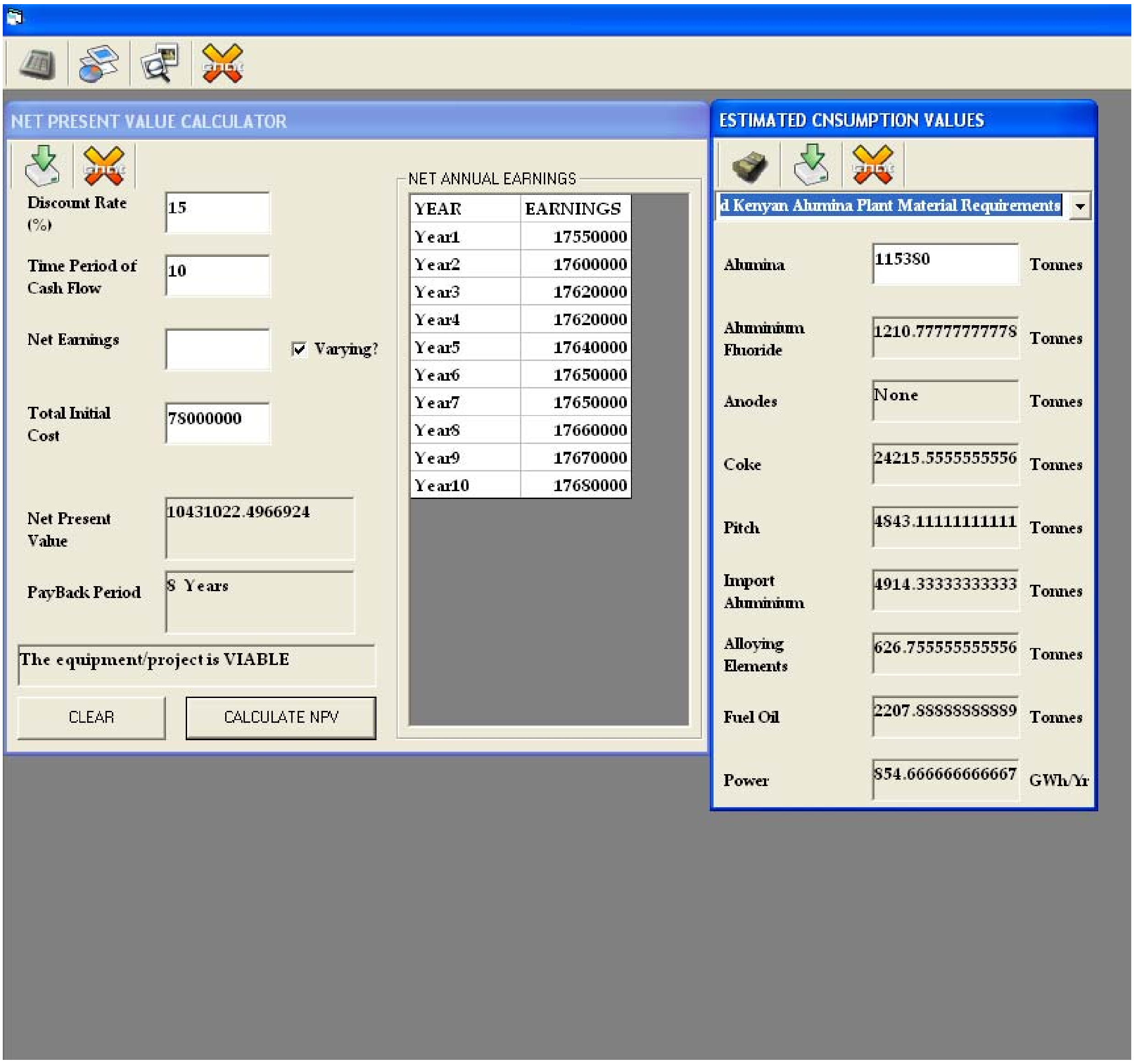


Figure 7.13: Proposed Alumina Plant NPV model and material requirement results in Kenya, *Source: Survey data 2009*

Table 7.13: NPV Calculation, *Source: Survey data 2009*

Year	r %	DF	NE	PV	SumPV	TIC	NPV
			Million USD				
1	15	0.8696	17.55	15.26	88.43	78.00	10.43
2	15	0.7561	17.60	13.31			
3	15	0.6575	17.62	11.59			
4	15	0.5718	17.62	10.07			
5	15	0.4972	17.64	8.77			
6	15	0.4323	17.65	7.63			
7	15	0.3759	17.65	6.64			
8	15	0.3269	17.66	5.77			
9	15	0.2843	17.67	5.02			
10	15	0.2472	17.68	4.37			

7.8 Limitations

The limitations of the study were primarily associated with poor data records and difficulty in its collection, due to some companies failing in responding to the questionnaires.

7.9 Challenges faced in Aluminium sector in Kenya

The following are some of the critical issues for the future development of this sector.

- Aluminium manufacturers in Kenya are secondary producers, importing primary raw materials from Europe, India, China, South Africa and other countries that have integrated Aluminium plants. The chances of Aluminium production in the country are minimal due to lack of high-grade bauxite, bauxite reserves, enough electricity and oil.

- While the export of scrap metal has been discouraged through the 2009/2010 budget, there is still challenge of providing the scrap flow data.

- Some companies that are generating complex aluminium waste like dross (aluminium-zinc), are finding it difficult to dispose the waste locally due to lack of the processing plants, hence they are forced to export the waste back to the supplying companies overseas, which leads to higher operating costs.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The study established that there was an increase in past and future consumption and production of aluminium material. The fact that almost all aluminium containing raw materials are imported illustrates that Kenya depends fully on these material in order to meet its materials needs. Some of the Aluminium manufacturers (importers) in Kenya have plans of increasing their capacities in production by upgrading the existing plants and utilizing improved technology. This is because the market volume within COMESA region is growing at a relatively steady rate. Investment and development in this industry is vital to keep the market share in power supply, construction, packaging, kitchenware, engineering and others. The market can be improved and sustained if the Government can revise the existing policies (tax and energy) to favour aluminium production that will encourage more investors in the sector.

In the near future it appears that urbanization in Kenya and the neighbouring countries will continue due to high population growth rates, creating a large market in infrastructure building and electricity supply. The future growth of this industry in Kenya will require significant resources such as energy, tax free or relatively low taxes on aluminium raw materials, new technology and skilled manpower, in order to meet the increasing aluminium demand.

The value chain analysis assisted in examining resource productivity and efficiency trends in aluminium industry, using time series data on material and energy inputs and outputs for measures of material and energy efficiencies. Material efficiency was observed to improve over period studied but with a relatively slower rate, while energy efficiency having unstable change due to the challenges energy production and supply is facing. Capacity utilization was observed to be increasing steadily during the study period apart from the 2007 post election violence. Generally, low capacity utilization in some of the sub-sectors studied has been brought about by insufficient domestic demand for locally manufactured products, stiff competition from imports and high cost of manufacturing.

Finally, the study established that it is viable to set up a 60,000 mt alumina processing plant in Kenya, based on consumption and production of aluminium material. But there must be consideration on power availability and cost. The government should also consider coming up with policies and taxes which will encourage investors.

8.2 RECOMMENDATIONS

This study categorized the quantities of aluminium material in various forms that flow across each stage in the supply chains. The amounts of this metal contained in goods that are held in use stage and their service life distribution at this stage, enabling estimation of the waste flows was not considered. Therefore there is need to establish an analysis model that will estimate the amount of this material at each stage.

This study focused on material flows and value chain analysis of only aluminium material in Kenya, it can be further expanded geographically (say COMESA or East African regions) and with different substantial metals. This will give a better understanding on how neighbouring countries contribute to the growth of economy in Kenya and vice a versa.

It would be important to undertake energy value chain analysis for various products/processes under other metal production sectors, for example copper. Such an analysis would be the basis of determining the percentage cost that is incurred at each stage of the production cycle. Value chain analysis will allow for the capture of the direct energy and feedstock inputs of each processing step (link) and builds the cumulative value of each product along the chain.

From the challenges faced by aluminium industry in Kenya discussed before, the following is recommended to improve and expand the industry:

- Kenya and other COMESA countries' governments should set an incentive to local aluminium manufacturers to import raw materials for aluminium manufacturing duty free or with special rates.
- There is need to support the local producers investing in EOL scrap and dross smelting plants by reducing the taxes on the scrap treatment chemicals, equipments and other required material in this process.

Establishment of alumina processing plant in Kenya will lead to an influence on the environment of the site location. Therefore, there is need to carry out an environmental impact analysis and propose ways of mitigating the impact. The environmental impact will have a direct effect on land use, soil, air quality, water quality and quantity, terrestrial ecology, demography and socio economics of the surrounding society. The investors will be able to come up with the required and appropriate environmental management plan during construction and operation phases.

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APPENDIX A

QUESTIONNAIRE

SURVEY OF ALUMINIUM MATERIAL FLOW AND VALUE CHAIN ANALYSIS IN THE KENYAN INDUSTRY

Department of Mechanical Engineering

JKUAT

Introduction

This survey is a part of MSc. study in Design and Production Engineering by Mr. Peter Weramwanja, under the supervision of Professor J. M. Kihiu, Department of Mechanical Engineering, JKUAT, and Professor D. McCormick, Institute for Development Studies, University of Nairobi. The goal of this study is to investigate the supply chain systems and demand for aluminium material consumers in Kenya. This questionnaire is composed of five parts.

Part I: General company information

Part II: Key terms

Part III: Raw Material Preparation and Processing

Part IV: Approximate Energy consumed, Material Consumption and cost

Part V: Research Interest

Benefits of the study to your company

This study aims to determine aluminium material categories and transformation processes, and examine its flow. The data will be used by the current and potential investors to forecast market trends in terms of aluminium material availability and efficiency by comparing with the global trends. If you are interested in obtaining this research data, please indicate your intention in the last part of the questionnaire, titled Research Interest.

Confidentiality

Your reply will be kept completely confidential.

Filling in the questionnaire

This questionnaire seeks information from the manufacturing section, not the whole company. It is expected that the production manager, production engineer or quality assurance manager will respond to the questionnaire. Recognizing the respondent's valuable time, this questionnaire should require not more than 40 minutes to complete.

Follow-up interviews

This research study also plans to conduct some in-depth case studies by visiting plants and interviewing appropriate persons. Your willingness to allow me carry out the case study will be very much appreciated. For this purpose, please indicate your response in question B in the Research Interest section at the end of the questionnaire.

Contact person

Please return the completed questionnaire to:

Peter Marko Weramwanja,
Department of Mechanical Engineering, JKUAT,
P.O Box 62 000 – 00200,
Nairobi.

Should you have any queries, please do not hesitate to contact me at:

E–mail: weramwanja@eng.jkuat.ac.ke or werason79@yahoo.com
Telephone 067 – 52711 ext 2242
Mobile 0723 – 86 46 52

I. General Company Information

Company Name: ....

Address: ....

Telephone: ....

E – Mail: ....

Contact Person: ....

II. Key terms

Prompt scrap; - it is generated at manufacturing sites that produce new goods containing aluminium, cuttings, and turnings, salt slag and dross from aluminium production

End of life scrap (EOL); - old scrap that arises when goods become obsolete after use.

Capacity utilization rate; - ratio of the achieved production capacity to the designed capacity of the equipment.

III. Raw Material Preparation and Processing

1. Which type of products do you produce? Tick appropriately.

Power Cables	[ ]	
Kitchen Utensils	[ ]	
Engineering Tools	[ ]	
Construction	[ ]	
Packaging	[ ]	
Other	[ ]	Specify.

2. What properties and factors make you prefer aluminium than other metals in production of your products?

Light	[ ]
Strong	[ ]
Easy to join	[ ]
Good formability	[ ]
Easy to machine	[ ]
Corrosion resistant	[ ]
Good conductor of electricity	[ ]
Not poisonous	[ ]
Good reflector of light & heat	[ ]
Recyclable	[ ]
Other	[ ] Specify.

3. In which form do you get your raw material?

Locally sourced bauxite	[ ]
Imported bauxite	[ ]
Imported billets	[ ]
Imported ingots	[ ]
Imported coils	[ ]
Imported scrap (EOL)	[ ]
Imported scrap (Prompt)	[ ]
Local scrap (EOL)	[ ]
Local scrap (Prompt)	[ ]
Other	[ ] Specify.

4. Which are the initial material processing activities that you carry out in your raw material preparation?

Resizing / Slitting [ ]
Smelting [ ]
Rolling [ ]
Drawing [ ]
Extruding [ ]
Machining [ ]
Other [ ] Specify.

5. If resizing / slitting and machining, how do you utilize the off-cuts (Prompt scrap)?

Recycle internally [ ]
Sell locally [ ]
Export [ ]
Other [ ] Specify.

6. If smelting, what type of equipment do you utilize?

Induction furnace [ ]
Blast furnace [ ]
Electrical arc furnace [ ]
Basic oxygen furnace [ ]
Other [ ] Specify.

7. If smelting the raw material, do you add any scrap material (prompt or EOL) to it?

YES [ ] NO [ ]

8. If yes, what is the source of the prompt or EOL scrap?

Machine shops [ ]
Car wheels and pistons [ ]
Cylinder heads [ ]

Oil sumps and manifolds [ ]

Kitchen utensils [ ]

Packaging material [ ]

Any other [ ] Specify.

9. At what temperatures do you smelt your material?

$600\ ^0C$ - 700^0C [ ]

701^0C - 750^0C [ ]

$751\ ^0C$ - 780^0C [ ]

$781\ ^0C$ - 800^0C [ ]

Other [ ] Specify.

10. If utilizing bauxite in your production process, please indicate the typical composition.

Element	Al	Si	Mg	Mn	Fe	P	Cr	Ti	B	Cu	Zn
% composition											

11. Any other element, specify and give the percentage composition.

....

....

....

....

....

12. What is the designed capacity for your plant (tonnes per annum)?

Less than 200			[ ]
201	-	500	[ ]
501	-	1000	[ ]
1001	-	1500	[ ]
1501	-	2000	[ ]
2001	-	2500	[ ]
Over 2500			[ ]

13. Do you fully utilize the designed capacity of the plant / equipment?

Yes	[ ]
No	[ ]

14. If no, specify the approximate percentage utilized?

15. Are there plans to upgrade the plant / equipment capacity in the next five years?

Yes	[ ]
No	[ ]

16. If yes, by what capacity (tonnes per annum)?

Less than 50			[ ]
50	–	100	[ ]
101	–	500	[ ]
501	–	1000	[ ]
1001	–	1500	[ ]
1501	–	2000	[ ]
2001	–	2500	[ ]
Over 2500			[ ]

17. What are the reasons for upgrading the plant / equipment capacity?

Increased market demand	[ ]
Utilization of improved technology	[ ]
Venturing into new products	[ ]
Ready availability of raw materials	[ ]
Construction of another similar plant	[ ]
Other	[ ] Specify

18. Are there plans to downgrade the plant / equipment capacity in the next five years?

Yes	[ ]
No	[ ]

19. If yes, by what capacity (tonnes per annum)?

Less than 50			[ ]
50	–	100	[ ]
101	–	500	[ ]
501	–	1000	[ ]
1001	–	1500	[ ]
1501	–	2000	[ ]
2001	–	2500	[ ]
Over 2500			[ ]

18. What are the reasons for downgrading the production capacity?

Reduced market demand	[ ]
Increased costs of production	[ ]
Venturing into new products	[ ]
Reduced availability of raw materials	[ ]
Change in technology	[ ]
Other	[ ] Specify

IV. Approximate Energy consumed, Material Consumption and cost

Quantities (Metric tons) Raw Materials consumed

Raw Material.	2003	2004	2005	2006	2007
Locally sourced bauxite					
Imported bauxite					
Imported billets					
Imported ingots					
Imported coils					
Imported scrap (EOL)					
Imported scrap (prompt)					
Local scrap (EOL)					
Local scrap (prompt)					
Other					

Raw Material.	Source of Raw material (country of origin)				
	2003	2004	2005	2006	2007
Locally sourced bauxite					
Imported bauxite					
Imported billets					
Imported ingots					
Imported coils					
Imported scrap (EOL)					
Imported scrap (prompt)					
Local scrap (EOL)					
Local scrap (prompt)					
Other					

Raw Material.	Cost of Raw material (Kshs / ton)				
	2003	2004	2005	2006	2007
Locally sourced bauxite					
Imported bauxite					
Imported billets					
Imported ingots					
Imported coils					
Imported scrap (EOL)					
Imported scrap (prompt)					
Local scrap (EOL)					
Local scrap (prompt)					
Other					

Product.	Estimated Quantity of Products Produced (tonnes)				
	2003	2004	2005	2006	2007
Power Cables					
Kitchen Utensils					
Engineering tools					
Construction					
Packaging					
Others					

Year	Approximate Energy consumed (kWhr)				
	2003	2004	2005	2006	2007
Power Consumed					

Product.	Estimated Quantity of Products on local market (tonnes)				
	2003	2004	2005	2006	2007
Power Cables					
Kitchen Utensils					
Engineering tools					
Construction					
Packaging					
Others					

Product.	Estimated % quantity of Products on local market				
	2003	2004	2005	2006	2007
Power Cables					
Kitchen Utensils					
Engineering tools					
Construction					
Packaging					
Others					

Product.	Estimated Quantity of Products on international market (tonnes)				
	2003	2004	2005	2006	2007
Power Cables					
Kitchen Utensils					
Engineering tools					
Construction					
Packaging					
Others					

Country	Estimated % Quantities to the Export market (country of delivery)				
	2003	2004	2005	2006	2007
Tanzania					
Rwanda					
Uganda					
Burundi					
Somalia					
Sudan					
Zambia					
Ethiopia					
Botswana					
Angola					
Eritrea					
Djibouti					
Other					

V. <u>Research Interest</u>

1. Are you interested in obtaining the results of this study?

   Yes [ ] No [ ]

   If yes, please indicate the name of your organization

   ....

2. Would your plant allow me and be prepared to carry out the case study?

   Yes [ ] No [ ]

3. Would you have any other relevant comments to make in relation to this study?

   ....

   ....

   ....

   ....

   ....

   ....

   ....

   ....

   ....

   ....

Thank you for your cooperation.

APPENDIX B

PROGRAM

NPV CALCULATION

```
Dim DF, PV, SumPV, NPV, TIC, R, PBP, SPV, IC, YR As Double
Dim NE(100) As Double
Dim cnProject As New ADODB.Connection
Dim rsNPV As New ADODB.Recordset

Private Sub chkOne_Click()
Dim I, J As Integer
If chkOne.Value = 1 Then
    'set the number of rown as columns in the flex grid depending on user inputs
    msGrid.Cols = 2
    I = Val(txtOne(1).Text) + 1
    msGrid.Rows = I
        msGrid.Col = 0
    msGrid.Row = 0
    msGrid.Text = "YEAR"
    msGrid.Col = 1
    msGrid.Row = 0
    msGrid.Text = "EARNINGS"
    'lable the number of years
    msGrid.Col = 0
    J = 1
    Do While J < I
        msGrid.Row = J
        msGrid.Text = "Year" & J
        J = J + 1
    Loop
   msGrid.Enabled = True
   txtOne(2).Text = Empty
   txtOne(2).Enabled = False
Else
    msGrid.Cols = 0
    msGrid.Rows = 0
    msGrid.Enabled = False
    txtOne(2).Enabled = True
End If
lblOne(4).Caption = Empty
lblOne(6).Caption = Empty
End Sub

Private Sub cmdClear_Click()
Dim I As Integer
I = 0
 Do While I <= 3
```

Page 1

```
    txtOne(I).Text = Empty
    I = I + 1
 Loop
chkOne.Value = 0
msGrid.Cols = 0
msGrid.Rows = 0
msGrid.Enabled = False
lblOne(4).Caption = Empty
lblOne(6).Caption = Empty
txtOne(2).Enabled = True
End Sub

Private Sub cmdOne_Click()
'Declare variables to be used
Dim J, I  As Double
'data verification
If Len(Trim(txtOne(0).Text)) > 4 Then
   MsgBox "The Discount Rate can not exceed 9999%", vbOKOnly + vbCritical, "DISCOUNT RATE
TOO LARGE"
   txtOne(0).SetFocus
   Exit Sub
End If
If Val(txtOne(0).Text) = 0 Then
   MsgBox "Please enter a value for Discount Rate", vbOKOnly + vbExclamation, "DISCOUNT RATE
EMPTY"
   txtOne(0).SetFocus
   Exit Sub
End If
If Len(Trim(txtOne(1).Text)) > 2 Then
   MsgBox "The Time Period for cash flow can not exceed 99 years", vbOKOnly + vbCritical, "TIME
PERIOD TOO LARGE"
   txtOne(1).SetFocus
   Exit Sub
End If
If Val(txtOne(1).Text) = 0 Then
   MsgBox "Please enter a value for Time Period", vbOKOnly + vbExclamation, "TIME PERIOD
EMPTY"
   txtOne(1).SetFocus
   Exit Sub
End If
If Len(Trim(txtOne(3).Text)) > 10 Then
   MsgBox "The Total Initial Cost can not exceed 9999999999", vbOKOnly + vbCritical, "TOTAL
INITIAL COST TOO LARGE"
   txtOne(3).SetFocus
   Exit Sub
```

```
End If
If Val(txtOne(3).Text) = Empty Then
   MsgBox "Please enter a value for Total Initial Cost", vbOKOnly + vbExclamation, "TOTAL
INITIAL COST EMPTY"
   txtOne(3).SetFocus
   Exit Sub
End If

J = Val(txtOne(1).Text)
R = Val(txtOne(0).Text) / 100
TIC = Val(txtOne(3).Text)
If chkOne.Value = 0 Then
   'net earnings constant
   If Len(Trim(txtOne(2).Text)) > 10 Then
      MsgBox "The Net Earnings can not exceed 9999999999", vbOKOnly + vbCritical, "NET
EARNINGS TOO LARGE"
      txtOne(2).SetFocus
      Exit Sub
   End If
   If Val(txtOne(2).Text) = 0 Then
      MsgBox "Please enter a value for Net Earnings", vbOKOnly + vbExclamation, "NET EARNINGS
EMPTY"
      txtOne(2).SetFocus
      Exit Sub
   End If

   I = 1
   Do While I <= J
      NE(I) = Val(txtOne(2).Text)
      I = I + 1
   Loop
Else
   'net earnings NOT constant

   I = 1
   Do While I <= J
      msGrid.Col = 1
      msGrid.Row = I
      If Len(Trim(msGrid.Text)) > 10 Then
         MsgBox "The Net Earnings for Year " & I & " can not exceed 9999999999%", vbOKOnly +
vbCritical, "NET EARNINGS TOO LARGE"
         Exit Sub
      End If
      If msGrid.Text = Empty Then
         MsgBox "Please enter a value for Net Earnings for Year " & I, vbOKOnly + vbExclamation,
```

```
"NET EARNINGS EMPTY"
            Exit Sub
        End If

        NE(I) = Val(msGrid.Text)
        I = I + 1
    Loop
End If
'Actual calculation of NPV
SumPV = 0
I = 1
Do While I <= J
    DF = 1 / ((1 + R) ^ I)
    PV = NE(I) * DF
    SumPV = SumPV + PV
    I = I + 1
Loop
NPV = SumPV - TIC
lblOne(4).Caption = NPV
'check if project is viable
If Val(NPV) < 0 Then
    lblOne(6).Caption = "The equipment/project is NOT VIABLE"
    lblOne(6).ForeColor = &HFF&
Else
    lblOne(6).Caption = "The equipment/project is VIABLE"
    lblOne(6).ForeColor = &H0&
End If
'calculate the payback period
J = Val(txtOne(1).Text)
R = Val(txtOne(0).Text) / 100
IC = Val(txtOne(3).Text)

SPV = 0
I = 1
Do While SPV <= IC
    DF = 1 / ((1 + R) ^ I)
    If I > J Then
        NE(I) = txtOne(2).Text
    End If
    PV = NE(I) * DF
    SPV = SPV + PV
    I = I + 1
Loop
lblOne(8).Caption = I - 1 & "  Years"
End Sub
```

```
Private Sub Form_Load()
msGrid.Enabled = False
chkOne.Value = 0
msGrid.Cols = 2
msGrid.Rows = 2
frmNPV.Height = 7470
frmNPV.Width = 8070
With tblControls
   Set .ImageList = ImageList1
   .Buttons(2).Image = 17
   .Buttons(4).Image = 11
End With
DatabaseConnect
End Sub

Private Sub msGrid_KeyPress(KeyAscii As Integer)
If KeyAscii = vbKeyBack Or (KeyAscii >= vbKey0 And KeyAscii <= vbKey9) Or KeyAscii = 46 Then
   If KeyAscii = vbKeyBack Then
      'remove the last character to the right
      If msGrid.Text = Empty Then
         Exit Sub
      Else
         msGrid.Text = Left(msGrid.Text, Len(Trim(msGrid.Text)) - 1)
      End If
   Else
      msGrid.Text = msGrid.Text + Chr$(KeyAscii)
   End If

   Exit Sub
Else
   KeyAscii = 0
   MsgBox "Please enter Numeric numbers only", vbOKOnly + vbInformation, "INVALID"
End If
End Sub

Private Sub tblControls_ButtonClick(ByVal Button As MSComctlLib.Button)
Select Case Button.Index
   Case 2: SaveData
   Case 4: ExitForm
End Select
End Sub

Private Sub txtOne_KeyPress(Index As Integer, KeyAscii As Integer)
If KeyAscii = vbKeyBack Or (KeyAscii >= vbKey0 And KeyAscii <= vbKey9) Or KeyAscii = 46 Then
```

```
    Exit Sub
Else
    KeyAscii = 0
    MsgBox "Please enter Numeric numbers only", vbOKOnly + vbInformation, "INVALID"
End If
End Sub

Private Sub SaveData()
Dim I, J As Integer
If lblOne(6).Caption = Empty Then
    MsgBox "Please calculate the Net Present value before attempting to save", vbOKOnly +
vbInformation, "NO DATA"
    Exit Sub
End If
'delete previous records
If rsNPV.RecordCount > 0 Then
    rsNPV.MoveFirst
    Do Until rsNPV.EOF = True
        rsNPV.Delete
        rsNPV.MoveNext
    Loop
End If
'save current record
J = Val(txtOne(1).Text)
I = 1
SumPV = 0
Do While I <= J
    If chkOne.Value = 0 Then
        NE(I) = Val(txtOne(2).Text)
    Else
        msGrid.Col = 1
        msGrid.Row = I
        NE(I) = Val(msGrid.Text)
    End If
    DF = (1 + R) ^ -I
    PV = NE(I) * DF
    SumPV = SumPV + PV

    rsNPV.AddNew
    rsNPV!NE = NE(I)
    rsNPV!DF = DF
    rsNPV!YR = I
    rsNPV!PV = PV
    rsNPV.Update
I = I + 1
```

```
Loop

If rsNPV.RecordCount > 1 Then
   rsNPV.MoveFirst
End If
rsNPV!R = txtOne(0).Text
rsNPV!SumPV = SumPV
rsNPV!TIC = txtOne(3).Text
rsNPV!NPV = lblOne(4).Caption
rsNPV.Update
MsgBox "The data was successfuly saved in the database", vbInformation + vbOKOnly, "SAVED"
End Sub

Private Sub ExitForm()
Dim Resp As Integer
Resp = MsgBox("Are you sure you want to exit?", vbYesNo + vbQuestion, "EXIT?")
If Resp = vbNo Then
   Exit Sub
Else
   Unload Me
End If
End Sub

Public Sub DatabaseConnect()
Set cnProject = New ADODB.Connection
cnProject.Open "PROVIDER=Microsoft.Jet.OLEDB.4.0;" & "Data Source=" & App.Path &
"\Project.mdb;"
'set recordset connection properties
Set rsNPV = New ADODB.Recordset
rsNPV.Open "NPV", cnProject, adOpenKeyset, adLockOptimistic
End Sub
```

Material Requirements

```
Dim cnProject As New ADODB.Connection
Dim rsConsumption As New ADODB.Recordset

Private Sub Form_Load()
With tblControls
   Set .ImageList = ImageList1
   .Buttons(2).Image = 14
   .Buttons(4).Image = 17
   .Buttons(6).Image = 11
End With
```

```
frmComposition.Height = 8115
frmComposition.Width = 4425
cboOne.Text = Empty
cboOne.AddItem "Proposed Kenyan Alumina Plant Material Requirements"
DatabaseConnect
End Sub

Private Sub tblControls_ButtonClick(ByVal Button As MSComctlLib.Button)
Select Case Button.Index
   Case 2: Generate
   Case 4: SaveData
   Case 6: ExitForm
End Select
End Sub

Private Sub ExitForm()
Dim Resp As Integer
Resp = MsgBox("Are you sure you want to exit?", vbYesNo + vbQuestion, "EXIT?")
If Resp = vbNo Then
   Exit Sub
Else
   Unload Me
End If
End Sub

Private Sub Generate()
If cboOne.Text = "Proposed Kenyan Alumina Plant Material Requirements" Then
   lblOne(9).Caption = (Val(txtOne(0).Text) * 8500) / 810000
   lblOne(10).Caption = "None"
   lblOne(11).Caption = (Val(txtOne(0).Text) * 170000) / 810000
   lblOne(12).Caption = (Val(txtOne(0).Text) * 34000) / 810000
   lblOne(13).Caption = (Val(txtOne(0).Text) * 34500) / 810000
   lblOne(14).Caption = (Val(txtOne(0).Text) * 4400) / 810000
   lblOne(15).Caption = (Val(txtOne(0).Text) * 15500) / 810000
   lblOne(16).Caption = (Val(txtOne(0).Text) * 6000) / 810000
Else
   MsgBox "Please select the plant listed on the drop down menu", vbOKOnly + vbExclamation,
"INVALID"
   cboOne.SetFocus
End If
End Sub

Private Sub txtOne_KeyPress(Index As Integer, KeyAscii As Integer)
If KeyAscii = vbKeyBack Or (KeyAscii >= vbKey0 And KeyAscii <= vbKey9) Or KeyAscii = 46 Or
KeyAscii = 13 Then
```

```
    If KeyAscii = 13 Then
        Generate
    End If
    Exit Sub
Else
    KeyAscii = 0
    MsgBox "Please enter Numeric numbers only", vbOKOnly + vbInformation, "INVALID"
End If
End Sub

Private Sub SaveData()
If txtOne(0).Text = Empty Then
    MsgBox "please enter the quantity of Alumina", vbExclamation + vbOKOnly, "EMPTY"
    txtOne(0).SetFocus
    Exit Sub
End If
If cboOne.Text = Empty Then
    MsgBox "please select the type of plant", vbExclamation + vbOKOnly, "EMPTY"
    cboOne.SetFocus
    Exit Sub
End If
If lblOne(9).Caption = Empty Then
    MsgBox "please press the Generate Values icon on the toolbar to generate the various quantities ",
vbExclamation + vbOKOnly, "EMPTY"
    Exit Sub
End If
'delete previous records
If rsConsumption.RecordCount > 0 Then
    rsConsumption.MoveFirst
    Do Until rsConsumption.EOF = True
        rsConsumption.Delete
        rsConsumption.MoveNext
    Loop
End If
rsConsumption.AddNew
rsConsumption!Type = cboOne.Text
rsConsumption!Alumina = txtOne(0).Text
rsConsumption!AluminiumFluoride = Val(lblOne(9).Caption)
rsConsumption!Anodes = Val(lblOne(10).Caption)
rsConsumption!Coke = Val(lblOne(11).Caption)
rsConsumption!Pitch = Val(lblOne(12).Caption)
rsConsumption!ImportAluminium = Val(lblOne(13).Caption)
rsConsumption!AlloyingElements = Val(lblOne(14).Caption)
rsConsumption!FuelOil = Val(lblOne(15).Caption)
rsConsumption!Power = Val(lblOne(16).Caption)
```

```
rsConsumption.Update
MsgBox "The data was successfuly saved in the database", vbInformation + vbOKOnly, "SAVED"
End Sub

Private Sub DatabaseConnect()
Set cnProject = New ADODB.Connection
cnProject.Open "PROVIDER=Microsoft.Jet.OLEDB.4.0;" & "Data Source=" & App.Path &
"\Project.mdb;"
'set recordset connection properties
Set rsConsumption = New ADODB.Recordset
rsConsumption.Open "Consumption", cnProject, adOpenKeyset, adLockOptimistic
End Sub
```

APPENDIX C

GLOSSARY

ALUMINA - Alumina is the oxide of aluminium and the compound from which aluminium metal is commercially obtained.

ALUMINIUM - Aluminium is a versatile, silvery-white metal. When exposed to the atmosphere, aluminium rapidly forms an oxide film that prevents it from reacting with air and water. This gives it exceptional corrosion-resistant properties.

ANODE - The anode is a positively charged mass or surface that attracts negatively charged ions (anions).

BATH - Bath is an aluminium industry idiom referring to the cryolite-based electrolyte pool in the reduction cell.

BAUXITE - Found as a collection of small, reddish-brown nodules in a light brown, earthy matrix, bauxite is the prime source of alumina. 30 to 60 weight percent of alumina.

BAYER PROCESS - The Bayer process, developed by Karl Bayer in 1888, refines bauxite ore into alumina grains. It is the process currently in use worldwide.

BILLETS - A semi-finished product which are similar to blooms but of smaller cross sectional size (usually less than or 5" X 5" / 7" X 7"). These are used as input material for production of finished aluminium long products viz bars and rods, light sections, et cetera.

CALCINING - Calcining is the process of heating a material to a sufficiently high temperature to drive off volatile components or to oxidize the material without fusing it. The aluminium industry uses calcining in the Bayer Process to produce alumina and to prepare coke for anodes.

CAPACITY UTILIZATION RATE - Capacity utilization rate is the ratio of the achieved production capacity to the designed capacity of the equipment.

CASTINGS - Castings describe metal objects which are made into a shape by pouring or injecting molten/liquid metal into a mould

CATHODE - The cathode is a negatively charged surface that attracts positively charged ions (cations).

COKE - Coke is a carbon product of the crude oil refining industry

CRYOLITE - Cryolite is a mineral that when molten dissolves alumina to form aluminium and oxide ions.

DATA - These are pieces of information about a certain aspect of social, economic or political life. Data is plural, with the singular being datum.

DROSS - Dross is the material that forms on the surface of molten aluminium as it is held in a furnace. It is composed of impurities that have surfaced as a result of gas fluxing, oxidized aluminium that is the result of molten aluminium exposure to the furnaces atmosphere and aluminium that becomes entrapped in the surface material. Dross is periodically skimmed off the surface of molten aluminium and processed to recover its aluminium content.

ELECTROLYSIS - Electrolysis is an electrochemical process in which the charged species in an electrolyte are attracted to the electrodes where they react with the electrons of the electrical current. Positively charged ions migrate to the cathode and negatively charged ions migrate to the anode.

ELECTROLYTE - An electrolyte is a nonmetallic electrical conductor in which current is carried by the movement of ions.

END OF LIFE SCRAP - EOL scrap is the old scrap that arises when goods become obsolete after use or recovered from used and/or dismantled products.

ENERGY CONSUMPTION - This is measured in Giga calorie per metric tonne of aluminium produced.

EXPORT MARKET - This is a place for selling goods or services away from one's location or home country.

EXTRUSION - Extrusion is the process of forcing the metal ingot (or billet) to flow through a die to create a new cross-section with reduced area and of desired shape.

GLOBALISATION - It is the increasing linkages between and among actors located in different countries. This linkages are social, economic, cultural and political.

GOVERNANCE - The process of co-ordinating activities in a particular system, for example a chain.

HOME SCRAP - Home scrap is the scrap generated by aluminium making process and the associated primary processes.

INGOT - Ingot as used in this report describes an aluminium casting of simple shape. It includes billets, pigs, sows, T-bar, and other simple semifinished shapes.

INTERVIEW - This is the process of putting questions to someone in order to gather information. Interviews can be structured, semi-structured or unstructured.

KILOWATT-HOUR (kWh) - A kilowatt-hour (kWh) is a unit of energy.

LIFE CYCLE ANALYSIS (LCA) - Life cycle analysis is an internationally recognized analysis model of a product's impact on energy, environment, economic and social values. It extends from material acquisition and production, through manufacturing, product use and maintenance, and finally, through the end of the product's life in disposal or recycling.

LOCAL MARKET - This is a place for selling goods and services within one's location or home country. Buyers are within short distance from the seller.

LONDON METAL EXCHANGE - Is the world's largest market for trading base metals, including physical and financial (futures and options) trades for copper, lead, zinc, tin, aluminium, aluminium alloy and nickel.

MAPPING - To make a plan of how activities or processes are connected. The arrangement is a pictoral representation of the actual reality.

METAL - The final form of material derived from the processing of concentrate.

MINING - The removal of minerals from the ground.

ORE - A mixture of minerals, host rock and waste material which is expected to be profitably mined.

POT - Pot is an aluminium industry idiom that describes an electrolytic cell. The term was derived from the shape of the first cells.

POWER CONSUMPTION - This is measured in terms of number of units of electrical power consumed in kWh per metric tonne of aluminium produced.

PRIMARY ALUMINIUM - Primary aluminium refers to aluminium metal produced directly from alumina feedstock by chemical reduction.

PRIMARY DATA - Information collected directly from those who know (for example, factory managers, workers).

PRECIPITATION - Removal of crystals of alumina hydrate from the caustic soda solution of the liquor stream.

PROMPT SCRAP - Prompt scrap is the scrap generated at the initial stages of aluminium manufacturing sites that produce new goods containing aluminium, cuttings and turnings, salt slag and dross from aluminium production.

QUESTIONNAIRE - A set of questions for use in an interview. A questionnaire can be open-ended (those with blanks for filling in responses) or closed questions (those with fixed alternatives)

RED MUD - Red mud is the residue of insoluble materials that results from extracting alumina from bauxite ore. It is also referred to as "bauxite residue".

REDUCTION CELL - A reduction cell is a container holding single or multiple anodes, cathodes and an electrolytic bath used for reducing material.

REFINED - The final stage of metal of production in which residual impurities are removed from the metal.

RESEARCH - A systematic process of finding out something. It is (expected to be) planned and orderly so as to ensure the production of information which can be understood and checked.

RETAIL - Process of selling goods and services to the customer, often in small quantities.

ROLLING - Rolling describes the process that results in the reduction of the cross-sectional area of a metal shape as it is passed through rotating rolls.

SECONDARY ALUMINIUM - Secondary aluminium metal is produced from recycled aluminium products and wastes.

SECONDARY DATA - Information collected from books, newspapers or statistical yearbooks.

SMELTING - The process of extracting a mineral from its ores by heating to separate the metal infused form from non-metallic materials and other undesired minerals (often called slag)

SLAB - A semi-finished product obtained through a continuous caster and cut into various lengths.

STANDARDS - Something established as a rule, normally for measuring capacity, quality or other aspects.

SUPPLIER - A person or organisation which provides raw materials, machinery or other inputs to an enterprise on the basis of an agreement.

VALUE ADDED - The worth of a thing that is added to a good or service at each stage of its production or distribution.

VALUE CHAIN - This is the set of value-adding activities through which a product passes from the design to the consumption stages. The worth of the product increases at each point of the process.

VALUE CHAIN ANALYSIS - Value chain analysis is a method that captures the energy and material inputs and outputs of each processing step (link) and builds the cumulative value for each product along the chain.

WHOLESALE - Selling goods and services in large quantities, especially from the manufactures.

WORKER - A person who provides his/her physical or mental energy to an industrial, domestic or other concern in return for a living. The worker's energy is rewarded with wage.