Project code: 2012IB17

Final Report

Widening the coverage of PAT Scheme

Sectoral Manual - Copper industry

Prepared for

Shakti Sustainable Energy Foundation

The Energy and Resources Institute

...towards global sustainable development

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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TERI is grateful to Sterlite Industries Ltd for sharing detailed data on the year wise production and energy consumption of copper and its plant's associated products. TERI likes to acknowledge Mr. Pugazenthy, Executive Director, India Lead Zinc Development Association and also the members of Indian Copper Development Centre for directing to right resources.

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The Energy and Resources Institute (TERI)

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Abbreviations

ACP	:	Anode Casting Plant
BEE	:	Bureau of Energy Efficiency
CAGR	:	Compound Annual Growth Rate
CCR	:	Continuous Cast Rod
CSR	:	Corporate social responsibility
DCs	:	Designated Consumers
DGCI&S	:	Directorate General of Commercial Intelligence and Statistics
GDP	:	Gross Domestic Product
GJ	:	Giga Joules
GW	:	Giga Watt
HCL	:	Hindustan Copper Limited
HPGR	:	High pressure grinding roller
HIL	:	Hindalco Industries Limited.
IBM	:	Indian Bureau of Mines
ICC	:	Indian Copper Complex
ICSG	:	International Copper Study group
IISc	:	Indian Institute of Science
ISRS	:	Institute of Scrap Recycling Industries Inc.
KCC	:	Khetri Copper Complex
LME	:	London Metal Exchange
MCP	:	Malanjkhand Copper Project
NAPCC	:	National Action Plan on Climate Change
NGO	:	Non-governmental Organization
NMEEE	:	National Mission on Enhanced Energy Efficiency
PAP	:	Phosphoric Acid Plant.
PAT	:	Perform, Achieve and Trade
PCRA	:	Petroleum Conservation Research Association
SAO	:	Sulphuric Acid Plant
SEC	:	Specific Energy Consumption
Toe	:	Tonnes of oil equivalent
VRM	:	Vertical roller mill

1.0 Executive summary

The Bureau of Energy Efficiency (BEE) under the Ministry of Power has been entrusted with the implementation of the National Mission on Enhanced Energy Efficiency (NMEEE) under the National Action Plan on Climate Change (NAPCC). Perform, Achieve and Trade (PAT), a key component of the mission, is a market based mechanism to improve the energy efficiency in energy intensive large industries and facilities in a cost-effective way. The PAT mechanism is designed to facilitate the Designated Consumers (DCs) to achieve their legal obligations under the Energy Conservation Act (EC Act) in 2001, which was amended in 2010. There are 478 identified DCs which will have to reduce their energy consumption by a specific target as given by BEE. The BEE further plans to widen the coverage of PAT scheme, in subsequent phases, by adding more new industrial subsectors depending on their energy intensity.

The copper sector report prepared for Shakti Sustainable Energy Foundation studies the energy consumption details of the copper sector to enable establishment of a threshold limit for the eligibility as designated consumers. This subsector overview report was prepared covering information and data on large and medium manufacturers in terms of production capacity, technologies used, energy performance, etc. Contributing to over 3 % of the world copper market, Indian copper industry accounts for about 0.2 % of the India's GDP. With sectors such as telecom, automobile and infrastructure (including building, power and renewable energy) highly influencing the copper sector, its growth has been significant over a period of time. The major producers of copper in India are Hindustan Copper Limited, Hindalco Industries Ltd and Sterlite Industries Ltd. Of these, Hindalco and Sterlite directly import copper concentrate to produce copper metal.

The specific energy consumption of Sterlite Industries Ltd. was found to be the least compared to Hindalco Industries Ltd. and Hindustan Copper Ltd.'s ICC smelter. The specific energy consumption of all the plants were higher than the benchmark figures of 0.236 toe per tonne of copper cathode and close to world average figures of 0.330 toe per tonne of copper cathode according to Global Industrial Energy Efficiency Benchmarking, UNIDO. The total estimated annual energy consumption of different copper plants in India varies between 6000 toe to 51000 toe. With the existing annual energy consumption and SEC levels of different copper plants, an energy consumption level of 10,000 toe may be considered as threshold limit for copper industry. This would qualify all the three producers namely HCL, HIL and Sterlite to quality as DCs under PAT. SIL - Silvasa and Jhagadia Copper Limited may be further looked into based on the boundary defined and their energy consumption details

2.0 Introduction

The Indian copper sector was initially dominated by Hindustan Copper Ltd, which is a public sector company. The market was made open to private players only after 1992. The copper sector is invariably dependent on the dynamics of other related industries such as construction, electrical, electronics & communication, transportation, power, telecommunication, industrial machinery, etc. Like most other sectors, the copper sector is both energy (electricity) intensive as well as capital intensive and is based on factors such as (1) plant capacities, (2) routes of raw material procurement, (3) technology usage and (4) environmental regulations.

2.1 Sector importance

Among non-ferrous metals, copper is widely used in several industries for various applications owing to its following properties. The extensive list of copper products and its usage is given in **Appendix 2/1**.

- Higher thermal and electrical conductivities
- Better antibacterial quality
- Better malleability and ductility
- Good alloying properties
- Machinability and formability
- Excellent heat transfer medium
- Non-magnetic nature
- Corrosion resistant
- Durable
- Recyclable
- Techno-Commercially cost effective

Under the 12th Five Year Plan, capacities to the tune of 75 GW are planned in the power sector [5]. Along with the power sector, the rapid growth in other sectors such as white goods, telecom, electrical, industrial machinery etc. would lead to growing demand for copper. The consumption level of copper may also indicate the development of a nation in terms of its GDP. Figure 2.1 shows the linkage between per capita use of refined copper and the GDP per capita of different nations. India's position regarding this is found to be relatively low.

The market share of Indian copper industry is about 3 % of the global market [20]. The copper industry is closely dependent on the performance and demand in power, telecommunication and infrastructure sectors and hence is linked to the economic and industrial growth of a country. In spite copper being used in a variety of applications, the turnover of the Indian copper industry was around Rs 35 billion in 2008 accounting for just 0.2 % of the GDP [26].

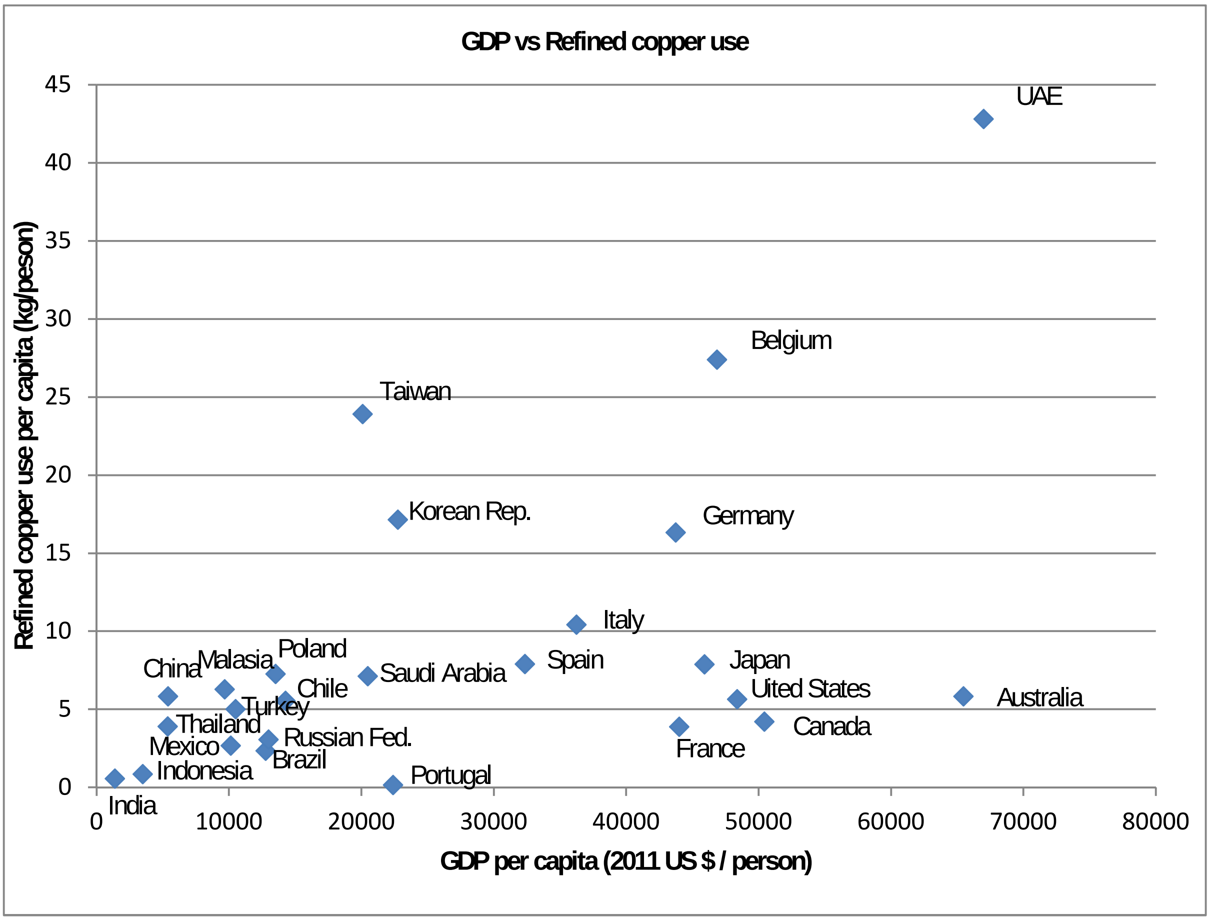

Figure 2.1: Refined copper use vs. GDP of different countries

Ref: The World Copper Fact book 2012, International Copper Study Group. [19]

2.2 National / International scenario

2.2.1 Copper reserves in India

India has large reserves of copper ore. Copper ores are available in 14 states in India. But Rajasthan, Jharkhand, Madhya Pradesh, Andhra Pradesh, Karnataka and Sikkim are the only states where copper is extracted on an economical basis. As per the National Mineral Inventory as on 1.4.2010, the total copper ore resources available in India is placed at 1558.46 million tonnes and 25.3 % of this falls under reserves. Copper metal is produced in India copper ore reserves available domestically as well as imported concentrates. The reserves and resources as per the National Mineral Inventory as on 01.04.2010 is given in Table 2.1.1a. The copper resources in India are mostly concentrated in Rajasthan (49.9% of the total), Madhya Pradesh (24.2% of the total) and Jharkhand (18.5%). The brief state wise distribution of copper resources according to the National Mineral Inventory is given in Figure 2.2.1 and is detailed in Appendix 2.2.

Table 2.1.1a: All India reserves and resources of copper as on 01.04.2010 in '000 tonnes

Copper	Reserves	Remaining resources	Total resources
Ore (Total)	3,94,372 (25.3%)	11,64,086 (74.7%)	15,58,458
By Grades			
Ore with 1.85 % and above Cu	0 (0%)	2,641 (100%)	2,641
Ore with > 1.00 % and < 1.85 % Cu	3,81,698 (56.5%)	2,94,447 (43.5%)	6,76,145
Ore with > 0.50 % and < 1.00 % Cu	588 (0.1%)	6,16,982 (99.9%)	6,17,570
Ore with 0.50 % and below Cu	12,086 (4.6%)	2,50,016 (95.4%)	2,62,102
Metal	4,768.33 (38.8%)	7,518.34 (61.2%)	12,286.67

Source: National Mineral Inventory at Glance, Indian Bureau of Mines [1]

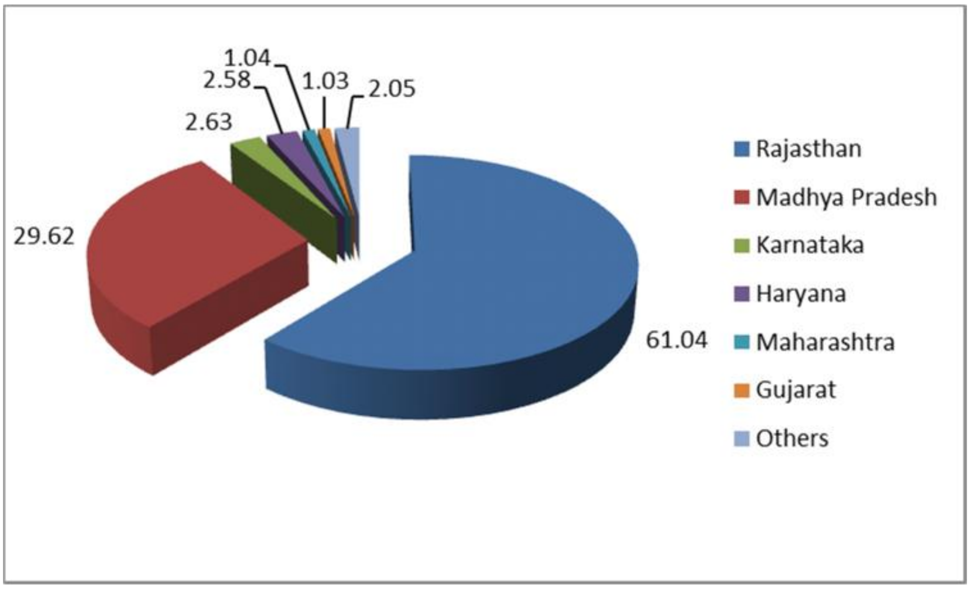

Figure 2.2.1: State-wise distribution of copper ore resources (in percentage)

Source: National Mineral Inventory at Glance, Indian Bureau of Mines [1]

The important copper belts in India are shown in table 2.2.1b.

Table 2.2.1b: Copper belts in India

S No	State	Copper belt
1	Jharkhand	Singhbhum copper belt
2	Rajasthan	Khetri copper belt
3	Madhya Pradesh	Malanjkhand copper belt
4	Andhra Pradesh	Agnigundala copper belt
5	Karnataka	Chitradurga copper belt
6	Gujarat	Ambamata multi metal deposit
7	Sikkim	Rangpo multi metal deposit

2.2.2 Production and consumption

2.2.2.1 World copper production trends

The global copper production as cited by the London Metal Exchange is given in Figure 2.2.2.1a.

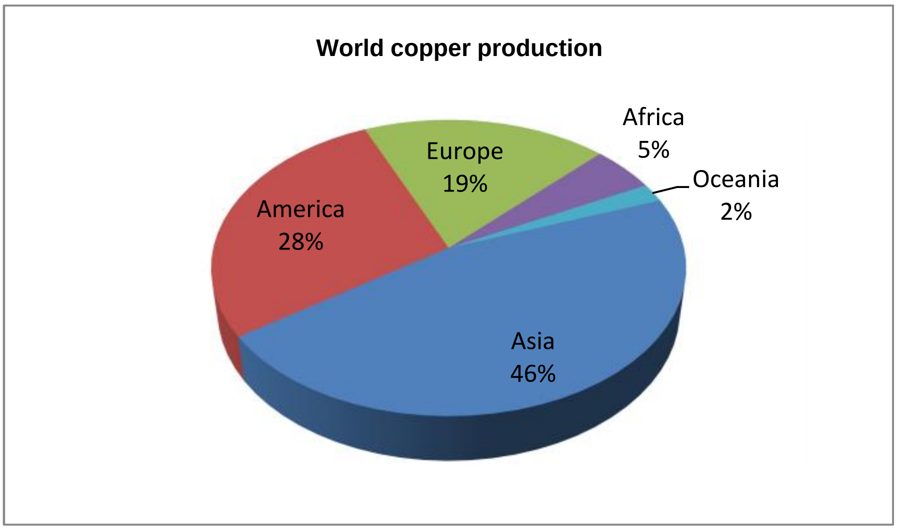

Figure 2.2.2.1a: Distribution of global copper metal production

Source: World Copper Production 2011, Industry usage, London Metal Exchange [2]

Chile remains the top producer of copper ore, followed by USA and China. India is emerging as a net exporter of copper from the status of net importer. The production of copper in India during 2010 was 33,000 tonnes. The country-wise production for the period 2008 to 2010 is given in **Appendix 2.3**. The world refined copper production trend as seen in figure 2.2.2.1b, is increasing rapidly. This indicates the increase in the usage of ore and the concentrate.

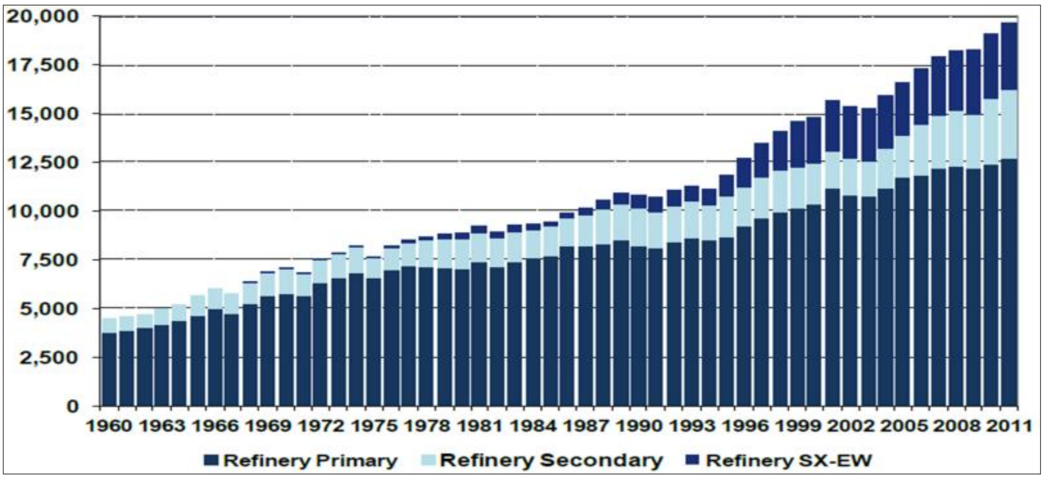

Figure 2.2.2.1b: World refined copper production trend (thousand metric tonnes)

Source: The World Copper Factbook 2012, ICSG [19]

Refinery Primary: Producing from ore and concentrates

Refinery Secondary: Producing from recycled materials and scrap

Refinery SX-EW: Producing copper through solvent extraction electrowinning process

2.2.2.2 Production in India

The Indian copper industry can be classified into two broad categories namely (1) Manufacturers of refined copper (copper cathodes) and (2) Manufacturers of copper products. According to The World Copper Fact book 2012, ICSG preliminary data of 2011 ranks India as 6th globally in refined copper production, while China remains the leading producer.

a. Copper ore production

The trend in the ore production, as shown in Figure 2.2.2.2a is found to vary in the bandwidth of 2.64 million tonnes to 3.50 million tonnes.

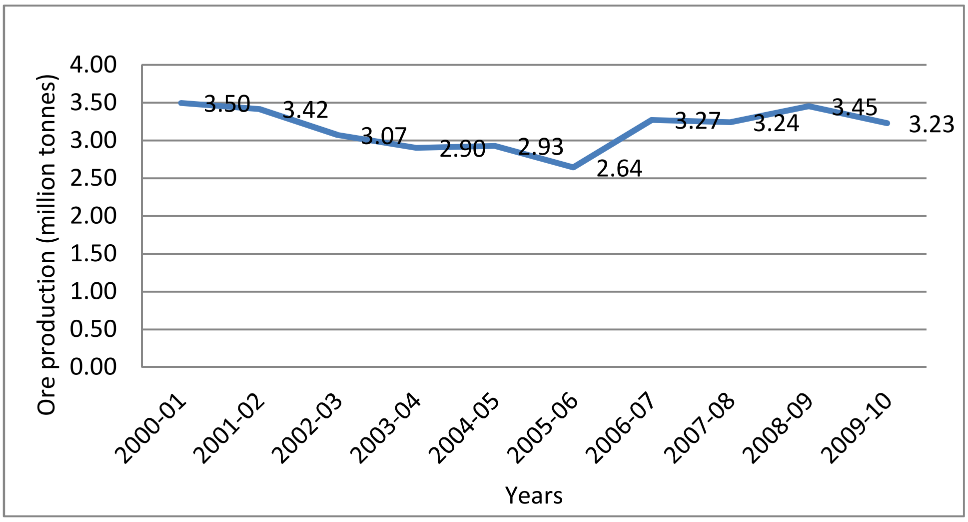

Figure 2.2.2.2a: Year wise copper ore production in India in million tonnes

Source: Market survey on copper (p. 52), Indian Bureau of Mines [4]

b. Copper concentrate production

There are three major copper producers in India. These include (1) Hindustan Copper Ltd, (2) Sterlite Industries (I) Ltd and (3) Hindalco Industries Ltd. Of these, Hindustan Coppers Ltd (HCL) is the sole producer of copper ores and thus copper concentrates in India. The copper concentrates are further used to produce copper metal. Hindalco Industries Ltd. and Sterlite Industries Ltd. directly import the copper concentrate to produce copper metal. Figure 2.2.2.2b indicates a slight decreasing trend in the production of copper concentrate in India.

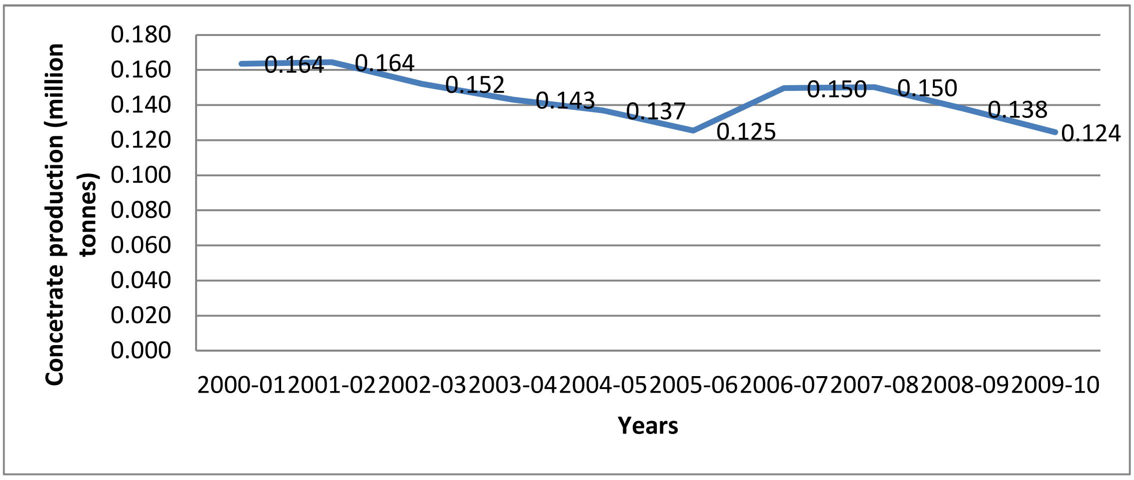

Figure 2.2.2.2b: Year wise copper concentrate production in India in million tonnes

Source: Market survey on copper (p. 55), Indian Bureau of Mines [4]

c. Copper metal production

The copper metal production has been significantly increasing over the last decade. The copper metal production during 2009-10 was 0.66 million tonne. The trend in refined copper production since the year 2007 is shown in figure 2.2.2.2c. The production includes both primary and secondary copper.

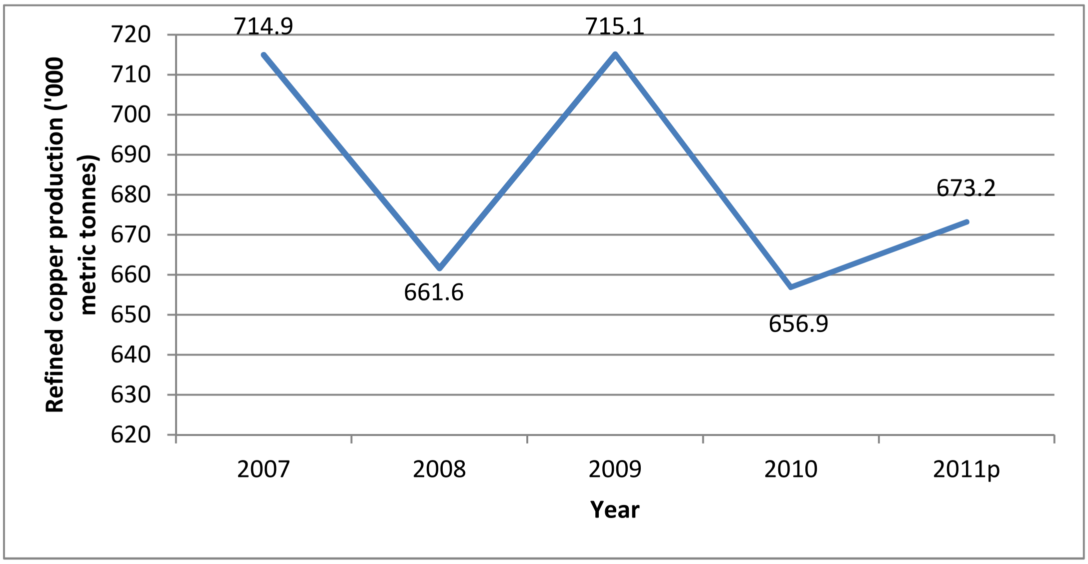

Figure 2.2.2.2c: Year wise refined copper production in India in million tonnes

Source: ICSG Copper Bulletin 2012[21]
Note: 2011p indicates preliminary data

Copper metal production is highly dependent on the availability of copper concentrate. It is observed that in spite there is a decrease in the concentrate production, the metal production remains unaffected rather constantly increasing and may be attributed to the imports of concentrates.

2.2.2.3 World copper consumption trends

Copper is transported to smaller copper product manufacturing or secondary units mainly in the form of cathode, wire rod, billet, slab or ingot. It is further converted to wires, rods, tubes, castings, etc. through various methods such as extrusion, rolling, melting, electrolysis etc. The final copper and its alloys are used for appliances, electronics, automobiles and in many such sectors. Globally copper has found its way into every possible application. With 31% of the global consumption, the electrical and electronics industry is the highest consumer of copper and the construction sector stands second at 25%. The distribution of global copper consumption from CRU (an independent business intelligence company into mining, metals and fertilizers) cited by the London Metal Exchange is given in Figure 2.2.2.3a and the refined copper consumption, which shows an increasing trend is given in Figure 2.2.2.3b.

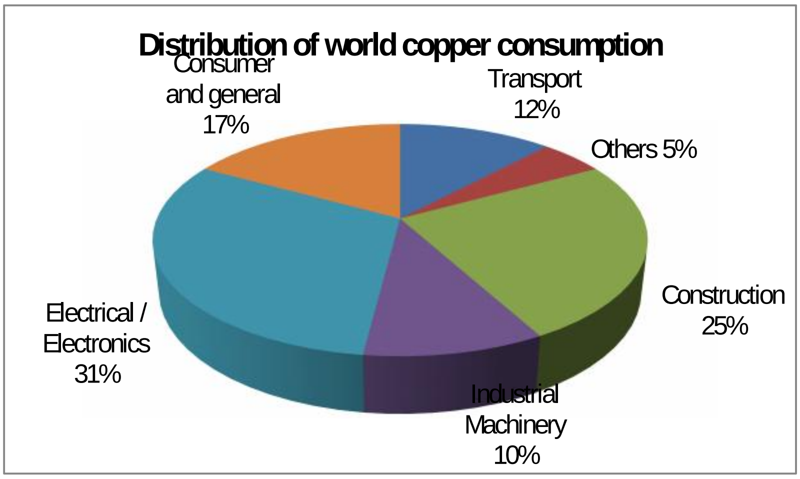

Figure 2.2.2.3a: Global consumption of copper consumption

Source: World copper consumption 2011, Industry usage, London Metal Exchange [2]

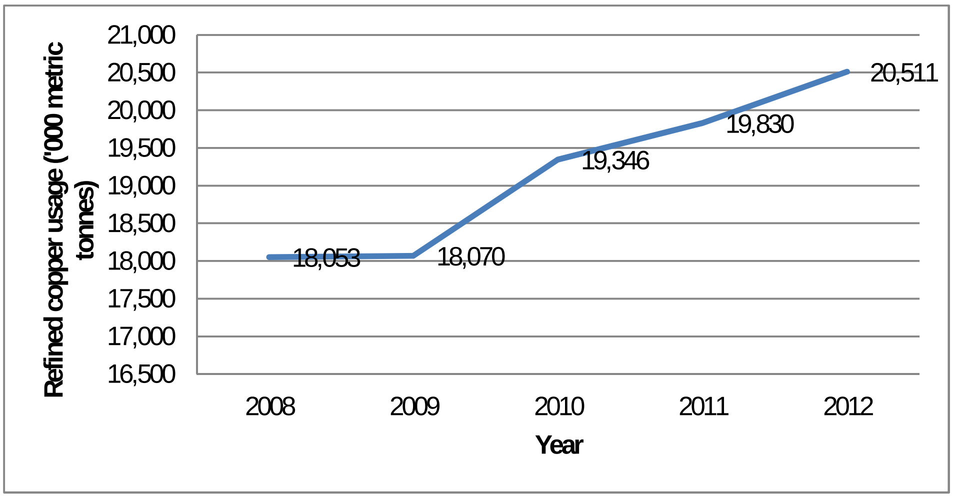

Figure 2.2.2.3b: World refined copper usage trend

Source: ICSG Copper Bulletin 2012[21]

2.2.2.4 Copper consumption trend in India

The telecom sector is found to be the largest copper consumer in India. It is envisaged that with the advent of wireless technology in telecom services, the consumption of copper in telecom sector is expected to go down. The copper consumption in different end-use sectors in India is given in Figure 2.2.2.4a.

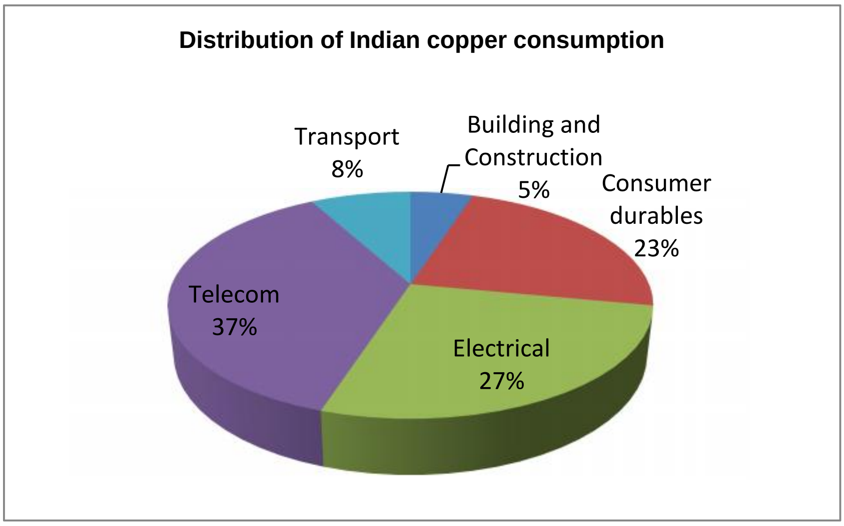

Figure 2.2.2.4a: Copper consumption in different sectors in India

Source: Market survey on copper (p. 5), Indian Bureau of Mines [4]

High demands of the power sector have triggered significant growth in the copper consumption in India. Other significant consumers include buildings &construction, engineering, transport and consumer durables sectors. Major telecom companies (BSNL and MTNL) consume about 10% of the copper production in the country [25]. Figure 2.2.2.4b shows the variations in usage of copper in India from 2007 to 2011.

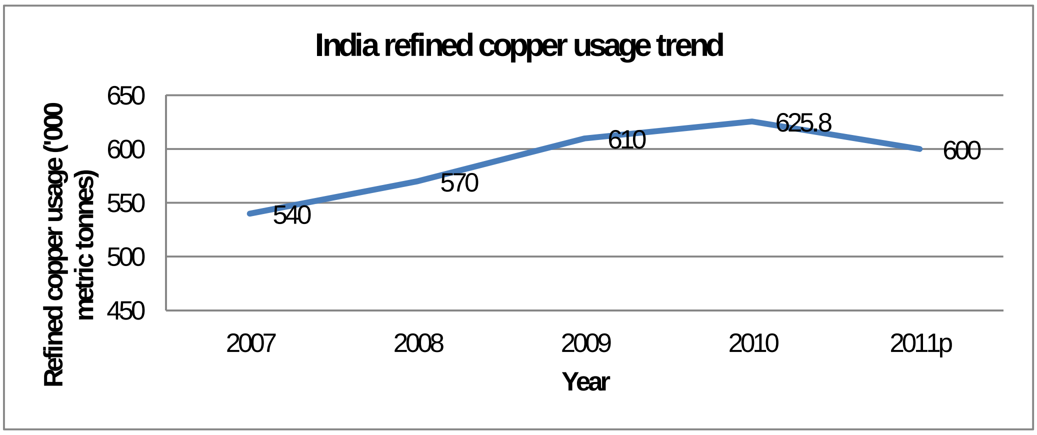

Figure 2.2.2.4b: Refined copper usage trend in India

Source: ICSG Copper Bulletin 2012[21]

Note: 2011p indicates preliminary data

2.2.3 Prices

Copper is traded under different categories such as copper cathodes, anodes, wire bars and rods, scrap and forms of alloys such as brass, bronze, etc. The price of copper depends on factors such as purity, growth in different industrial sectors, etc. The trading of copper in the domestic market in India is done mostly in Delhi and Mumbai. The London Metal Exchange (LME) is central among the many international commodity exchanges where copper is traded. The month-wise price trend of copper in the international market for 2010, 2011 and 2012 from LME is given in Figure 2.2.3. The price details [16] in the Figures 2.2.3 and 2.4 are given in Appendix 2/4.

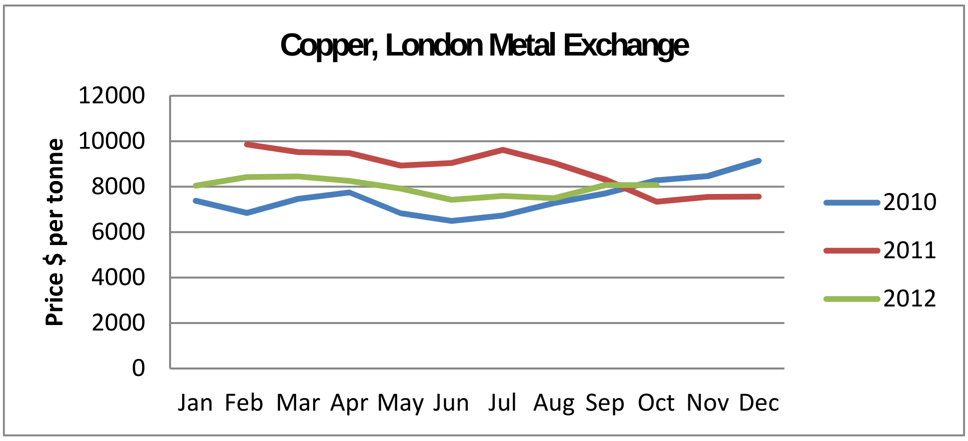

Figure 2.2.3: Monthly price trend of copper as per the London Metal Exchange

It can be observed that the prices have been fluctuating drastically every year. The prices in 2012 were lower than those of 2011 during January to September. The international prices mainly depend on the consumption patterns of China, USA and Germany.

2.2.4 Imports and exports

2.2.4.1 Imports

Imports and exports of various forms of copper are part of a growing trade in many countries. The global total refined copper imports for 2009 according to the World Metal Statistics, as cited by the Indian Bureau of Mines in their document "Market Survey of Copper", was around 7.97 million tonnes with a rapid increase of around 6 % every year. China has been the largest importer of refined copper at 3.2 million tonnes, followed by Germany at 0.66 million tonnes.

India imports a wide range of copper forms such as ores, concentrate, alloys, scrap etc. A large share of the copper ores and concentrates mainly come from Chile followed by Australia. The alloys are consistently imported from Australia, China, Germany and Russia. Scraps from UAE and Saudi Arabia hold large share of Indian imports. India's refined copper imports is relatively very low at 0.016 million tonnes [4]. Hindalco Industries Ltd. and Sterlite Industries Ltd. import almost their entire copper concentrate requirement from other countries. Recycling of copper also forms a significant business for the scrap industry. The copper scrap is imported under the trade names approved by Institute of Scrap Recycling Industries Inc. (ISRI).

2.2.4.2 Exports

The total global refined copper exports for 2009 according to the World Metal Statistics as cited by Indian Bureau of Mines in their document "Market Survey of Copper" was around 8.64 million tonnes with a rapid increase of around 7 % every year. Chile has been the largest exporter of refined copper at 3.19 million tonnes, followed by Japan at 0.63 million tonnes.

India currently is a net exporter of refined copper with an annual export quantity of 0.18 million tonnes as of 2009 [4]. India exports a wide range of copper forms such as alloys, scrap etc. Ores and concentrates are exported in very minimal amounts and are irregular. They are mainly exported to China and Germany. According to the Directorate General of Commercial Intelligence and Statistics (DGCI&S), as cited by Indian Bureau of Mines in their document "Market Survey of Copper", the total quantity of alloy export was to the tune of 0.25 million tonnes in 2009. Of this about 21 % was exported to Saudi Arabia and about 18.5% to UAE. The list of copper forms both imported and exported by India is given in Appendix 2/5.

2.3 Past growth and future prospects

The production and consumption trends for both India and the world imply that the demand for copper is increasing in line with the development. A 2.4% increase in the Compound Annual Growth Rate (CAGR) of world refined copper production was witnessed since 2000 and as per 2012 statistics, it stands at 20.1 million tonnes. This rise in production and consumption can be attributed to China, the fastest growing economy in the world. China's refined copper production witnessed 12.8% CAGR since 2000 and the country's share in the world copper consumption increased from 29% in 2008 to over 39% in 2012.

India witnessed a 7.9% increase in CAGR of refined copper production since year 2000 and stood at 705,000 tonnes in 2012. In the same year India's consumption was 3.94 lakh tonnes [18]. As per the International Copper Study group (ICSG), the copper may globally witness a surplus in 2013 as refined copper production is estimated to increase significantly by around 5% to 21.4 million tonnes in 2013. But the consumption is expected to grow by only 1% to 20.68 million tonnes due to the slow economic growth across the world [18].

Copper cathode: It is manufactured from the concentrates. This copper cathode is further sent to mills or foundries to be casted into wire rods, billets, and ingots ore to be alloyed with other metals

Refined copper: Refined copper is copper separated from its impurities. i.e. pure form of copper. This does not include alloys.

2.4 Major players and their production data

Hindustan Copper Limited is the only primary producer in India, which undertakes mining, beneficiation, smelting, refining and final product production. Hindalco Industries Ltd. and Sterlite Industries Ltd. primarily process the imported copper concentrate to produce end products like copper bars, rods and wires. Jhagadia Copper Ltd. is another major producer which produces refined copper by using copper scrap as raw material. The major players along with their key manufactured products are shown in Figure 2.4.

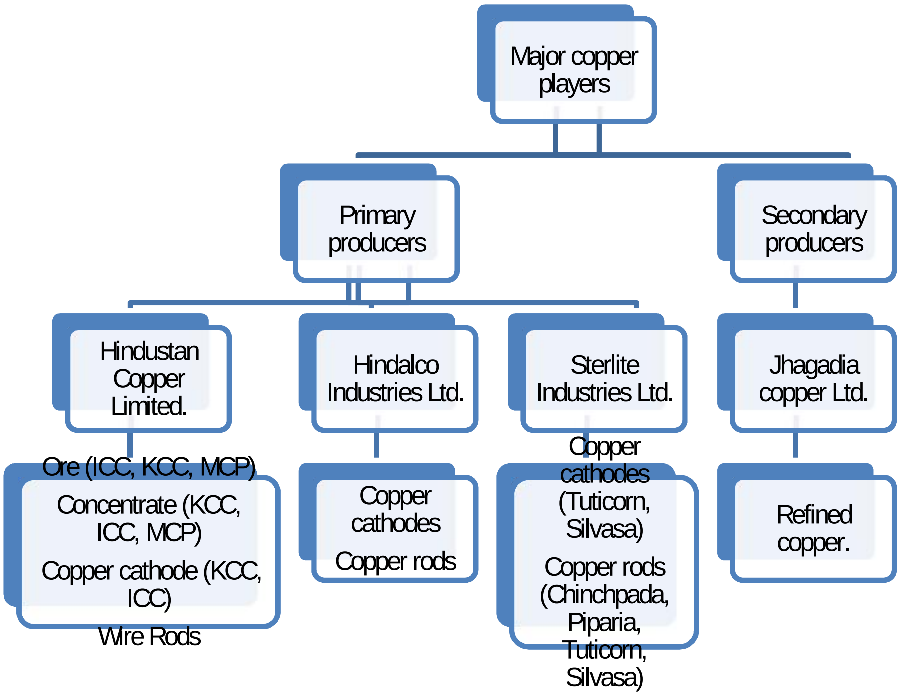

Figure 2.4: Major Indian players and their key copper products

The other by-products of the above industries include sulphuric acid, phosphoric acid, DAP (di-ammonium phosphate) and its complexes, gold, silver, etc.

2.4.1 Copper ore

Copper ore in India is produced by only HCL. The ore production of HCL is catered by the following:

(i) Indian Copper Complex (ICC) – Ghatsila, Jharkhand.
(ii) Khetri Copper Complex (KCC) – this currently has four mining projects. Khetri, Kolihan, Chandmari in Jhunjhunu district and Dariba in Alwar district.
(iii) Malanjkhand Copper Project (MCP) - Malanjkhand, Balaghat district, Madhya Pradesh. It is the largest open pit mine in the country.

2.4.2 Copper concentrate

Concentration of copper is again only undertaken by HCL in India. The concentrate production from HCL is majorly from:

(i) Indian Copper Complex (ICC) – Ghatsila, Jharkhand with a capacity of 1.55 million tpy.
(ii) Khetri Copper Complex (KCC) – Khetrinagar, Jhunjhunu district with a capacity of 2.02 million tpy.
(iii) Malanjkhand Copper Project (MCP) - Malanjkhand, Balaghat district, Madhya Pradesh with a capacity of 2.00 million tpy. It is the largest open pit mine in the country.

2.4.3 Copper metal production

Copper metal production in India involves both the public as well as the private sector. HCL has two plants i.e. KCC and ICC which have integrated smelters along with a continuous cast wire rods plant based on copper cathodes in Taloja, Raigad district. In addition to this, the private sector includes Hindalco Industries Ltd. at Dahej, Bharuch dist., Gujarat and Sterlite Industries, Tuticorin, Tamil Nadu, which produce from imported copper concentrates. Jhagadia Copper Ltd., Jhagadia, Bharuch district, Gujarat uses the secondary route of manufacturing copper by using scrap as input. The installed capacities of various industries are given in Table 2.4.3. The year-wise details of installed capacity and production of copper cathode from the major industries is given in Appendix 2.6. It may be noted that Khetri Smelt is not in operation since 2008.

Table 2.4.3: Installed capacities of the industries

Sl. No.	Name and location of smelters	Installed capacity (tpy)
1	Hindalco Industries Ltd. Dahej, Dist. Bharuch, Gujarat	5,00,000
2	Sterlite Industries Ltd., Tuticorin, Tamil Nadu	4,00,000
3	Jhagadia Copper Ltd., Jhagadia, Dist., Bharuch, Gujarat	50,000
4	Khetri Copper Complex, Khetri, Dist. Jhunjhunu, Rajasthan	31,000
5	Indian Copper Complex, Ghatsila, Dist. East Singhbhum, Jharkhand	20,500
	Total	10,01,500

Source: Market survey on copper (p. 55), Indian Bureau of Mines [4]

2.4.4 Copper scrap

Recycling of copper is mainly done in unorganized sector. Copper scrap mostly includes wastes from smelters, radiators, electric motors, used cable wires, household utensils, old transformers, etc. The state-wise distributions of such unorganised units along with recycling capacities are given in Table 2.4.4. It may be noted that not all these units are in operation. A large number of the operating units are run at 50% of their rated capacities.

Table 2.4.4: State-wise capacities of Reprocessing Units (Copper and its alloys) as registered with CPCB/MOEF as on 23-09-2010

S.No	State	No. of units	Capacity (tonnes/year)
1.	Andhra Pradesh	8	19,970
2.	Chhattisgarh	1	150
3.	Daman Diu & Dadra Nagar Haveli (Union Territory)	3	26,073
4.	Goa	1	20,000
5.	Gujarat	31	41,610
6.	Haryana	2	22,050
7.	Jammu & Kashmir	37	2,89,072
8.	Karnataka	4	4,500
9.	Madhya Pradesh	3	3,570
10.	Maharashtra	6	13,620
11.	Punjab	2	7,300
12.	Rajasthan	4	9,615
13.	Tamil Nadu	1	12,000
14.	Uttar Pradesh	6	9,640
15.	West Bengal	4	360
	Total	113	4,79,530

Source: MoEF, Central Pollution Control [6]

2.5 Important stakeholders

The stakeholder details specific to the copper sector are briefly described as follows:

- Primary producers involved in manufacturing of copper concentrate, copper cathodes and other copper products. These include (i) Hindustan Copper Ltd (ii) Hindalco Industries Ltd and (iii) Sterlite Industries Ltd
- Secondary producers involved in recycling copper from copper wastes and production of other copper products. These include (i) Jhagadia Copper Ltd and (ii) Other large, medium and small scale industries (around 310 registered re-processors)
- Government – Operates the major public sector enterprise (Hindustan Copper Ltd). It also defines trade policies and public private share in the industry.
- Copper bodies and associations
  - (i) International Copper Study Group: It is an intergovernmental organization which provides platform for the government and associations to discuss various issues of copper sector.
  - (ii) International Copper Promotion Council: Focuses on promoting usage of copper for safety, health, environment and energy savings.
  - (iii) Indian Copper Development Centre: Helps in promoting the right and efficient use of copper and its alloys. It is involved in developing the market for copper and provides guidance to the Indian copper industries.

2.6 Product categorization

The four major industries in India produce refined copper. There are also a number of industries in SME (small and medium enterprises) sector that produce various products of copper. A list of such products along with the number of industries as given by the Directory of Indian Copper Industries is given in Table 2.4.

Table 2.4: Number of industries producing copper products

Sl. no.	Product type	Number of industries
1	Bars, rods, sections	87
2	Castings and forgings	66
3	Chemicals	3
4	Continuous cast rod	8
5	Fabricated products	36
6	Ingots, billets and other alloys	26
7	Powders	17
8	Sheets, strips, foils, plates	55
9	Tubes, pipes	68
10	Wires, cables, conductors	142
11	Miscellaneous	18
	Total	526

Source: Directory of Indian Copper Industries, Indian Copper Development Centre [7]

The product-wise list of large scale industries along with their capacities is given in Appendix 2.7.

2.7 Current regulatory/ policy scenario and changes needed for growth

Like for every other metal, copper mining was also considered for foreign investment under The National Mineral Policy, 2003. Internationally, a large number of regulatory drivers play a key role in copper production, addressing the primary production, i.e. the mining industry and secondary production (i.e. construction, electrical, infrastructure, and transportation). Some of the elements under the policy and regulatory framework are as follows:

- Industrial Policy resolution: This gives an outline for the development and growth of the industry for a continuous increase in production which is important for a healthy economy. It indicates that the concerned states must play active role in the industrial growth.
- National Mineral Policy: Focuses on the best use of the minerals available with the help of good mining technology, beneficiation and economic utilization. This encourages the use of foreign investment and technology for efficient production.

The other policy aspects include the energy efficiency of the industries, which is enforced by the Energy Conservation Act. The Act has identified seven industry sectors as Designated Consumers (DCs) and PAT (Perform, Achieve and Trade) mechanism for mandatory adoption by DCs. However, copper industry is not part of DCs under the present list provided under the Act.

3.0 Energy performance

3.1 Copper manufacturing process and technological advancements

The manufacturing process and the technology adoption by Indian copper industry have not changed significantly especially on the process side. The utilities or auxiliaries on the other hand have a wide range of new energy efficient technologies entering the market on a regular basis. The manufacturing process and the types of technologies used in different stages are briefly described.

3.1.1 Mining

Mining (open-pit or underground) of metal ores uses explosives. Electricity is used for shovel loaders and drilling. In-pit crushing and conveying is currently preferred so as to replace the need of trucks for hauling. Over time, the mining sector has been improving in better fragmentation of ores.

3.1.2 Beneficiation

The beneficiation method(s) selected varies with the mining operations, ore characteristics and economic considerations. A suitable smelter grade concentrate is produced in this process. The unwanted gangue is removed and the sulphide ores are concentrated. An efficient beneficiation process helps in saving large quantity of energy (both electrical and thermal) along with the need for low furnace capacities. The principal production process of copper is given in Figure 3.1.2.

3.1.2.1 Comminution

The ore size is reduced to facilitate further process of ensuring the acceptable liberation of impurities and unwanted materials. It involves two stages:

a) Crushing

Size reduction of 1000mm to as low as 10 mm is achieved in the crushing process. Jaw or gyratory crushers are used for primary crushing. Cone or roll crushers are used for secondary crushing with the discharge product size ranging from 20-25 mm. The final third stage crushing discharge product size ranges from 3-15 mm. The technology used, i.e. the type of crushers used depends on the capacity of the plant and the nature of the ore.

b) Grinding

Grinding is done for obtaining fine ground discharge. The mills used are:

- Rod Mills - operated in open circuit.
- Ball Mills - operated in closed circuit with classifiers.
- Autogenous mills - Recently introduced. Applicable when ore is wet, sticky, tough and blocky.

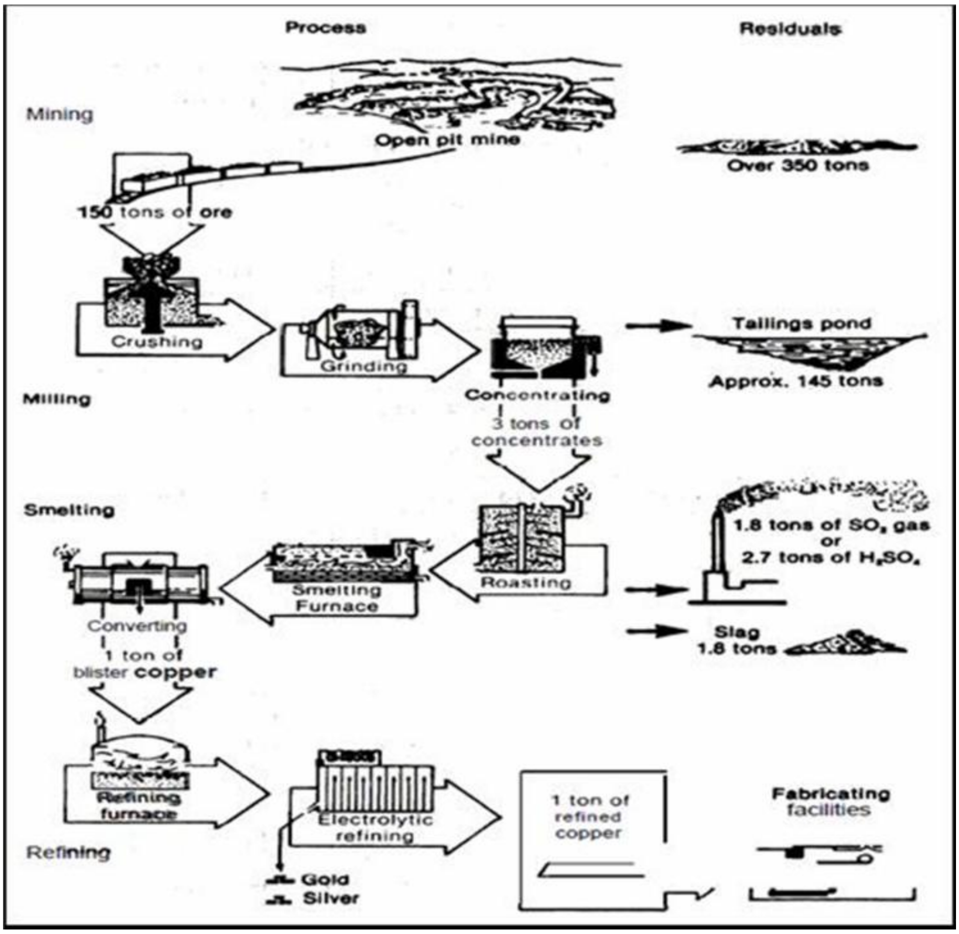

Figure 3.1.2: Copper production process

Source: JF McDivitt and G Manners, Minerals and Men (Baltimore, Md: The Johns Hopkins University Press, 1974)

The current crushing and grinding processes are highly energy inefficient. The general industrial practice is to allow the material to pass first through the rod mills followed by ball mills for achieving lower power consumption per tonne of ore ground. The type of mill used is dependent on the type of ore being processed. The use of High Pressure Grinding Roller (HPGR) and Vertical Roller Mills (VRMs) are already in place in many of the copper plants around the world. This technology is believed to be the most advanced and highly energy efficient for communition [27]. Here the high pressure induced causes the formation of micro-cracks in the feed particles which further generates a substantial amount of fine material. The pressed material can be fed directly to a given size ball mill, making it possible to increase the throughput of a given size ball mill and reduce the specific power consumption of the whole mill system.

The use of HPGR helps in downsizing the ball mills and the grinding media. This further helps in reducing the steel balls usage and energy consumption. Based on the capacity of the plant and the nature of the ore, necessary crushers and mills are used for the size reduction.

3.1.2.2 Concentration

Froth flotation process is the most widely used process for concentrating the ore. The concentration is done on the principal of creating differences in specific gravity of the sulphide minerals of copper and other base metals by using flotation reagents such as frothing agent, collectors, depressants and pH regulators. Depending on the extent of impurities, a number of floatation process cycles are carried out.

3.1.2.3 Dewatering

The concentrate from the floatation process is further dried by following dewatering techniques:

i) Sedimentation - up to 80% water removed
ii) Filtration - Further 10 % water removed. Uses both drum and disc filters.
iii) Drying - Spray, rotary drum and multiple hearth dryers are used in the copper mill. Rotary driers are most commonly used at present.

Studies on effective reagents for better recovery of copper during beneficiation are currently and research. Many plants are focusing on reducing their losses by recovering other metals from the ore tailings and enhancing their profits.

3.1.3 Smelting

Copper is extracted from its sulphide ores and concentrates by one of the following two processes.

3.1.3.1 Pyro-metallurgical Processes

It involves melting and oxidation for removal of iron, sulphur and silica. The method of operation and smelting practices is smelter dependent. The stages involved in the process are as follows:

a) Roasting

The concentrates are partially oxidised using air at 500 to 700^{0}C. Reverberatory smelting furnaces are used in order to dry and heat the feed for the smelter. Other furnace options include blast furnace and flash smelting furnace.

b) Smelting

i) *Matte smelting:* Copper matte containing 30 - 60 % of copper with specific gravity greater than 5 is formed by subjecting the concentrates to melt at 1150 - 1200 ^{0}C. A variety of smelting technologies are used based on the composition of the feed to the furnace or the type of product required. The selection also depends on the type of logistics, fuel, and other sources available.
ii) *Reverberatory smelting:* The exhaust from this process causes serious pollution problems and has a thermal efficiency of 25 - 30 %.
iii) *Electric furnace smelting:* This process has low operational and capital cost and is most preferred in areas with low electrical energy costs. It consumes about 325 to 425 kWh per tonne of calcined concentrates with a high thermal efficiency and less air pollution.
iv) *Flash furnace smelting:* This process has disadvantages like copper losses in slag and requirement of additional treatment for fine dust released than when compared to reverberatory or electric smelting furnace.

c) Converting

The iron and sulphur impurities are removed from the matte obtained from the smelting process by using air oxidation method.

d) Slag making

The remaining copper oxides from the converting process are further re-sulphidised.

e) Copper making/refining

Impurities in minor quantities (As, Cd, Ge, Hg, Pb, Sb, Bi, and Sn) along with zinc are removed as vapour and through slag respectively. Fire refining is one such method. The other new and emerging process includes 'foam smelting' and 'electrolytic refining'. Over the past several decades, there have been no significant changes in smelting technology. However, there has been significant increase in the numbers of industries using these technologies. Figure 3.1.3.1e represents the increase in the copper smelting capacities and the use of different smelting technologies over time.

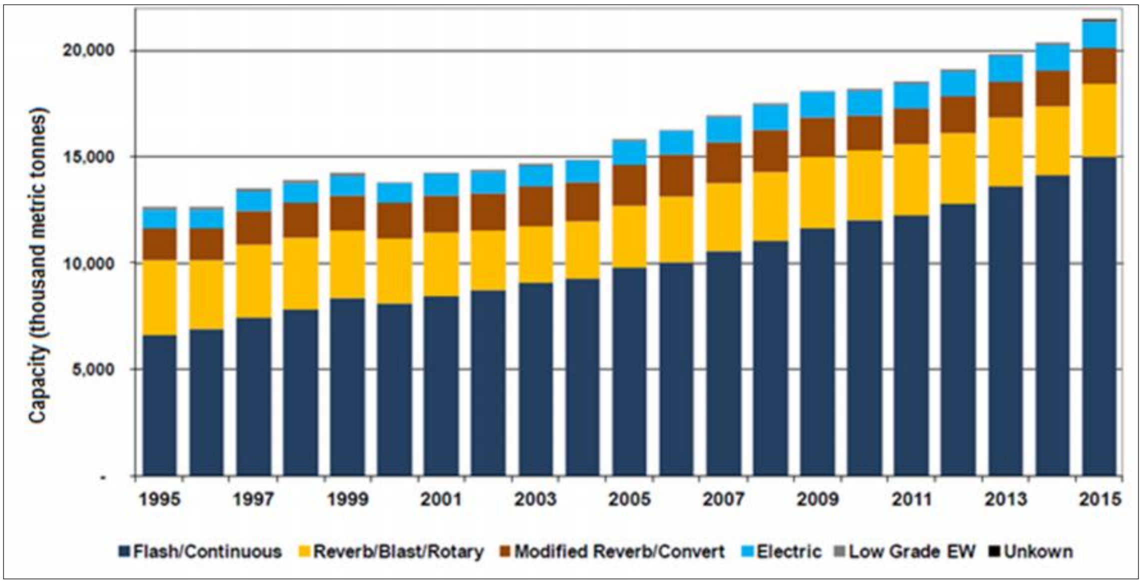

Figure 3.1.3.1e: Trends in global capacity and technology usage in copper smelting

Source: The World Copper Factbook 2012, ICSG [19]

Electric furnaces and flash furnaces are generally efficient. However, due to high energy costs, electric furnaces are not used to a large extent as compared to the flash furnaces. Increasingly plants now prefer flash furnaces because of advantages such as waste heat recovery for fire heating combustion air and drying of furnace charge or cogeneration opportunities to generate electricity. However in India, major technology changes have not been observed in the copper plants since their installation. The technology details of these plants are given in Table 3.1.3.1e

Table 3.1.3.1e: Technology details of major copper plants in India

Plant	Technology	Year of installation	Status
HCL, Ghashilla	Reverberatory	1928	In operation
HCL, Khetri	Flash	1971	Mothballed
Sterlite, Tuticorin	Isamelt	1996	In operation
Hindalco (Birla), Dahej	Flash	1997	In operation
Hindalco (Birla), Dahej	Ausmelt	2003	Mothballed
Hindalco (Birla), Dahej	Mitsubishi	2005	In operation

3.1.3.2 Hydro-metallurgical processes

This process is a recent one and copper from oxide ores is produced through this process. Due to less availability of oxide ores, it is relatively not economical for copper extraction through this process than when compared to the pyro-metallurgical process. However the low response and compatibility of oxide ores with froth flotation process indicate the need of techniques other than the pyro-metallurgical process. The hydrometallurgical process consists of the following.

i) Leaching

It includes different methods such as (a) in-situ leaching, (b) dump/heap leaching, (c) vat leaching/ percolation leaching (d) agitation leaching and (v) bacterial leaching. The type of leaching solely depends on the prevailing conditions of the location of ore availability and the economics.

ii) Solvent extraction

Solvent extraction is also called as cementation where copper from the solution is flaked or powdered, forming cement copper.

iii) Electro winning

The remaining dissolved copper present in the solution after the leaching operation is recovered by the copper cathode. Pyro-metallurgical or hydro-metallurgical processes are preferred based on the oxide levels of the ore. Other generic technological improvements include:

- Automatic truck dispatching which makes more efficient use of haulage and decreases diesel consumption.
- In-pit crushing and conveying, which can eliminate the need for truck haulage altogether and substituting electricity for diesel fuel.
- Computer control of other processes to improve operating efficiency by maintaining operations as close to the ideal as possible.
- Changing from reverberatory to flash furnaces helps to cut total smelting and refining energy requirements by one-third.
- The use of leaching and solvent extraction eliminates melting and converting altogether.

Improvements in smelter burner design and optimization of excess air quantities in the smelters have been a continuous process.

3.2 Capacity utilization

The capacity utilization of the plants is highly dependent upon the market demand and the economic viability of the production. The capacity utilization trends of the four major copper industries, shown in figures 3.2a to 3.2d.

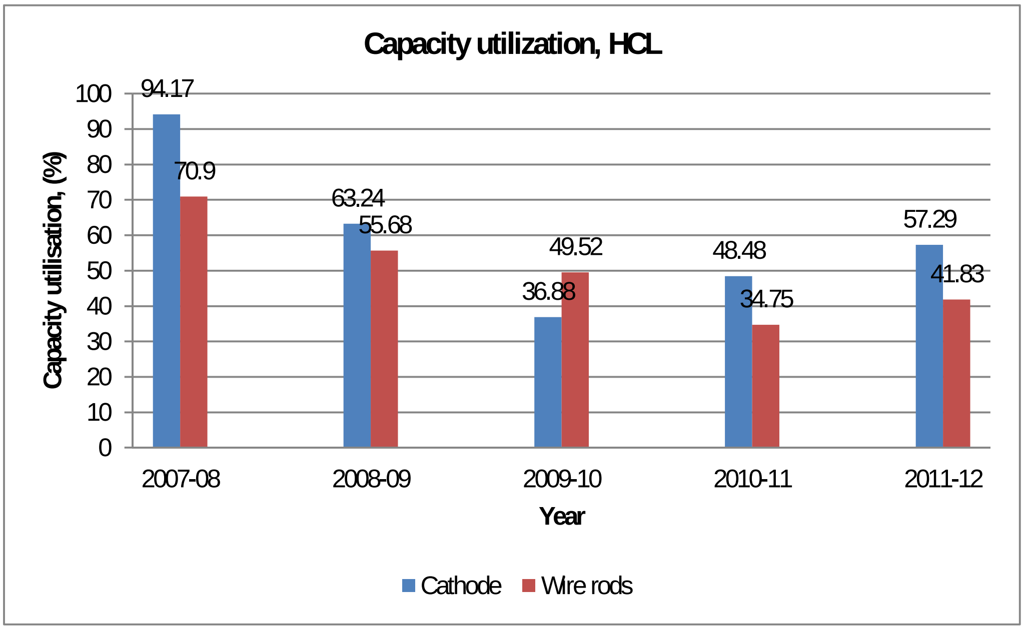

Figure 3.2a: Capacity Utilization of HCL

Source: CMIE Prowess database [23]

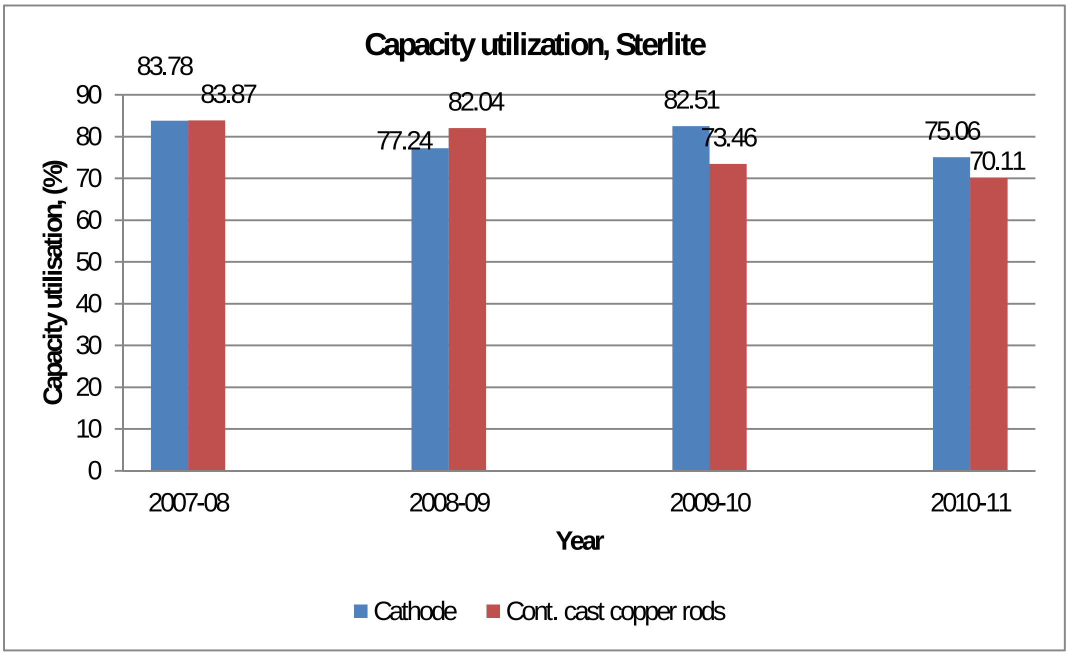

Figure 3.2b: Capacity utilization of Sterlite

Source: CMIE Prowess database [23]

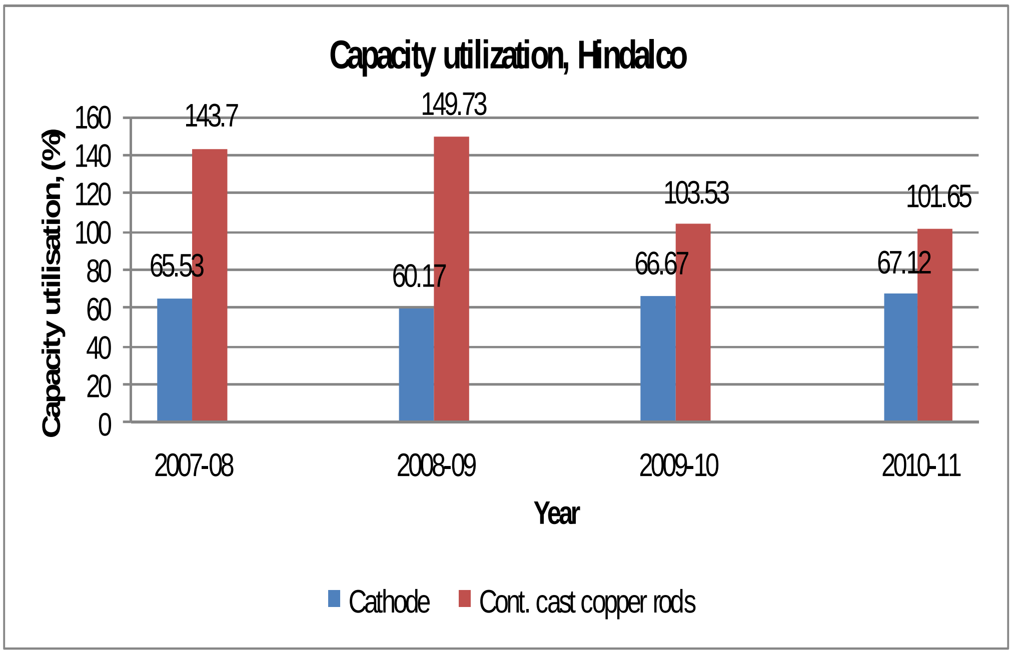

Figure 3.2c: Capacity utilization of Hindalco

Source: CMIE Prowess database [23]

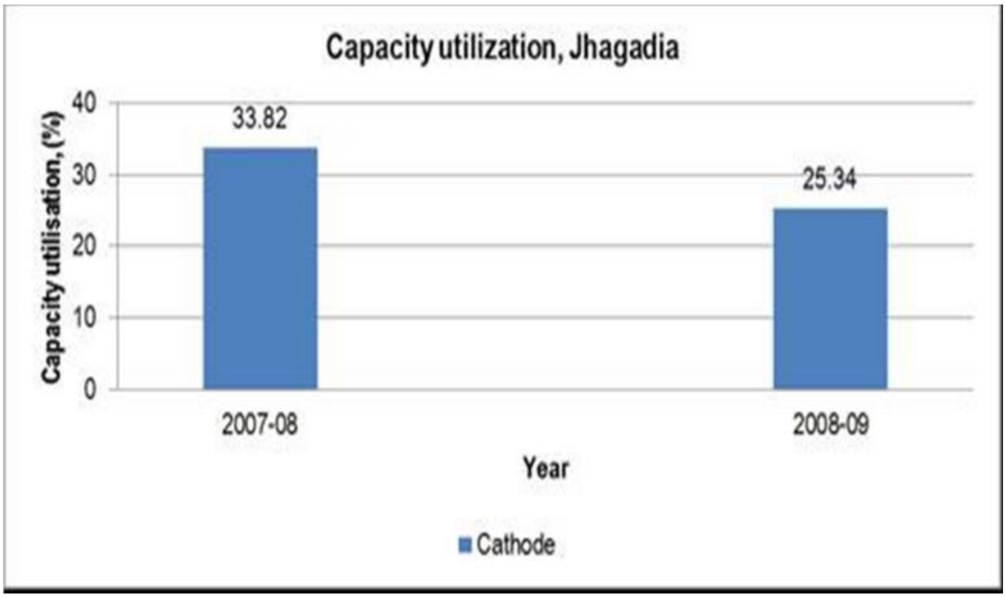

Figure 3.2d: Capacity utilization of Jhagadia

Source: CMIE Prowess database [23]

It was observed that the capacity utilization of HCL drastically dropped from 94% in 2007-08 to about 57% in 20011-12 for the copper cathode. This is mostly due to the closure of the KCC Smelter and refinery since December 2008 which had a capacity of 49500 tonnes. [24]. On the other hand, Sterlite Industry Ltd and Hindalco Industries Ltd have been performing quite well.

3.3 Energy performance and major energy consuming areas

A significant quantum of energy, both electrical and thermal, is consumed in copper manufacturing process (refined copper and copper products). However, the energy consumption level is dependent on parameters such as process used, technology adopted and end products. Many stages involved in the copper manufacturing or product making are highly energy intensive. Beneficiation process, for example is an important step which removes the need of larger capacity smelting furnaces which are energy guzzlers. The average specific energy consumption for smelting of one tonne calcined concentrates varies from 375 to 425 kWh of electricity [4].

Large varieties of utilities are used for different purposes at different stages. They include huge and different types of furnaces, machinery for mining, milling etc. The rising costs of fossil fuels also are currently pushing most of the industries to adopt energy efficiency. Energy requirements vary widely for different pyro-metallurgical processes. The detailed section wise percentage energy consumption values are given in Appendix 3.1.

Table 3.3 shows the share of energy consumption for different technologies in different stages of copper production. Mining, milling and smelting account for about 80% of the total energy consumption. The balance energy is consumed in process steps such as converting, cleaning and refining. These steps account for relatively lower energy consumption. This share is further lower in case of 'Flash type' based units. It may be noted that since the major production of copper in India is accounted by imported concentrates, use of flash type smelting technologies is advantageous and will have lower energy consumption levels.

Table 3.3: Share of energy consumption by different technologies and processes (all figures in %)

	Electric furnace	INCO flash	Outokumpu flash	Mitsubishi reactor	Noranda reactor
Open-pit mining	19.1	23.9	22.7	22.2	22.7
Milling	40.6	50.8	48.2	47.2	48.2
Smelting	21.5	7.5	10.4	13.5	11.7
Converting	6.2	1.1	2.4	3.3	2.0
Gas cleaning	7.3	9.2	9.2	6.9	8.3
Electro refining	5.3	7.5	7.1	6.9	7.1

3.4 Energy saving potential and major areas

As discussed mining, milling, smelting and concentrating are the major energy consuming areas in the copper industry. These account to more than 80 % of the total energy consumption. However, this is highly technology dependent. For e.g. an electric furnace consumes tremendous energy when compared to other technologies used for smelting or converting process. The other potential areas for taking up energy efficiency measures are utilities such as compressors, pumps, fans and blowers and other mechanical and electrical utilities which come under the auxiliary energy consumption. Estimation of energy saving potential highly depends on technology used, process steps, equipment used and operating practices. Past comprehensive energy audits carried out by TERI for selected sections of the plants in copper industry shows an energy saving potential of about 5% of the total energy used.

4.0 Analysis of energy consumption data

4.1 Energy consumption of major industries

The energy consumption details of major industries such as Hindustan Copper Ltd. (HCL), Hindalco Industries Ltd. and Sterlite Industries Ltd. (SIL) were studied. The total annual production and the SEC values of the industries were available. These values were further analysed for their applicability into PAT. The values mentioned below for the copper industries include cumulatively for all the copper facilities of individual major industries. The specific energy consumptions of the major industries are given as follows:

4.1.1 Hindustan Copper Limited

The specific energy consumption (SEC) for 2009-10 to 2012-13 of HCL including its various sites (mine, concentrators, smelters, refineries) is provided in table 4.1.1a. The copper production by HCL is shown in table 4.1.1b.

Table 4.1.1a: Specific energy consumption of HCL

		Specific energy consumption (toe/tonne)			
Sl. No	**Sites**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
1	Kolihan Mine (power)	0.002	0.002	NA	NA
2	Khetri Concentrator (power)	0.002	0.002	NA	NA
	Total	0.004	0.004	NA	NA
3	ICC Smelter (power)	0.095	0.081	0.085	0.0807
4	ICC Refinery (power)	0.029	0.027	0.025	0.2562
5	ICC Smelter (fuel)	0.469	0.4460	0.435	0.4266
	Total	0.593	0.555	0.546	0.533
6	Malanjkhand Mine (power)	0	0	NA	NA
7	Malanjkhand Concentrator (power)	0.002	0.002	NA	NA
	Total	0.002	0.002	NA	NA

Source: Annual Report 2010-11 [9], Hindustan Copper Ltd.

Table 4.1.1b: Copper production of HCL

Particulars	2009-10	2010-11	2011-12
Ore '000 tonnes	3,205	3,603	3,479
Metal - in concentrate (tonnes)	28,202	31,683	31,377
Cathode (tonnes)	17,516	24,001	28,358
CC wire rod (tonnes)	41,999	22,993	26,310

Source: Annual Report 2010-11 [9], Hindustan Copper Ltd.

The average total energy consumption for ICC Complex for the period 2009-10 to 2011-12 has been estimated by considering its corresponding SEC and copper cathode production. Based on these, the average total energy consumption for the years 2009-10 to 2011-12 is 13,063 toe.

4.1.2 Hindalco Industries Ltd

The average SECs and the production details of copper cathodes and copper rods of Hindalco Industries for the period 2009 to 2012 are provided in tables 4.1.2a to 4.1.2b.

Table 4.1.2a: Copper SEC (toe/tonne) of Hindalco Industries Ltd.

	2009-10	2010-11	2011-12
Copper cathodes			
Electricity	0.129	0.132	0.132
Furnace Oil	0.018	0.014	0.011
Propane	0	0	0
Naphtha	0	0	0.001
RLNG	0.071	0.086	0.093
Total	**0.225**	**0.232**	**0.237**
Copper rods			
Electricity	0.005	0.005	0.005
RLNG	0.049	0.049	0.049
Total	**0.054**	**0.054**	**0.054**
Total SEC (cathodes + rods)	**0.280**	**0.287**	**0.291**

Source: Annual Report 2009-10 [10], 2010-11 [11], Hindalco Industries Ltd.

Table 4.1.2b: Gross sales of copper produced by Hindalco Industries Ltd.

	2009-10	2010-11
Copper cathode (tonne)	1,46,164	1,42,167
Copper rod (tonne)	1,85,213	2,07,640

Source: Annual Report 2009-10 [10], 2010-11 [11], Hindalco Industries Ltd.

The total energy consumption for production of copper cathode and copper rods (that were sold in 2009 to 11) by the Hindalco was estimated to be 42,991 toe for 2009–10 and 44,317 toe for 2010–11.

4.1.3 Sterlite Industries Ltd

Refineries consume about 85 % electrical energy and 38% of the thermal energy of the total energy consumption. The plant-wise production of different types of copper products and their specific energy consumption data are given in table 4.1.3a and table 4.1.3b respectively.

Table 4.1.3a: Production details of SIL

Particulars	Unit	2007-08	2008-09	2009-10	2010-11	2011-12
Concentrate	tonne	10,82,095	10,46,624	11,39,617	10,52,432	NA
Anode	tonne	3,24,496	3,02,338	3,32,056	3,00,998	3,06,174
Cathode - Tuticorin	tonne	1,62,940	1,41,066	1,54,799	1,41,574	1,69,525
Rod Tuticorin	tonne	81,724	76,292	55,895	54,059	44,850
Cathode - Silvassa	tonne	1,76,462	1,73,154	1,80,047	1,62,709	1,56,427
Rod Silvassa	tonne	1,43,302	1,43,637	1,41,298	1,34,301	1,16,407
Rod Chinchpada	tonne	90,300	89,838	89,273	84,327	84,479
Rod Piparia	tonne	53,001	53,799	52,024	49,974	31,928
Total Cathode	tonne	3,39,402	3,14,220	3,34,847	3,04,283	3,25,953

Source: Plant provided data.

Table 4.1.3b: Specific energy consumption details at different intermediate plants

Type	Unit	2007-08	2008-09	2009-10	2010-11	2011-12
SMELTER	GJ/MT of Anode	5.62	6.17	6.13	6.13	5.91
	GJ/MT of Conc	1.68	1.78	1.79	1.75	
	GJ/MT of Cathode	5.37	5.93	6.08	6.06	5.55
SAP	GJ/MT of Sulphuric Acid	0.32	0.37	0.38	0.46	0.49
	GJ/MT of Anode	1.02	1.22	1.20	1.49	1.65
	GJ/ MT of Cathode	0.97	1.17	1.19	1.48	1.55
REFINERY TUTICORIN	GJ/ MT of Cathode Tuticorin	1.79	1.78	1.76	1.86	1.70
	GJ/ MT of Total Cathode	0.86	0.80	0.81	0.87	0.88
REFINERY SILVASSA	GJ/MT of Cathode Silvassa	2.08	1.98	2.09	2.30	2.20
	GJ/ MT of Total Cathode	1.08	1.09	1.12	1.23	1.06
ACP SILVASSA	GJ/MT of Anode casted					3.36
	GJ/ MT of Total Cathode	0.24	0.25	0.21	0.27	0.28
CCR TUTICORIN	GJ/ MT of Rod	1.90	1.99	1.98	1.99	1.93
	GJ/ MT of Cathode	0.46	0.48	0.33	0.35	0.27
CCR Chinchpada	GJ/ MT of Rod	1.80	1.76	1.80	1.65	2.00
	GJ/ MT of Cathode	0.48	0.50	0.48	0.46	0.52
CCR Piparia	GJ/ MT of Rod	1.99	1.95	1.93	2.01	2.07
	GJ/ MT of Cathode	0.31	0.33	0.30	0.33	0.20
CCR SILVASSA	GJ/ MT of Cathode	0.79	0.84	0.78	0.79	0.72
Slime plant - Tuticorin	GJ/ MT of Leached Slime					35.88
	GJ/ MT of Cathode	0.05	0.06	0.08	0.08	0.05
Slime plant - Silvassa	GJ/ MT of Leached Slime					57.62
	GJ/ MT of Cathode	0.04	0.03	0.04	0.05	0.06
Selenium Tuticorin	GJ/ MT of Selenium					30.63
	GJ/ MT of Cathode	0.01	0.01	0.01	0.01	0.01
Dore Tuticorin	GJ/ MT of Cathode	0.00	0.01	0.03	0.01	0.00
PMB Lab Tuticorin	GJ/ MT of Cathode	0.11	0.10	0.16	0.16	0.12
PAP	GJ/MT of Phosphoric Acid	2.00	1.33	1.59	2.41	1.05
	GJ/ MT of Cathode	0.90	0.69	0.97	1.22	0.49
Total Energy	GJ/ MT of Cathode	9.87	10.59	11.06	12.19	10.92
	Toe/MT of Cathode	**0.24**	**0.25**	**0.26**	**0.29**	**0.26**

The average SEC covering all Sterlite facilities was found to be 0.26 toe/MT of cathode for the years 2007-08 to 2011-12. The average annual energy consumption including all facilities (excluding value added products) of Sterlite for the same period was estimated to be 68,617 toe. Of this, smelter energy consumption was the highest and was 43,433 toe in 2011-12. The average annual energy consumption for Sterlite Industries facilities for the period 2007-08 to 2011-12 in different locations are given in table 4.1.3c.

Table 4.1.3c: Total energy consumption of different Sterlite facilities

Facility	Location	Total energy consumption (toe per year)
Refinery	Silvasa	8,659
	Tuticorin	6,557
CCR	Chinchpada	3,793
	Piparia	2,279
	Silvasa	6,088

Note: Smelter energy consumption data not included in above table.

Total average energy consumption of Sterlite Tuticorin plant (including smelter and refinery) is 51,556 toe. The Tuticorin smelter produces copper anode which is further converted into copper cathode by electrolytic process at Tuticorin and Silvasa refineries. The detailed energy consumption data provided by major copper producers in India are given in Appendix 4.1. A brief process of copper production along with value added products of different plants for SIL is given in Appendix 4.2. The estimated energy consumption of HCL and Hindalco indicates the significant energy intensive nature of copper industries.

4.2 Methodology

The methodology followed for estimation of energy consumption by various industries in copper sector is briefed below.

- The energy consumption details of the industries have been used from the annual reports and/or energy audit reports of the respective industries.
- The energy details include SECs of various products. The energy details obtained from various units were converted to tonnes of oil equivalent per tonne of product and further analysed in accordance to its applicability for considering under PAT.

The calorific values and the specific gravity of the fuel used for the calculations are given in Table 4.2.

Table 4.2: Gross calorific values of different fuels

Fuel	Gross calorific value (kcal/kg)
LPG	10,700
FO	10,500
HSD	10,270
LPG	10,990
Propane	12,029
RLMG*	10,238

* kcal per m^3

Source: Engineering toolbox [14]; Material safety data sheet, Hindustan Petroleum [28]; Energy conservation in utilities, PCRA [29]; Calorific values of different fuels, IISc. [30]

4.3 Possible energy efficiency measures

The energy efficiency measures are mainly dependant on the process followed, technology, equipment used and adoption of best operating practices. A few commonly applicable energy efficiency measures are given as follows:

a) Electrical systems and drives
   - Transformer load management
   - Harmonic analysis

b) Compressed air systems
   - Replacement of inefficient air compressors with energy efficient compressors.
   - Optimization of compressed air requirements

c) Pumps and cooling towers
- Installation of right capacity pumps
- Avoiding unnecessary throttling of pipes through valves.
- Use of variable frequency drives for dynamic systems.

d) Furnaces
- Installation of appropriate burner and best practices
- Improvement of insulation and refractories

e) Lighting systems
- Adoption of energy efficient lighting systems
- Installation of timers

f) Captive power plant and steam system
- Cogeneration
- Waste heat recovery
- Effective steam management – better insulation and steam traps

Other process side energy efficiency measures include preheating of material for rotary vacuum driers to reduce batch process time, copper wash water being reused for washing spent anodes, etc. These measures are generally plant specific.

4.4 Conclusions and recommendations

The SECs of different copper producers in India shown in figure 4.4a indicates that the SECs of Indian companies are higher than the benchmarked SEC level, thereby indicating significant scope for energy efficiency improvements. The estimated annual energy consumption of copper plants in India is shown in figure 4.4b.

Figure 4.4a: Comparison of SEC levels*

***Note:** The benchmark and world average figures have been referred from UNIDO's Global Industrial Energy Efficiency Benchmarking – A Energy Policy Tool Working Paper [31]

The total energy consumption of SIL–Tuticorin plant was found to be higher than that of HIL and HCL, which may be mainly attributed to higher installed capacity of SI-Tuticorin plant. Though the total energy consumption of HCL (ICC complex) was found to be lower, its SEC level was found to be higher than the referred world average SEC. The total estimated annual energy consumption of different copper plants varies between 6000 toe to 51000 toe. With the existing annual energy consumption and SEC levels of different copper plants, an energy consumption level of 10,000 toe may be considered as threshold limit for copper industry. This would qualify all the three producers namely HCL, HIL and Sterlite to quality as DCs under PAT. SIL - Silvasa and Jhagadia Copper Limited may be further looked into based on the boundary defined and their energy consumption details.

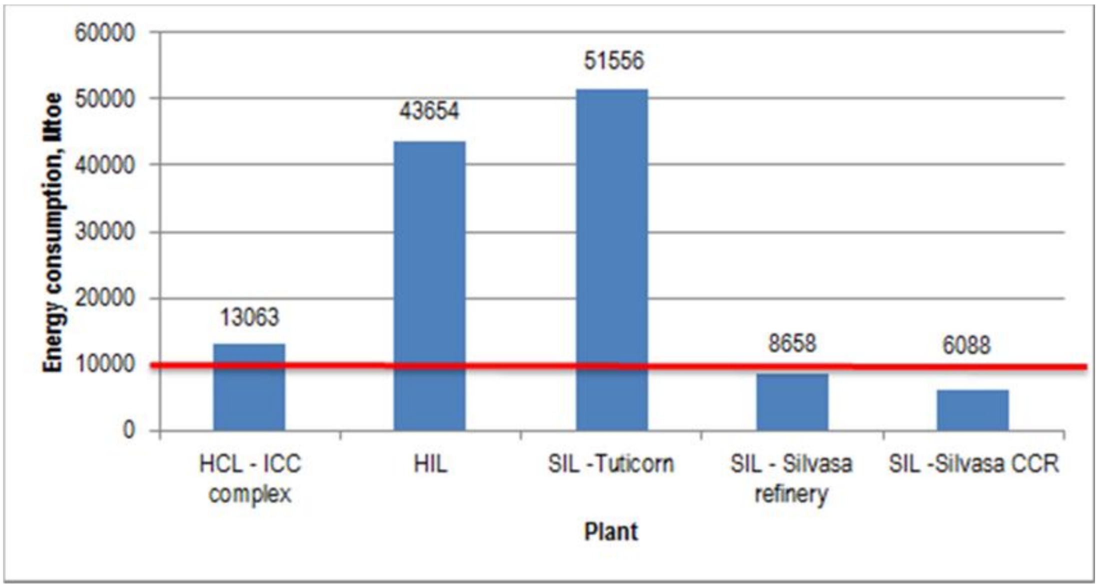

Figure 4.4b: Comparison of energy consumption of plants

Different studies and energy audits in copper industries show that at least 5% energy saving potential exists in Indian copper industries. A comparison of SEC of Indian copper industries with benchmark level further indicates potential for significant energy efficiency improvements through process and technology improvements in various copper plants in India.

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6.0 Appendices

Appendix 2.1

Copper products and its applications.

S.No.	Products and its application
1	Electrical and electronics
2	Industrial machinery
3	Transportation
4	Consumer products
5	Building and construction
6	Strips, foils, screens and sheathing
7	Gears
8	Coins
9	Vessels
10	Brassware
11	Locks and keys
12	Fungicides
13	Paints
14	Tubes, pipes and sections
15	Breaks and Bearings
16	Refrigeration and air conditioning
17	Food supplements
18	Nutrients
19	Wiring
20	Connectors
21	Motors
22	Roofing
23	Circuit boards
24	Fittings
25	Radiators
26	Fasteners
27	Valves
28	Taps
29	Heat exchangers
30	Sprinklers

Appendix 2.2

Reserves and resources of copper

NATIONAL MINERAL INVENTORY AT A GLANCE

5.15 : Reserves/Resources of Copper as on 01.04.2010
(By Grades / States)

(In '000 tonnes)

	Reserves				Remaining Resources								Total
	Proved	Probable		Total	Feasibility	Pre-feasibility		Measured	Indicated	Inferred	Reconnaissance	Total	Resources
	STD111	STD121	STD122	(A)	STD211	STD221	STD222	STD331	STD332	STD333	STD334	(B)	(A+B)
All India													
Ore	**133388**	**127100**	**133884**	**394372**	**15781**	**21323**	**12429**	**147989**	**224976**	**741588**	**0**	**1164086**	**1558458**
Metal	**1604.73**	**1508.36**	**1655.24**	**4768.33**	**213.01**	**223.01**	**23.45**	**1453.04**	**1686.84**	**3918.99**	**0**	**7518.34**	**12286.67**
By Grades													
Ore with 1.85 % & above Cu	0	0	0	0	0	62	0	430	813	1336	0	2641	2641
Ore with 1.00 % to below 1.85 % Cu	125287	127100	129311	381698	12406	19031	168	76053	46391	140398	0	294447	676145
Ore with (+)0.50% to below 1.00% Cu	557	0	31	588	0	2230	2008	23366	85012	504366	0	616982	617570
Ore with (-) 0.50% Cu	7544	0	4542	12086	3375	0	10253	48140	92760	95488	0	250016	262102
Metal	1604.73	1508.36	1655.24	4768.33	213.01	223.01	23.45	1453.04	1686.84	3918.99	0	7518.34	12286.67
By States													
Andhra Pradesh													
Ore	0	0	0	0	686	666	105	0	5791	1000	0	8248	8248
Metal	0	0	0	0	6.88	9.12	1.05	0	97.45	8.32	0	122.82	122.82
Gujarat													
Ore	0	4955	845	5800	0	0	0	129	0	7131	0	7260	13060
Metal	0	80.75	13.78	94.53	0	0	0	0.69	0	113.38	0	114.07	208.60
Haryana													
Ore	0	0	0	0	0	2230	0	0	0	30678	0	32908	32908
Metal	0	0	0	0	0	11.82	0	0	0	101.80	0	113.62	113.62
Jharkhand													
Ore	16540	49127	21151	86818	11720	17990	0	74857	64488	32252	0	201307	288125
Metal	163.04	448.83	196.91	808.78	202.76	194.30	0	869.43	606.35	412.65	0	2285.49	3094.27
Karnataka													
Ore	836	1301	373	2510	0	0	2008	1750	6833	20434	0	31025	33535
Metal	8.78	17.56	4.31	30.65	0	0	11.24	22.00	65.77	99.61	0	198.62	229.27

Appendix 2.3

Country-wise mine copper production

('000 tonne)

S. No	Country	2008	2009	2010
1	Australia	886	854	870
2	Canada	607	494	525
3	Chile	5,328	5,394	5,419
4	China	1,090	1,070	1,200
5	Congo	234	3,310	380
6	India	31	30	33
7	Indonesia	633	999	872
8	Kazakhstan	422	406	380
9	Mexico	269	228	270
10	Peru	1,268	1,276	1,247
11	Poland	429	439	425
12	Russia	750	676	703
13	United States	1,310	1,180	1,110
14	Zambia	555	697	690

Source: Mineral information, USGS [3]

Appendix 2.4

Metal exchange	Year-2010 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Bombay metal market, Rs. Per Kg										
Copper heavy scrap	356.96	343.18	362.42	373.88	357.2	355.58	361.96	372.72	382.32	392.48
Copper wire bars	391.24	376.68	396.29	407.35	390.04	388.19	395.08	407.16	418.36	427.52
London metal exchange, $/tonnes										
Copper	7385.61	6847.69	7462.37	7744.39	6837.2	6498.66	6734.63	7283.04	7708.93	8291.85

Metal exchange	Year-2011 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Bombay metal market, Rs. Per Kg										
Copper heavy scrap		462.96	459.92	462.77	451.85	452	462.76	452.17	444.58	415
Copper wire bars		500.65	497.52	500.36	489.23	487.81	500.08	489.61	481.33	450.14
London metal exchange, $/tonnes										
Copper		9867.18	9530.11	9482.91	8926.49	9045.12	9618.8	9040.82	8314.33	7347.5

Metal exchange	Year-2012 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Bombay metal market, Rs. Per Kg										
Copper heavy scrap	454.44	462.83	469.16	474.67	477.12	473.27	476.37	473.26	480.18	477.28
Copper wire bars	489.92	497.91	118.24	510.13	513.32	509.46	511.77	509.3	516.77	514.04
London metal exchange, $/tonnes										
Copper	8043	8422.03	8456.55	8258.88	7919.29	7419.79	7588.71	7491.91	8068.03	8069.08

Source: Price Trends, Metalworld.co.in [16]

Appendix 2.5

Types of copper imports in India

S.No	Imports
1	Copper ores and concentrates
2	Other ash and residues containing copper
3	Copper mattes
4	Cement copper (precipitated copper)
5	Blister copper for electrolytic refining
6	Unrefined copper, copper anodes for electrolytic refining
7	Cathodes of refined copper
8	Wire-bars, billets, tubes and pipes of refined copper
9	Refined copper Unwrought
10	Copper scrap under ISRI code
11	Copper powder (Lamellar and Non-Lamellar) structures and flakes
12	Electrolytic and non-electrolytic copper rods
13	Copper bars wrought
14	Hollow bars of copper wrought
15	Plates, sheets etc. of refined copper
16	Foil of refined copper (baked and not backed)
17	Winding wire of enamelled copper.

Source: Imports of copper and other items as per HS Codes (p. 133), Market Survey of Copper, IBM

Appendix 2.6

Capacity and production of copper cathode

			Production (tonne)				
Company	**Number of factories**	**Installed Capacity**	**2006**	**2007**	**2008-09**	**2009-10**	**2010-11***
Hindustan Copper Ltd.	2	49,500	27,415	32,601	44,742	10,646	11,484
Sterlite Industries (I) Ltd.	1	4,00,000	2,23,524	2,49,031	3,39,294	2,54,670	2,23,825
Hindalco Ind. Ltd. (Unit : Birla Copper)	1	5,00,000	2,08,965	2,33,797	3,20,930	2,58,626	2,50,637
Total	4	9,49,500	4,59,904	5,15,429	7,04,966	5,23,942	4,85,946

* upto Dec 2010

Appendix 2.7

Product-wise list of large scale industries along with their capacities

S.No	Industry name	Type – Capacity (M.T.)
Refined Copper		
1	Hindalco Industries Limited	Copper smelting and refining, continuous cast copper rods – 5,00,000
2	Hindustan Copper Limited	Copper cathode – 49,500; Copper wire rod – 60,000
3	Jhagadia Copper Limited	Copper cathode manufacturing via secondary route – 50,000
4	Sterlite Industries (India) Ltd	Copper cathode – 4,00,000; Copper rods – 2,40,000
Bars/Rods Sections		
1	Cubex Tubings Limited	Continuous casting and extraction – 10,000
2	Multimetals Limited	Casting, extrusion and drawing
Continuous Cast Rod		
1	Finolex Cables Ltd	Continuous casting – 50,000
2	Hindalco Industries Limited	NA
3	Hindustan Copper Limited	NA
4	Sterlite Industries (India) Ltd	NA
Fabricated Products		
1	Bharat Heavy Electricals Limited	Foundry (Bhopal, Hardwar and Hyderabad for captive requirements), electrical equipment manufacturing.
2	Crompton Greaves Ltd	Electrical equipment manufacturing (13 manufacturing locations in India)
Forgings		
1	Modison Metals Ltd	Foundry, powder metallurgy and plating (multiple products)
Powders/P.M. products		
1	GKN Sinter Metals Limited	Sintered bearings and parts – 3,25,000 nos; Metal powders – 2,160 kg
Sheets/Strips/Foils/Plates/Circles		
1	Arcotech Ltd	Melting , rolling and finishing – 24,000
2	Devi Metals Technologies	Rolling – 3000
3	Indian Smelting and Refining Company Limited (THE)	Rolling – 14,730; Casting – 10,800 (Thane) and 24,000 (Pune)
4	Meta Copper and Alloys Limited	Foundry and rolling – 42,000
Tubes/Pipes		
1	Cubex Tubings Limited	NA
2	Multimetals Limited	NA
Wires/Cables/Conductors		
1	Havell's India Limited	Manufacturing electrical equipment, switchgears, cables, etc. (multiple products)
2	NICCO Corporation Limited	Wire and cable manufacturing
3	Paramount Communication Ltd.	Cable manufacturing; Jelly filled telephone cables – 52,99,000 ckm; Optical fiber cables – 20,000 km; Power cables – 60,000 km.

S.No	Industry name	Type – Capacity (M.T.)
4	RPG Cables Limited	Wire and cable manufacturing; Power cables – 8700 ckm; House wiring cables – 33,000 ckm; Telecommunication cables – 80 ckm.
Miscellaneous		
1	Chittaranjan Locomotive Works	Electric locomotive manufacturing.

Note: The term Large Scale Industries is as categorized in the Directory of Indian Copper Industries, Eighth Edition 2010, by Indian Copper Development Centre.

Appendix 3.1

Energy use in copper industry

Type	Electric furnace	INCO flash	Outokumpu flash	Mitsubihsi reactor	Noranda reactor
Open-pit mining					
Drilling	0.58	0.73	0.69	0.67	0.69
Blasting	3.70	4.64	4.40	4.30	4.40
Loading	1.75	2.20	2.09	2.04	2.08
Hauling	12.47	15.62	14.82	14.50	14.81
Ancillary	0.61	0.76	0.72	0.70	0.72
	19.11	23.94	22.72	22.22	22.70
Milling					
Commination	0.15	0.19	0.18	0.18	0.18
Beneficiation	40.39	50.60	48.02	46.97	48.00
	40.55	50.79	48.20	47.14	48.17
Smelting	21.52	7.45	10.38	13.47	11.73
Converting	6.17	1.12	2.40	3.33	2.00
Gas cleaning	7.33	9.23	9.20	6.90	8.30
Electrorefining	5.32	7.48	7.10	6.94	7.09
Total (kcal/ton)	100.00	100.00	100.00	100.00	100.00

Source: Energy use in the copper industry, Office of Technology Assessment [8]

Appendix 4.1

Specific energy consumption and production from copper industries

a. Hindustan Copper Limited

Specific fuel consumption by HCL

		Specific energy consumption			
Sl .No	Sites	2009-10	2010-11	2011-12	2012-13
1	Kolihan Mine, kWh/T	26.23	23.25	NA	NA
2	Khetri Concentrator, kWh/T	24.13	23.42	NA	NA
3	ICC Smelter, kWh/T	1108	946	990	943
4	ICC Refinery , kWh/T	333	318	294	297
5	ICC Smelter (Fuel), Lit/T	531	505	493	483
6	Malanjkhand Mine, kWh/T	0.52	0.49	NA	NA
7	Malanjkhand Concentrator, kWh/T	20.68	19.7	NA	NA

Source: Annual Report 2010-11 [9], Hindustan Copper Ltd.

Copper production by HCL

Particulars	2009-10	2010-11	2011-12
Ore '000 tonnes	3,205	3,603	3,479
Metal - in concentrate (tonnes)	28,202	31,683	31,377
Cathode (tonnes)	17,516	24,001	28,358
CC wire rod (tonnes)	41,999	22,993	26,310

Source: Annual Report 2010-11 [9], Hindustan Copper Ltd.

b. Hindalco Industries Ltd.

Copper specific fuel consumption of Hindalco Industries Ltd.

	Unit	2009-10	2010-11
Copper Cathodes			
Electricity	kWh/T	1,504	1,539
Furnace Oil	Liters/T	19	15
Propane	Kg/T	0.01	0
Naphtha	Kg/T	7	0.04
RLNG	SCM/T	69	84
Copper Rods			
Electricity	kWh/T	62	60
RLNG	SCM/T	48	48

Source: Annual Report 2009-10 [10], 2010-11 [11], Hindalco Industries Ltd.

Copper gross sales of Hindalco Industries Ltd.

	2009-10	2010-11
Copper cathode (ton)	146164	142167
Copper rod	185213	207640

Source: Annual Report 2009-10 [10], 2010-11 [11], Hindalco Industries Ltd.

c. Sterlite Industries Ltd.

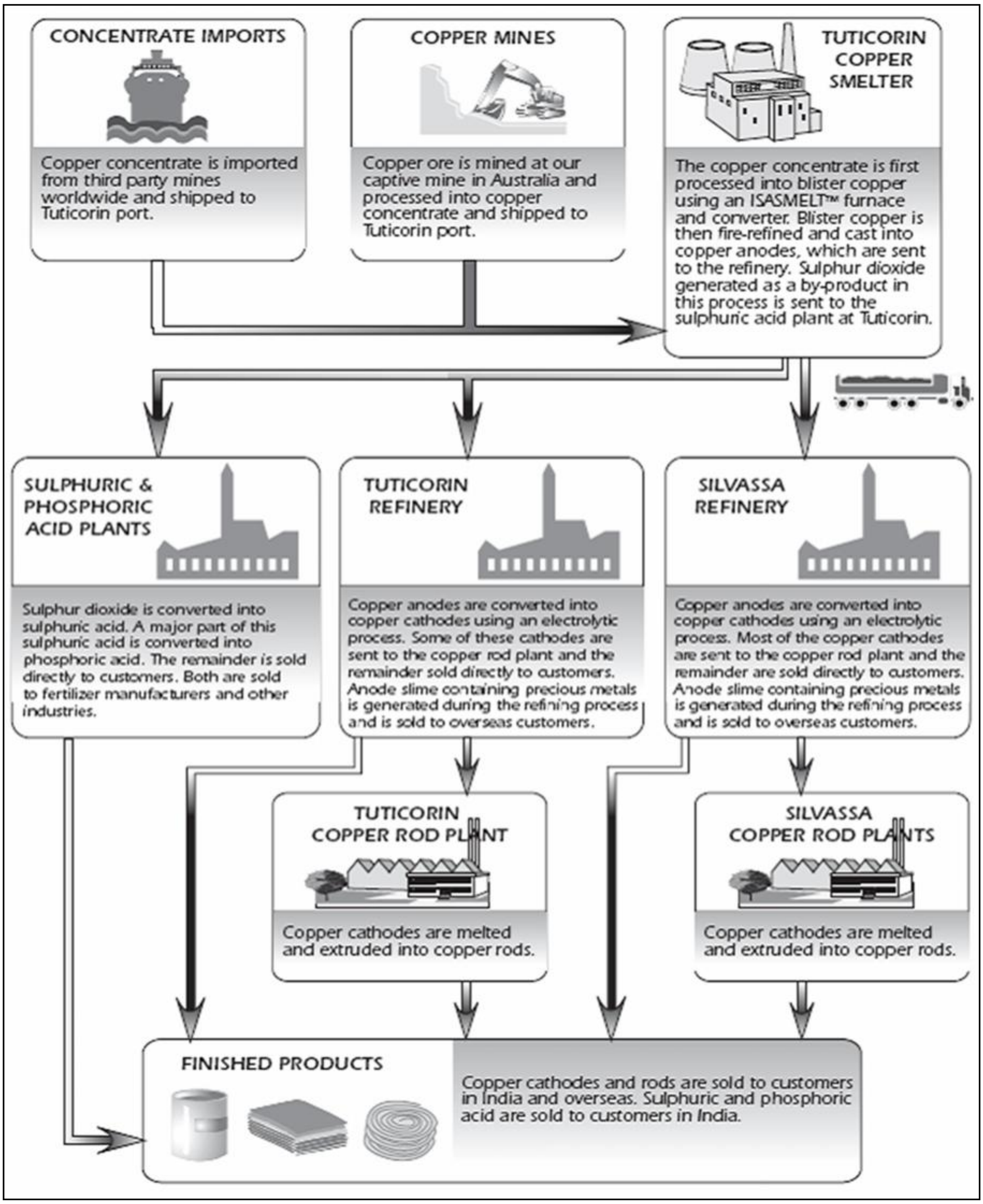
SEC and copper production of SIL

Particulars	2009-10	2010-11
Specific energy consumption (GJ/ton)	9.44	9.97
Specific energy consumption (toe/ton)	0.22	0.24
Copper cathode production (tonnes)	334174	303999
Copper rod production (tonnes)	197000	187892

Source: Annual Report 2010-11 [12], Sterlite Industries Ltd.

Appendix 4.2

Material flow of Copper and its value added products (for Sterlite Industries Ltd)



Source: Production Process, Copper, Sterlite Industries (India) Limited.

7.0 Glossary

Copper anode: It is an intermediate product from the furnaces which are further electrolysed in an appropriate solution such as Sulphuric acid, to yield high purity copper cathodes.

Copper cathode: It is manufactured from the concentrates. This copper cathode is further sent to mills or foundries to be casted into wire rods, billets, and ingots ore to be alloyed with other metals.

Copper concentrate: Copper concentrate is obtained after removal of unwanted gangue from the ore based on its chemical and physical properties. The trend is on lines with the ores production.

Refined copper: Refined copper is copper separated from its impurities. i.e. pure form of copper. Does not include alloys.

Copper ore: Type of rocks containing majority of copper metal, obtained during mining.

Copper scrap: Crude remains of copper metal, their alloys and other copper products which are in general recycled by secondary producers.

Refinery Primary: Used for producing refined copper from the normal process of using copper concentrate obtained from copper ores.

Refinery Secondary: Used for producing refined copper from recycled copper scrap.

Refinery SX-EX: Production of refined copper from solvent extraction and electro winning process.