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Final Report

Widening the coverage of PAT Scheme

Sectoral Manual - Zinc industry

Prepared for

Shakti Sustainable Energy Foundation

The Energy and Resources Institute

...towards global sustainable development

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Disclaimer

This report is part of Shakti Sustainable Energy Foundation (SSEF) and The Energy and Resources Institute's (TERI) attempt to study the zinc resources, production, its energy consumption trends and energy efficiency improvement opportunities of the major Zinc Industries in India. The data furnished in the report is purely indicative based on available information from and few assumptions. The views expressed in this document do not necessarily reflect the view of Shakti Sustainable Energy Foundation. The organisation accepts no liability for the content of this document, or for the consequences of any actions taken on the basis of the information provided. While every care has been taken in compiling this report, TERI and Shakti Sustainable Energy Foundation accepts no claim for any kind of compensation, if any entry is wrong, abbreviated, omitted or inserted incorrectly either as to the wording space or position in the report.

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TERI would like to acknowledge Mr. Pugazenthy, Executive Director, India Lead Zinc Development Association and its members for directing us towards right resources.

The Energy and Resources Institute (TERI)

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Abbreviations

BEE	:	Bureau of Energy Efficiency
BZL	:	Binani Zinc Ltd.
CAGR	:	Compound Annual Growth Rate
CSR	:	Corporate social responsibility
DCs	:	Designated Consumers
GDP	:	Gross Domestic Product
GJ	:	Giga Joules
GW	:	Giga Watt
HPGR	:	High pressure grinding roller
HZL	:	Hindustan Zinc Limited
IBM	:	Indian Bureau of Mines
ISRS	:	Institute of Scrap Recycling Industries Inc.
LME	:	London Metal Exchange
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
SAP	:	Sulphuric Acid Plant
SEC	:	Specific Energy Consumption
TERI	:	The Energy and Resources Institute
tpd	:	Tonnes per day
tpy	:	Tonnes per annum.
Toe	:	Tonnes of oil equivalent

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 have been given specific targets by BEE to reduce their existing energy consumption. BEE has further plans to widen the coverage of PAT scheme in subsequent phases through addition of more new industrial subsectors based on their energy consumption.

This report prepared for Shakti Sustainable Energy Foundation studies the energy consumption details of zinc sector to explore possibilities of inclusion of zinc sector under PAT cycle and establish threshold limits. This report was prepared covering information and data on large and medium manufacturers, production capacity, technologies used, energy performance and relevant regulatory & policy issues that have bearing on performance of the sector. With about 4.8 % of the global reserves of zinc, the Indian zinc industries produce about 5 % of world's zinc production. Galvanizing forms the largest consuming markets for zinc.

The total estimated annual energy consumption of zinc plants in India varies from 12,000 toe to 1,75,000 toe. The total energy consumption of HZL – Dariba and HZL – Chanderia are higher as compared to HZL-Debari and BZL. This may be attributed to their higher production capacities thereby resulting in higher energy consumption levels. Almost all the operating plants of HZL and BZL exhibit a total annual energy consumption of more than 12000 MTOE. This value is the minimum energy consumption set for chlor-alkali industry sector. Therefore, it is suggested that a threshold limit of 12000 MTOE per year is set for zinc sector and both major producers of zinc comprising 4 operating plants would be included as 'designated consumer' (DC). The benchmark energy consumption of zinc sector shows that there exists an energy saving potential of 8 to 13% in Indian zinc industries.

2.0 Introduction

Zinc is a bluish-white lustrous metal and normally covered with a white coating on exposure to the atmosphere. Indian zinc industry entered its transformation along with the privatization of the largest zinc producer, Hindustan Zinc Ltd in the year 2002. This sector is mainly dependent on the dynamics of the steel industry for galvanizing. Sectors like Infrastructure, communication, transportation, etc. also influence the market for zinc. Zinc industry comprises two major players that are energy intensive along with a large number of small and medium scale reprocessing units.

2.1 Sector importance

The Indian zinc sector is currently dominated by Hindustan Zinc Ltd (HZL). The market scenario witnessed a change after the acquisition of HZL by Sterlite Industries (India) Ltd. This sector is highly dependent on the infrastructure development of the country. One of the key factors includes its use as an excellent protector for steel. Production of zinc is in general done along with lead. Both these minerals in general coexist in different concentrations. The industries are capital and power intensive.

Among the non-ferrous metals, zinc is widely used in various applications among various industries for its following properties:

- Enhance the life and performance of steel by galvanizing
- High strength and Formability
- Corrosion resistance
- Recyclability

The uses of zinc in different applications are given below:

- Use in dry cell batteries
- Use as alloy with copper due to low melting points
- Use in dye castings
- Use as various forms of compounds in chemicals, paints, powders etc.

The major uses of zinc in different industries are shown in the following figure 2.1.

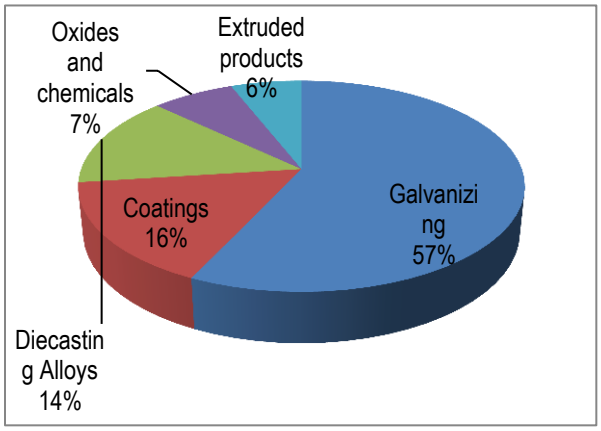

Figure 2.1: Share of industrial sectors consuming zinc

Source: Market survey on zinc & lead, Indian Bureau of Mines [1]

Mining and quarrying sector accounts for 2.5 % of India's GDP. Zinc is one of the 87 minerals from the mining industry as according to the Indian Ministry of Mines. Though zinc sector does not have a major impact on the country's GDP, its applications are widely used in above mentioned industries. A brief description of which is given as follows:

- Galvanization of steel to improve its longitivity in corrosive conditions such as telecommunication and electrical towers, transportation, refrigeration, etc.
- Batteries developed for military and aeronautical applications, power electric vehicles, etc.
- Zinc alloys are used widely in dye casting industries, architecture, interior design applications, etc.

2.2 National / International scenario

2.2.1 Zinc resources

Zinc and lead deposits occur together in most commonly occurring minerals of sulphide forms. The other minerals of zinc include smithsonite ($ZnCO_3$), zincite (ZnO), hemimorphite (Zn_4SiO_7), willemite (Zn_2SiO_4), etc. India has significant resources of zinc ores which is distributed among 12 states. The other states include Bihar, Maharashtra and Madhya Pradesh. As per the National Mineral Inventory, total resources available in India are placed at 685.6 million tonnes (as on 1.4.2010). About 15.8 % of this falls under reserves. The reserves and resources as per the National Mineral Inventory as on 01.04.2010 is given in table 2.2.1. The resources in India are mostly concentrated in Rajasthan (94.8%) followed by Maharashtra and Madhya Pradesh. The brief state-wise distribution of zinc and lead resources according to National Mineral Inventory is given in figure 2.2.1 and is detailed in annexure 2.1.

Table 2.2.1: All India reserves and resources of zinc and lead as on 01.04.2010 in '000 tonnes

Zinc	Reserves	Remaining resources	Total resources
Ore (Total)	1,08,980	5,76,614	6,85,594
By Grades			
Ore with 10 % and above Pb & Zn	76,094	63,755	1,39,849
Ore with 5 % to 10 % Pb & Zn	32,886	2,19,416	2,52,302
Ore with < 5.00 % Pb & Zn	0	2,93,444	2,93,444
Metal			
Lead	2,245.01	9,304.38	11,549.39
Zinc	12,453.26	24,211.64	36,664.9

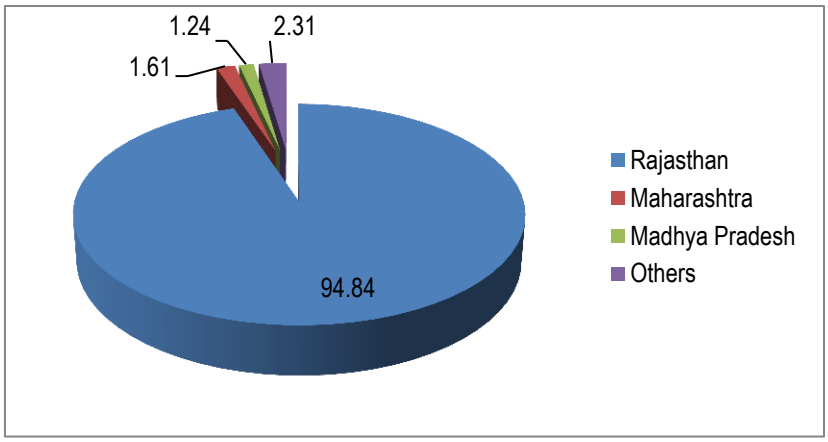

Figure 2.2.1: State-wise distribution of zinc metal resources

Source: National Mineral Inventory at Glance, Indian Bureau of Mines [2]

The important zinc belts in India are listed below.

1. Ajmer lead-zinc belt, Rajasthan
2. Zawar lead-zinc belt, Rajasthan
3. Rajpura-Dariba lead-zinc belt, Gujarat-Rajasthan
4. Rampura Agucha lead-zinc belt , Madhya Pradesh - Rajasthan
5. Deri-Ambaji lead-zinc belt, Rajasthan-Gujarat
6. Pur-Banera lead-zinc belt , Rajasthan
7. Rangpo lead-zinc-copper deposit, Sikkim

2.2.2 Production and consumption

2.2.2.1 World zinc production trends

Though Australia has the largest reserves of zinc, China is the leading mine producer of zinc. The distribution of global zinc reserves and mine production according to Mineral Commodity Summaries 2013 is shown in figure 2.2.2.1a.

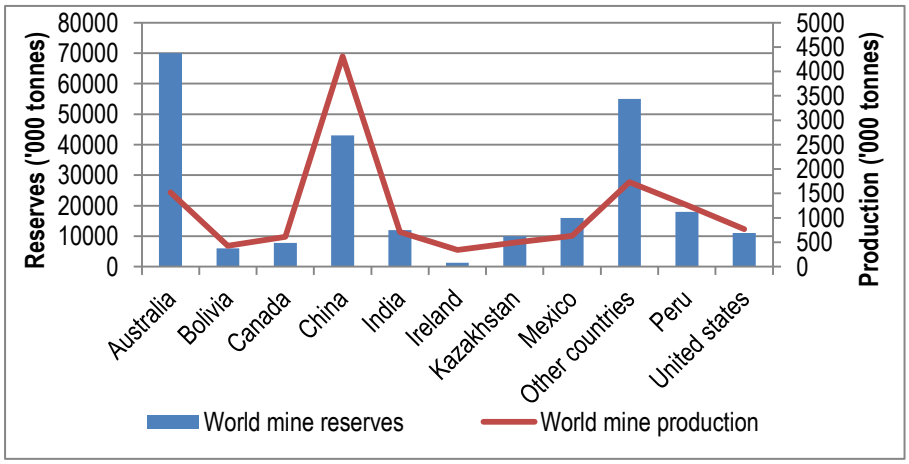

Figure 2.2.2.1a: Distribution of global mine reserves and zinc production (2011)

Source: USGS, Mineral Commodity Summaries 2013 [pdf], p. 189.

Australia, China and Peru forms about 55% of the total mine production of zinc in the world. The world mine and smelter production trend of zinc as seen in figure 2.2.2.1b is found to be increasing gradually.

Mine production refers to the ore that is mined.

Smelter production or metal production is metal produced from ore/ concentrate. Slab Zn production is again metal production, but mostly traded in slab shape.

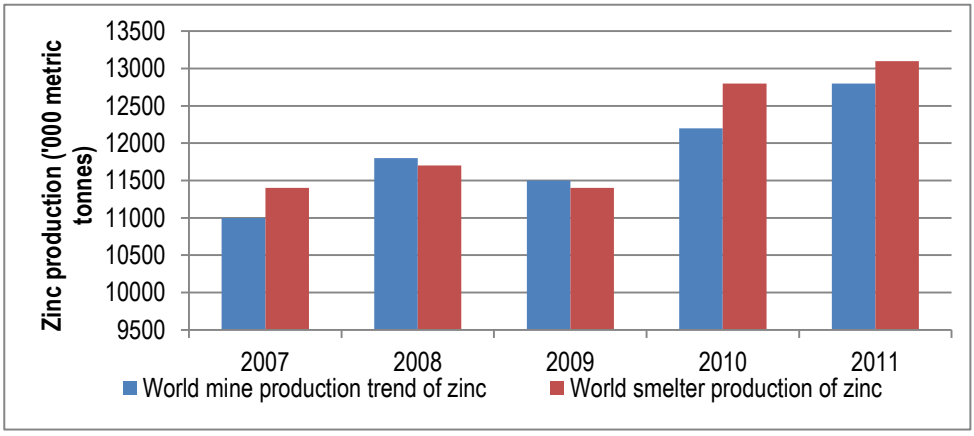

Figure 2.2.2.1b: World mine and smelter production trend of zinc ('000 metric tonnes)

Source: USGS, 2011 Minerals Yearbook, Zinc Advance Release, p 84.6 [4]
Note: that the smelter production includes recycling of zinc products.

2.2.2.2 Zinc Production in India

Rajasthan is the only zinc and lead ore producing state in India. The metal content in the ore keeps varying every year. The mine, smelter production trend is found to be increasing every year, indicating the rising capacity and capability of the zinc-lead mining sector (figure 2.2.2.2a).

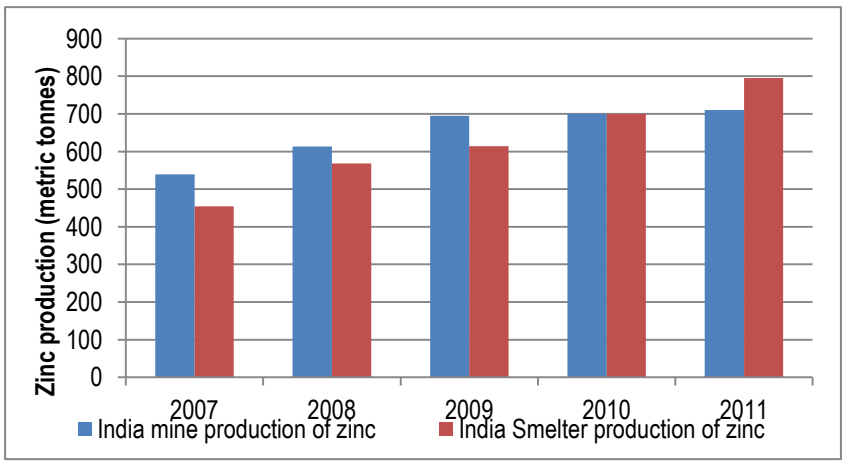

Figure 2.2.2.2a: Zinc ore and smelter production

Source: Market survey on zinc & lead, Indian Bureau of Mines [1]

The production of zinc ingot metal has increased by 21 % compared to its previous year with 96 % contribution from HZL. The production year on year for the zinc metal is observed to be increasing since the last decade. The production trend is given in figure 2.2.2.2b. The detailed values are given in annexure 2.2.

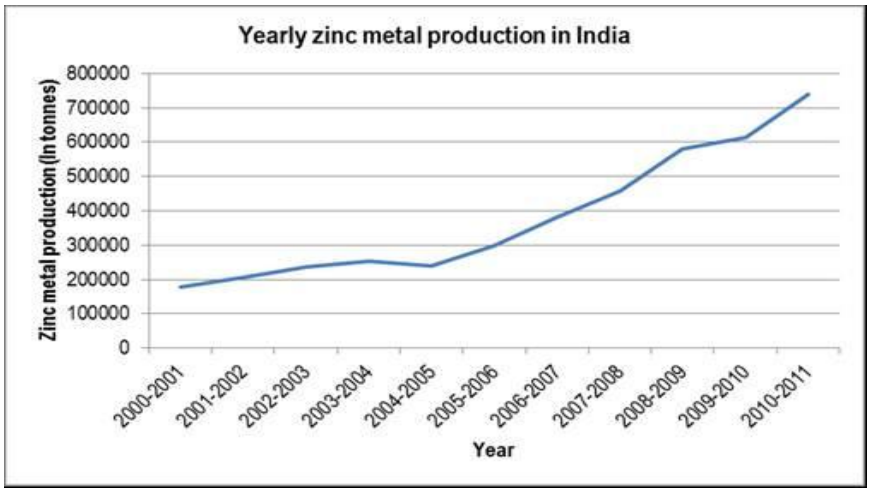

Figure 2.2.2.2b: Production trend of zinc metal in India

Source: Market survey on lead and zinc (p. 41), Indian Bureau of Mines [1]

i) World zinc consumption trends

Zinc is mostly consumed in the form of metals or its oxides. It is best used for galvanizing industries followed by coatings, making of brass, dye casting alloys, oxides, chemicals and extruded products. China is the leading consumer of zinc. The demand for slab zinc in China has shown significant growth. Its demand from 2003 to 2009 has increased by 144 %. China contributed about 43 % of the world's total demand in 2009 [2]. The annual consumption trends for world, Asia, Africa, Europe and America are given in figure 2.2.2.2c. The detailed values of the trend are given in annexure 2.3.

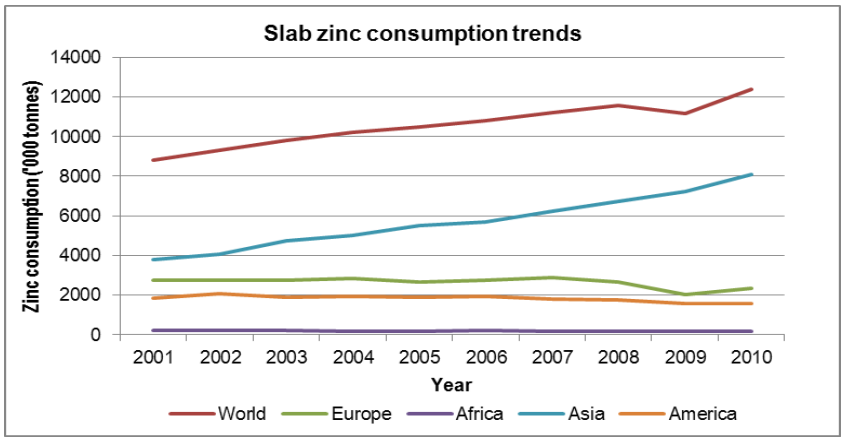

Figure 2.2.2.2c: Consumption trend of zinc slab

Source: Market survey on lead and zinc, Indian Bureau of Mines [1]

The consumption of slab zinc in Asia has always been high and keeps increasing at high rates with China being the major contributor. The levels in Europe and America are slightly dipping. Slab zinc utilization in Africa is mostly constant.

ii) Zinc consumption in India

The consumption details zinc is not available with the Indian Bureau of Mines due to little response from the zinc consuming industry. The apparent consumption of zinc, as calculated by the IBM for the years 2003-04 to 2009-10 is shown in figure 2.2.2.2d.

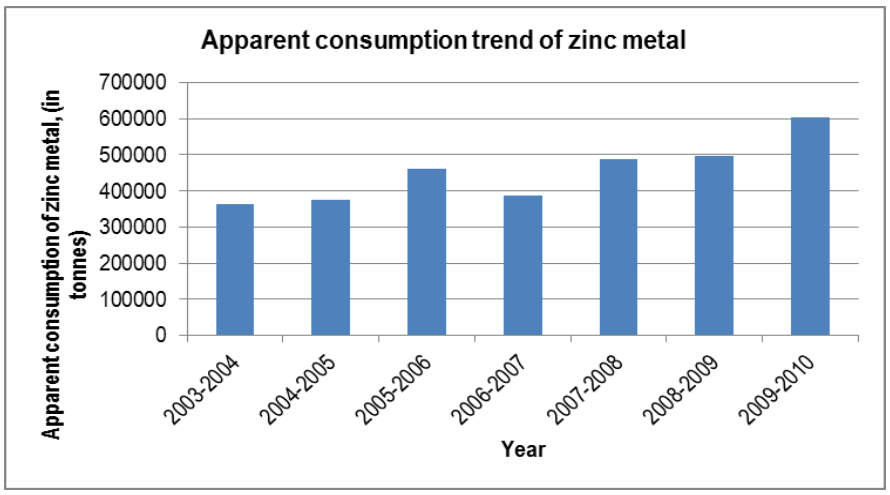

Figure 2.2.2.2d: India apparent consumption of zinc metal

Source: Market survey on lead and zinc (p.110), Indian Bureau of Mines [1]

2.2.3 Prices

Zinc is traded under different categories such as ingots, soft, dross, alloys, etc. The trading of ores and concentrates are also done in the international market. The factors affect the prices of the zinc metal include purity, size of lot, demand and supply, transportation costs and import and export duties. The trading for zinc takes place either by spot prices or fixing prices for future days. London Metal Exchange settled prices are considered to be the base for many other markets. Trading in India is based on two main markets, Delhi and Mumbai. The monthly price trend of zinc slab for the years 2011, 2012 and 2013 from the Bombay metal market is given in figure 2.2.3. The price details are given in annexure 2.4. It is observed that the prices on an average have been increasing year on year. The prices within the year of 2013 have also increased by 10 %.

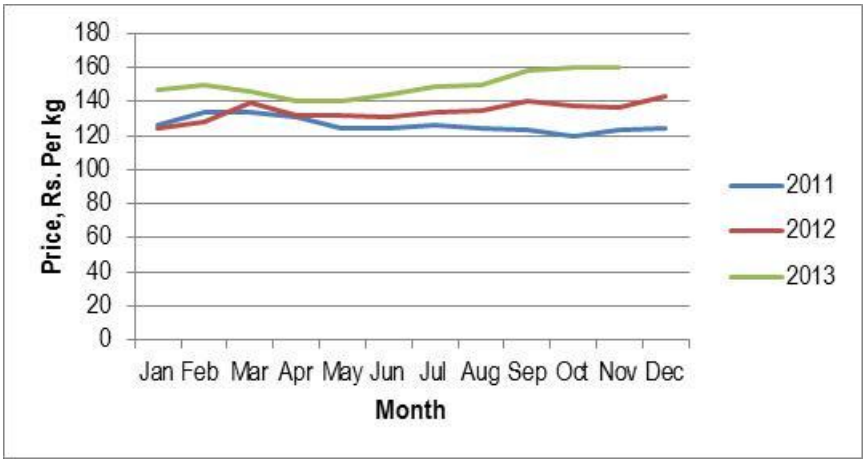

Figure 2.2.3: Monthly price trend of zinc slab for years 2011, 2012 and 2013

Source: Metalworld.co.in [5]

2.2.4 Imports and exports

The world imports of slab zinc were to the tune of 3.66 million tonnes in 2009 [1]. With about 19% contribution, USA was the top importer followed by China at 18 %. The share of zinc production of India is small and India is a net importer of zinc. The different types in which zinc are imported as zinc ores, concentrates, alloys (scrap, forms of bars, rods, plates, etc.). India imported 0.14 million tonnes of zinc ore and concentrates in 2010-11. Imports of zinc ores and concentrates in 2010-11 have increased by close to 47 % compared to year 2009-10. Imports of ores and concentrates in 2010-11 were mainly from Peru (63%) followed by Australia (36%). In 2010-11, of the total imported zinc alloys, about 18 % of the scraps were from Kazakhstan followed by 10% from Iran. About 14 % of the total imported alloys in form of bars, rods, plates, etc. are imported from Bangladesh, followed by 12.5 % from Malaysia. There are several other countries from which India imports the alloys are Germany, Iran, UAE, China, Australia, etc. The detailed distribution of the imports to India from various countries is given in Annexure 2.5.

The world exports of the slab zinc were to the tune of 3.8 million tonnes in 2009. Contributing to about 16 % of the total exports, Canada was the highest exporter, followed by Australia at 9.4 %. Zinc exports from India include ores, concentrates, alloys, etc. Exports of zinc ores and concentrates in India have increased to 0.44 million tonnes in 2010-11 from 0.19 million tonnes in 2009-10. Almost the entire quantity was imported by China. Of the total 0.3 million tonnes of zinc alloys and scrap, 23 % was exported to Malaysia. The other countries include Korea, China, Nigeria, etc.

2.3 Growth in past and future prospective

The demand for Zinc in India is expected to remain strong in the coming years on account of growth in the key zinc consuming industries like infrastructure, realty and manufacturing. Moreover growth in automobile and consumer durables industry would also further stimulate the increase in consumption of zinc. The mine production of zinc has been increasing steadily. Its demand depends mainly on steel industry especially in preparing galvanized sheets. The production of zinc metal has increased to 0.86 million tonnes in 2010-11 from 0.73 million tonnes in 2009-2010[2]. With a total production capacity of 0.91 million tonnes, very soon the existing plants might have to operate on full capacity to meet the demand. The Compounded Annual Growth Rate (CAGR) of zinc is shown in table 2.3.

Table 2.3: CAGR of refined zinc consumption (2001 to 2010)

	CAGR (%)
World	(+)3.91
Africa	(-) 0.84
America	(-) 1.67
Asia	(+) 8.94
Europe	(-) 1.33)

Source: Market Survey of Lead and Zinc, IBM. [1]

It is observed that there was an acceptable growth of 3.91% in the world of which Asia experiencing the major growth of 8.94 %. With this trend, the estimated consumption of the world by 2020 would be about 22.4 million tonnes and that of Asia would be 19.02 million tonnes. The trend also indicates the gradual decrease in the use of refined zinc in the remaining sections. In future, the use of alternative materials for various applications may pose a tough competition for zinc products, such as aluminium magnesium, plastic in dye-casting applications or ceramic coatings in some galvanizing applications. Zinc can also be replaced by titanium, magnesium or aluminium in chemicals.

2.4 Major players

Indian zinc industry comprises two major players– Hindustan Zinc Ltd (HZL) and Binani Zinc Ltd (BZL). The installed plant wise smelter capacities of these two manufacturers are given in figure 2.4. HZL was the world's largest integrated producer of zinc based on production volumes and in the lowest cost quartile in terms of all zinc mining operations worldwide in 2011 [19]

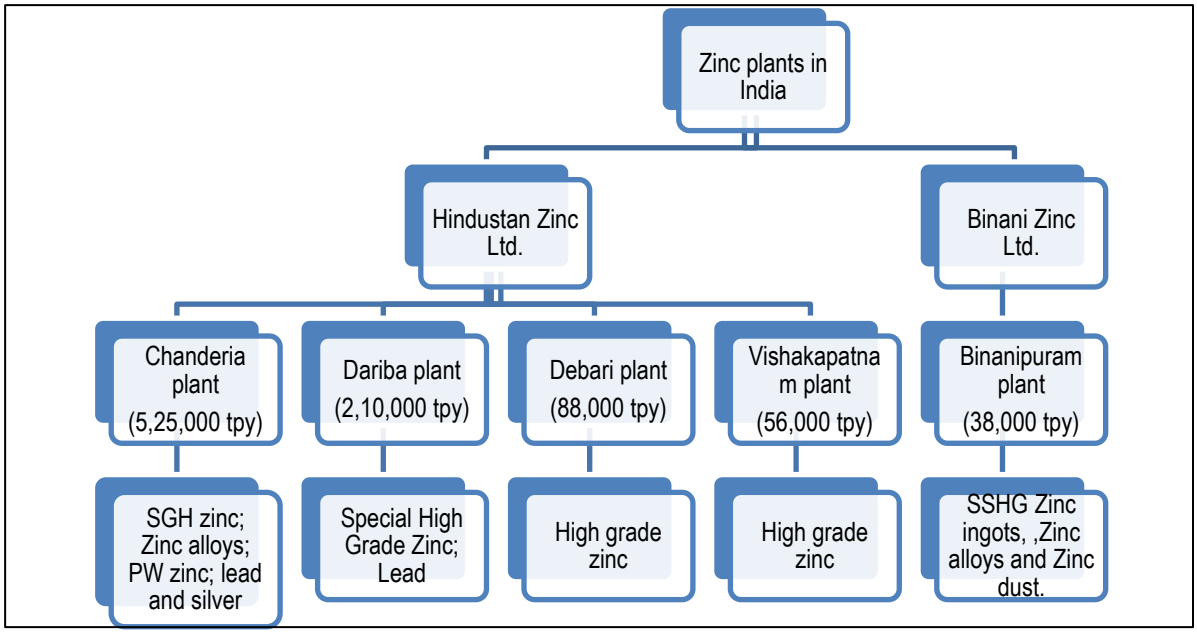

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Figure 2.4: Major players, their installed capacities and products produced (2009-10)

2.4.1 Zinc ore

Zinc ore in India is produced by HZL alone. Rampura Agucha mine was the largest zinc mine in the world in terms of contained zinc deposits in 2011 [19]. The ore production of HZL is catered by the following:

- Bhilwara, Rampura - Agucha district
- Rajsamand District
- Udaipur District

2.4.2 Zinc concentrate

Concentration of zinc is again only done by HZL in India. The total combined capacity of these plants is about 10, 140 tpd. The concentrate production in India from HZL is majorly from 3 main concentrator plants at:

- Zawar
- Rajpura - Dariba
- Rampura - Agucha

2.4.3 Zinc metal production

Only HZL produces primary zinc in India. HZL operates four smelters at Debari, Chanderia, Vishakhapatnam and Dariba. BZL produces zinc at its Binanipuram plant, Kerala by importing concentrates. The share of capacity of zinc smelters in India is shown in figure 2.4.3. The production of Vishakhapatnam plant has been suspended since February 2012.

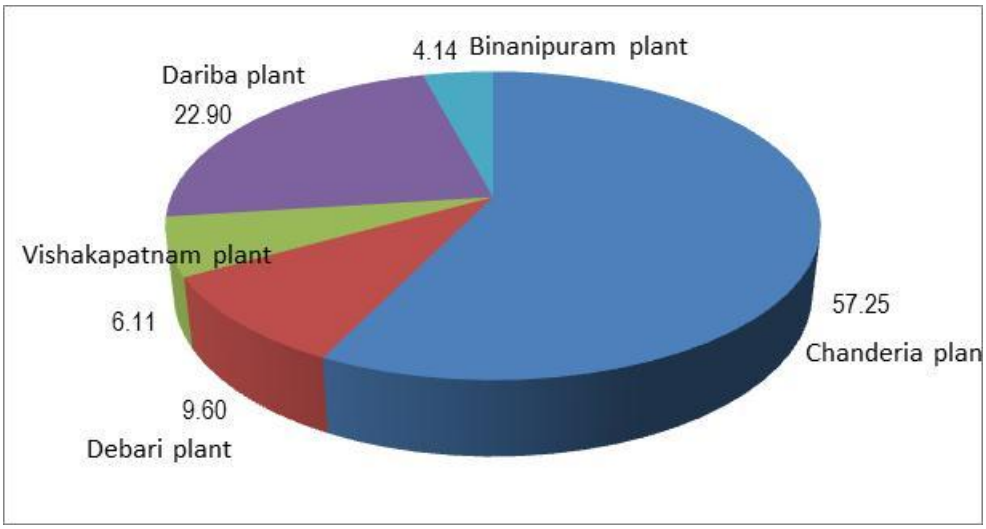

Figure 2.4.3: Percentage share of zinc smelter capacity in India

2.4.4 Zinc scrap

Galvanising industry is the largest consumer of zinc. About 57% of the zinc is used for galvanizing and this is non-recoverable. Hence recycling of zinc is relatively small compared to copper or lead. Like copper, recycling of zinc is also majorly attributed towards the unorganized sector. Various zinc products such as zinc skimming, zinc ash, zinc dross and zinc scrap to produce zinc metal, zinc oxide, and zinc sulphate. State-wise distribution of such units along with their capacities as registered with CPCB/ MOEF (as on September 2010) is given in table 2.4.4. According to IBM, only about 40 % of the reprocessing units are operating mostly at 30% of their capacity.

Table 2.4.4: State-wise capacities of zinc and its alloy reprocessing units

S. No	State/ Union territory	Number of units	Capacity (tonne/year)
1	Andhra Pradesh	6	6,731
2	Bihar	1	900
3	Chandigarh	3	2,850
	Chhattisgarh	1	400
4	Daman Diu & Dadra Nagar Haveli	4	16,020
5	Gujarat	20	63,464
6	Haryana	22	68,815
7	Himachal Pradesh	3	8,800
8	Jammu & Kashmir	5	29,500
9	Jharkhand	3	4,620
10	Karnataka	4	5,640
11	Madhya Pradesh	1	1,800
12	Maharashtra	11	14,682

S. No	State/ Union territory	Number of units	Capacity (tonne/year)
13	Orissa	2	5,892
14	Pondicherry	1	3,000
15	Punjab	34	65,052
16	Rajasthan	8	8,530
17	Tamil Nadu	5	3,280
18	Uttar Pradesh	15	64,855
19	West Bengal	21	27,632
	Total	**170**	**4,02,463**

Source: MoEF, Central Pollution Control [6]

2.5 Important stakeholders

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

- Primary producers that include Hindustan Zinc Ltd and Binani Zinc Ltd
- Secondary producers involved in recycling of zinc wastes and include about 170 units of large, medium and small scale industries.
- Government departments and ministries that define trade policies and public private share in the industry.
- Zinc bodies and associations
  - India Lead Zinc Development Association involved in market development and dissemination of technical information [16]
  - International Zinc Association, based in Brussels supports advance zinc products and markets through research development, technology transfer and communication [17]
  - International Lead and Zinc Study Group, formed by the United Nations caters to intergovernmental consultations on international trade. It also conducts special studies to understand world situations [18].

2.6 Product categorization

The two major industries in India, i.e. Hindustan Zinc Limited and Binani Zinc Ltd. produce refined zinc along with other value added products such as lead, sulphuric acid, silver, cadmium etc. Different forms of zinc metal manufactured in India include the following.

- Special High Grade (SHG) zinc
- Continuous Galvanizing Grade (CGG)
- High Grade (HG)
- Prime Western (PW)

The zinc metal is further used galvanizing, zinc oxide formation, dye castings, alloy preparation or rolled zinc which is used in building industry. Apart from this there are number of small, medium and large scale industries that produce various products of zinc through some usual methods of galvanizing and dye casting.

2.7 Current regulatory/policy scenario

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

- Industrial policy resolution provides 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 need for the state to play an active role in industrial growth.

- National mineral policy focuses the best use of the minerals available by the help of good technology in mining, beneficiation and economic utilization. This encourages the usage of foreign investment and technology for efficient production.

The other important policy includes the Energy Conservation Act 2001 that enforces efficient use of energy. Industries from seven different sectors (aluminium, cement, chloro-alkali, fertilizer, iron & steel, pulp & paper and thermal power plant) which are energy intensive are termed as designated consumers to which the regulation on energy efficiency is adopted. Bureau of Energy Efficiency has the authority to set the standards and monitoring. A market based mechanism called Perform Achieve Trade (PAT) has been launched which imposes mandatory specific energy targets to the Designated Consumers (DCs). The PAT mechanism covers DCs under the seven identified sub-sectors and does not include zinc industry.

3.0 Energy Performance

3.1 Zinc manufacturing process and technology use

The manufacturing process and the technological movements of the zinc industry in India have more or less remained the same. The utilities or auxiliaries on the other side have a wide range of new energy efficient technologies coming into the market regularly. Continuous efforts though are being made to implement innovative and new methodologies towards the process side for better economics. The manufacturing process along with various types of technological usage at different stages is briefly described.

3.1.1 Mining

Mining operation (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 mining operations and depends on ore characteristics and economic considerations. A suitable smelter grade concentrate is produced in this process. The unwanted gangue is majorly removed and the sulphide ores are concentrated. Efficient beneficiation process helps in saving large quantity of electrical and thermal energy along with using reduced optimum furnace capacity. Beneficiation of zinc ore is a very complex process as it involves separation of lead concentrates and zinc concentrates. Effective treatment is required in order to achieve both the lead and zinc metals. Other associated materials include minerals like silica, oxides and carbonates of other metals. Other metals include, copper, arsenic, bismuth, antimony, etc. For an economic extraction, zinc content in the ore should be a minimum of 48 %.

3.1.3 Processing of zinc ores

i) Crushing

Ore is crushed in there different stages depending on its size:

- Primary crushing - Jaw crusher or gyratory crusher.
- Secondary crushing - Cone crusher is used.
- Tertiary crushing - Short head cone crushers are used.

Double deck vibratory screens are used to sort the size while operating secondary and tertiary crushers in closed circuits. The technology use, i.e. the type and size of crushers used depends completely on the nature of the ore and the size of the plant.

ii) Grinding and classification

Ball mills are employed in closed circuit with cyclones here. Flotation reagents are added during the time of grinding. Precise grinding of ore is done here. Over grinding of the ore will aid the galena ore to form slimy particles which may result to more contamination of lead.

iii) Conditioning

Zinc and lead ores are separated from the mixture. The other gangue minerals include sphalerite galena, pyrite, pyrhotite, Iron oxides, silica, dolomite, precious metals like gold, silver, and other carbonaceous and graphitic minerals. Selective flotation is done to carefully win all the materials. Accordingly selective depressants, activators, collectors and frothers are used.

iv) Flotation

Post conditioned slurry along with different reagents added is subjected to flotation process in the flotation chambers. Modifiers like lime, gangue dispersants like sodium silicate, activators like copper sulphate, collectors like sodium isopropyl xanthate & aero floats and frothers like pine oil, cresilic acid, Methyl Isobutyl Carbinol (MIBC), etc. are used here.

v) Thickening Filtration, Drying and Tailing Disposal

Lead and zinc concentrates from the flotation process are separated and further thickened in thickeners and filtered in filters separately in order to reduce the water content. The excess water is thus recovered and sent for re-use. The over-flow of cyclone is sent to thickeners and the tailings from the cyclone are sent to tailing dam. The tailing water can be reused after some necessary treatment before sending to tailing dam. The process flow showing the steps followed after floatation is shown in figure 3.1.

3.1.4 Smelting

Zinc metal is produced from the zinc concentrates here. Based on the type of ore used, zinc is extracted from its concentrates either by pyro-metallurgical process or hydro-metallurgical process.

(i) Roasting

Partial oxidation of the concentrates at 9500C temperature with air is done. Types of roasting furnaces used are the following:

- Multiple hearth roaster
- Suspension roaster or
- Fluidised bed roaster

The zinc oxides formed are also called as zinc calcine. The sulphur dioxide released during the reaction as the by-product is used for further manufacturing sulphuric acid.

vi) Pyrometallurgical Process

The zinc calcine is further reduced in an atmosphere of carbon monoxide, thus forming zinc vapour and carbon dioxide at a reaction temperature of 14000C. The zinc vapour is later recovered through molten zinc bath. Four different types of processes that can be used here are: Horizontal retort process

- Vertical retort process
- Blast furnace process
- St Joseph mineral company process

This method can however produce up to 98% pure zinc. This grade can be used for galvanizing, but the purity is not enough for dye casting of alloys which require high grade zinc of 99.995 % purity. Thus further refining will be required.

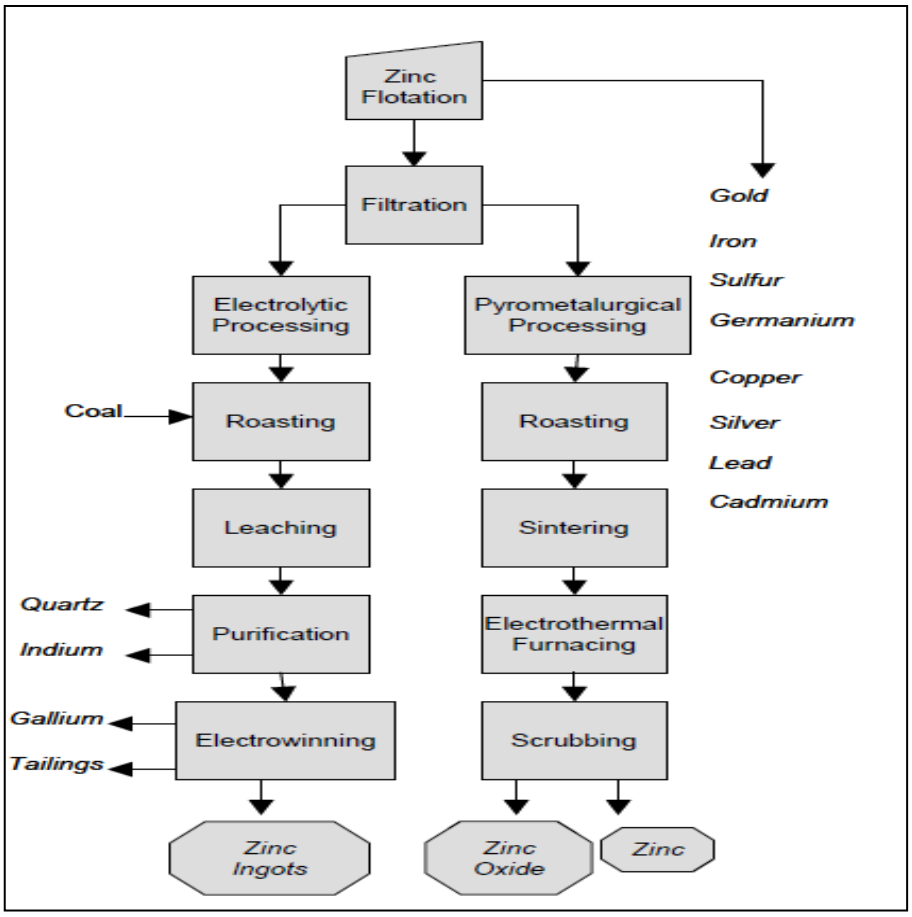

Figure 3.1.4: Process flow diagram for zinc production post floatation

Source: Lead and Zinc, Energy and Environmental Profile of the U.S. Mining Industry [7]

vii) Hydro-metallurgical process

This process is also known as Roast-Leach-Electrowin (RLE) Process. The process involves leaching, purification and electrolysis.

viii) Leaching

Zinc calcine is subjected to consecutive leaching by slightly acidic sulphuric acid and then to strong sulphuric acid to extract zinc and zinc ferrite in the form of zinc sulphate in the liquid form. The other metals such as lead and silver remain in the solid form.

ix) Purification

Above obtained zinc sulphide solution is further purified by cementation. Zinc dust and steam is used to remove copper, cadmium, cobalt, nickel which may act as impurities during electrolysis. The temperature of the purification tanks are maintained between 40^0C to 85^0C with a pressure ranging from 1atm. to 2.4 atm.

x) Electrolysis

Two different processes used are (i) low current density process (270 - 375 amperes per m^2) and (ii) high current density process (1000 amperes per m^2). Both these technologies have their pros and cons in terms of the production quantity as well as the health of the vessel. The zinc coated cathodes are further taken and the zinc is mechanically stripped from the aluminium plates. The system is operated at 300 ^{o}C to 350 ^{o}C in atmospheric pressure. Electrolysis process accounts for significant energy consumption.

3.1.5 Process types used in different plants.

The plant wise use of process is given in figure 3.1.5. It is seen that except for one unit in Chanderia plant of HZL, all the other plants mostly follow the Hydrometallurgical process.

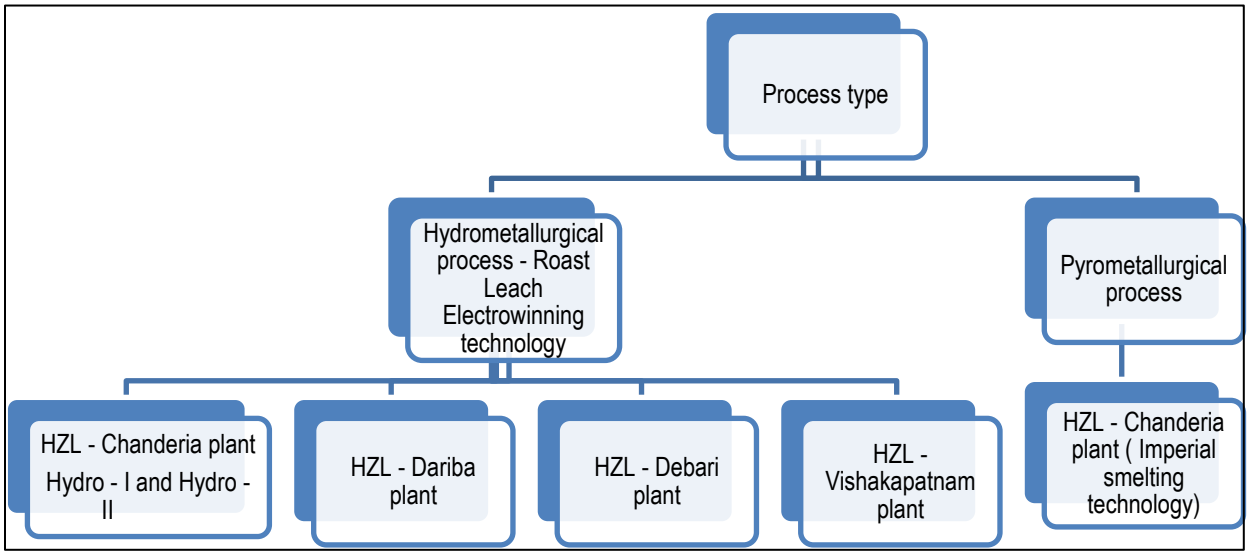

Figure 3.1.5: Process type used in different plants

3.1.6 Other technological advancements

The basic concept of producing zinc through the two different processes (hydro-metallurgical process and pyro-metallurgical process) has mostly remained unchanged. Over a period of time few improvements in technology have taken place which aids the production in terms of environment and user friendly operation and energy reduction of the plant. Plants have already been adopting such measures. Some of the steps that are in practice are as follows:

(i) Use of Hot Gas Precipitator (HGP) dust treatment plant to recover lead and silver
(ii) Installation of adiabatic cooling tower for zinc smelter to conserve water.
(iii) Use of Pro Float (magnetic agglomeration) for improvement in zinc recovery. This technology is used to agglomerate fine paramagnetic minerals to increase the zinc recovery in the floatation circuit.
(iv) Automated process control to optimise feed rate with bed temperature.
(v) Use of better efficiency utilities.

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 HZL as a whole in accordance with the CMIE data base is, shown in following figure 3.2a. The capacity utilization trends of Binani Zinc Ltd. in accordance with the CMIE data base is, shown in following figure 3.2b. As can be seen, HZL at present is not utilizing its complete capacity for the production of zinc ingots.

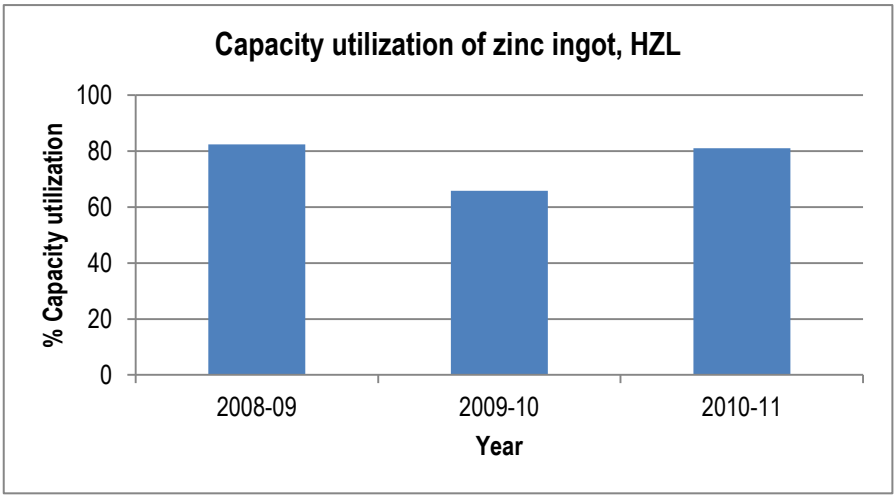

Figure 3.2a: Capacity Utilization of HZL

Source: CMIE Prowess database [8]

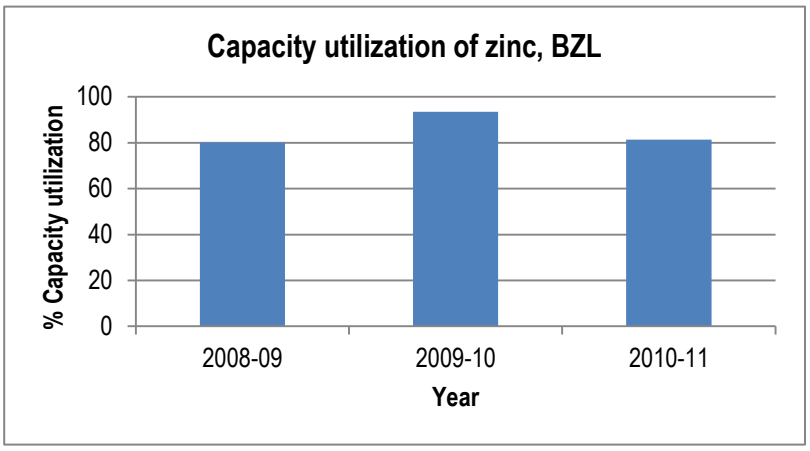

Figure 3.2b: Capacity Utilization of BZL

Source: CMIE Prowess database [8]

3.3 Energy performance and major energy consuming areas

Zinc industry consumes significant energy, both thermal and electrical. However the energy consumption is process, technology, product specific. Many process stages involved in the zinc 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. Large varieties of utilities are used for different purposes at different stages. They include different types and capacities of furnaces, machinery for mining, milling etc. The rising costs of fossil fuels also are currently causing most of the industries to move towards energy efficiency.

3.4 Energy saving potential and major areas

As discussed mining, milling, smelting and concentrating are the major energy consuming areas in the zinc industry. These account to more than 70 % of the total energy consumption. However this is highly technology dependent. For e.g. an electric furnace consumes tremendous energy than when compared to other technological use in smelting or converting process. The other potential areas for energy efficiency improvements include compressors, pumps, fans and blowers and other mechanical and electrical utilities. Initiatives include utilization of renewable energy sources such as wind and solar.

4.0 Analysis of energy consumption data

4.1 Energy consumption of the major industries

The energy consumption details of major industries - Hindustan Zinc Ltd (HZL) and Binani Zinc Ltd (BZL) were studied to assess the performance. Wherever data was not available, the actual production and the average specific energy consumption were used to arrive at the total energy consumption of the plant, which were used. The total energy values were further analysed for their applicability into PAT.

4.1.1 Hindustan Zinc Limited

Apart from zinc, Hindustan Zinc Ltd (HZL) produces other value added products such as silver, lead and cadmium. The production details are given in table 4.1.1a. The specific energy consumption details of HZL for the years 2009-10 to 2011-12 are given in table 4.1.1b.

Table 4.1.1a: Production of zinc and other value added products at HZL

	2008-09	2009-10	2010-11
Silver (tonnes)	105.06	138.55	148.08
Sulphuric acid ('000 tonnes)	954.27	1,035.59	1,192.7
Lead ingot ('000 tonnes)	65.33	71.63	63.19
Zinc ingot ('000 tonnes)	551.72	578.41	712.47
Cadmium(tonnes)	471	487	493

Source: CMIE Database [8]

Table 4.1.1b: Specific energy consumption of HZL

Area	Specific energy consumption			
	2009-10	2010-11	2011-12	2012-13
HZL mines (toe/ tonne of concentrate)	0.040	0.049	0.052	0.058
HZL smelters (toe/ tonne of metal)	0.437	0.415	0.410	0.415

Source: Annual Report 2012-13, Hindustan Zinc Ltd, p.49 [9]

The total energy consumption of HZL has been estimated from average SEC values and production data of zinc ingots. The production details of Individual plant of HZL are not available. It may also be noted that the Vishakhapatnam plant of HZL is closed down since 2012. The total energy consumption of individual plants of HZL was estimated based on average capacity utilisation and the average SEC of HZL. With an average capacity utilization of 76% of HZL, the total energy consumption of HZL was estimated to be 2,74,957 toe, which is quite significant (table 4.1.1c).The total estimated annual energy consumption varies between 29,400 toe to 1,75,398 toe. The large range in energy consumption in HZL is attributed to the plant capacities and the production levels.

Table 4.1.1c: Estimated energy consumption of individual plants of HZL

Plant	Total energy consumption (toe)
Chanderia	1,75,398
Dariba	70,159
Debari	29,400
Total	**2,74,957**

HZL has installed about 474 MW of capacity of captive power generation (table 4.1.1d). Apart from this, it has also installed wind mills with a total capacity of 274 MW (table 4.1.1e). However, the actual wind power generation on average was only 25 MW.

Table 4.1.1d: Captive power plants in HZL

Plant	Captive power plant (MW)
Chanderia	234
Dariba	160
Zawar	80
Debari	-
Total	474

Source: *Annual Report 2012-13, Hindustan Zinc Ltd., p.24 [9]*

Table 4.1.1e: Wind power installations of HZL

State	Installed capacity of HZL (MW)
Rajasthan	88.8
Gujarat	88.8
Maharashtra	25.5
Karnataka	49.4
Tamil Nadu	21.0
Total	273.5

Source: *Annual Report 2012-13, Hindustan Zinc Ltd., p.7 [9]*

4.1.2 Binani Zinc Ltd

The zinc and its value added products production for the years 2007-08 to 2010-11 is given in table 4.1.2a.

Table 4.1.2a: Production of zinc and value added products at BZL

	2007-08	2008-09	2009-10	2010-11
Unwrought zinc ('000 tonnes)	31.9	30.44	35.55	30.91
Zinc alloys ('000 tonnes)			0.09	1.82
Cadmium (kgs)	52,089	39,350	68,553	67,277
Sulphuric acid ('000 tonnes)	48.58	45.86	50.26	46.87

Source: *CMIE Database [8]*

The SEC of smelter at Binani Zinc Ltd for the years 2011-12 and 2012-13 is given in table 4.1.2b.

Table 4.1.2b SEC of smelter at Binani Zinc Ltd. (toe/ tonne)

Section	2011-12	2012-13
Smelter	0.404	0.391

Source: *Annual Report 2012-13, Binani Zinc Ltd, p.10 [10]*

Table 4.1.2c: Total and specific energy consumption of Binani Zinc Limited

Year	Total energy consumption (toe/yr)	Specific energy consumption (toe/tonne of zinc ingot)
2006-2007	12,960	0.396
2007-2008	13,780	0.432
2008-2009	12,635	0.415

Source: TERI, *Comprehensive Energy Audit Report of Binani Zinc Limited, 2010 [21].*

The total annual energy consumption of Binani Zinc Ltd varied between 12,695 toe to 13,780 toe. Considering an average SEC of 0.391 toe per tonne in smelter, the total annual energy consumption of BZL is estimated to be 12,629 MTOE. The annual energy consumption of BZL was observed to be close to the minimum annual energy consumption levels of chlor-alkali industry (12,000 MTOE) as provided under PAT. The details of energy consumption of HZL and BZL are given in Annexure 4.1.

Ingot is a metal that is further cast into shape (**slab**) suitable for further processing.

4.2 Methodology

The methodology adopted for estimating the total energy consumption is provided below.

- The energy details from the annual reports and/ or the data from energy audit reports were used for the estimation of energy consumption.
- The energy consumption details obtained from various plants were converted to tonnes of oil equivalent per tonne of product to arrive at SEC values. The estimates of total energy consumption were used for their applicability under PAT.
- Individual plant level data on production and energy consumption were not available for HZL. Therefore, the individual plant level energy consumption for HZL plants has been estimated from the available total HZL group energy consumption data based on the percentage installation capacities of the plants.
- 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 and specific gravity of different fuels

Fuel	Gross calorific value (kcal/kg)
LPG	10,700
FO	10,500
HSD	10,270
LPG	10,990
Propane	12,028
RLNG	10,238

* *kcal/Sm3*

Source: Engineering toolbox [11]; Material safety data sheet, Hindustan Petroleum [12]; Energy conservation in utilities, PCRA [13]; Calorific values of different fuels, IISc. [14]

4.3 Possible energy efficiency measures

Various studies and energy audits of zinc plants indicate an average energy saving of about 5% in utilities. In addition, adoption of process improvements in different sections of zinc plant would further help in improving the overall energy efficiency of zinc plants. Some of the energy efficiency measures in zinc industries are given below.

- Natural briquettes are being used for firing boiler in place of furnace oil to reduce the steam generation cost.
- Installation of vapour absorption machine in sulphuric acid plants to generate refrigeration from the waste heat.
- Waste heat recovery from acid plant absorption towers for use in mineral processing steps such as zinc sulphate solution heating
- Furnace efficiency improvements through charge preheating, molten metal stirring and oxygen enrichment.
- Atomization should be done for conveying and efficient means of transportation (hauling of ores) at the mines.

The energy conservation options available include energy saving measures in utilities such as electrical system & drives, pumps, compressors, captive power plants and steam system.

4.4 Conclusions and recommendations

The average SEC level of smelters at HZL (includes all facilities) and BZL for the years 2011-12 and 2012-13 were found to be 0.413 toe per tonne of zinc (ingot) and 0.397 toe per tonne of zinc (ingot) respectively. As seen in figure 4.4a, SECs are comparatively higher as compared to the benchmark SEC level of 0.365 toe per tonne of slab zinc. It may be noted that the SEC values of Indian zinc industry are significantly lower than the world average of 0.566 toe per tonne of slab zinc (UNIDO [20]).

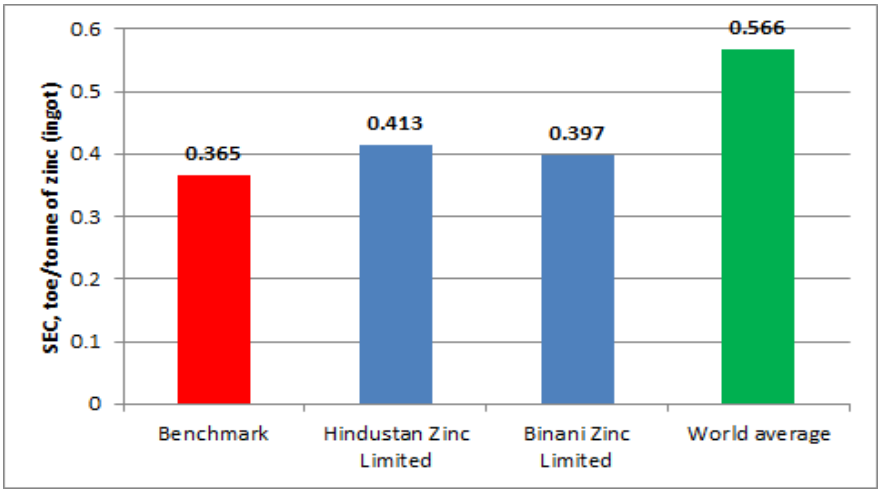

Figure: 4.4a: Comparison of specific energy consumption of plants*

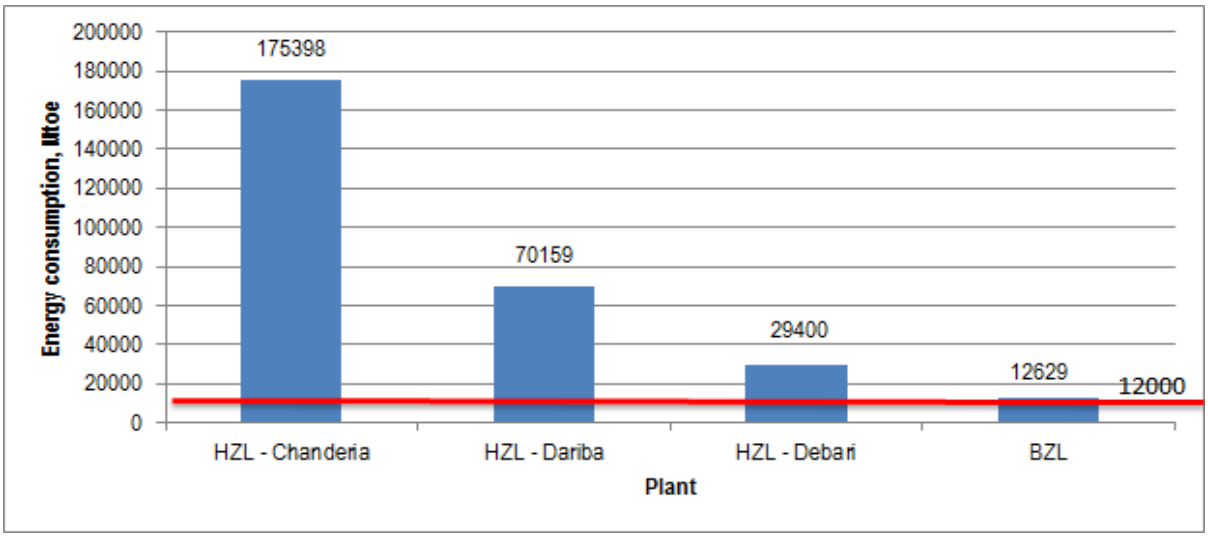

Figure 4.4b: Comparison of total energy consumption of zinc plants

The total energy consumption of HZL – Dariba and HZL – Chanderia are higher as compared to HZL-Debari and BZL. This may be attributed to their higher production capacities thereby resulting in higher energy consumption levels. Almost all the operating plants of HZL and BZL exhibit a total annual energy consumption of more than 12,000 MTOE. This value is the minimum energy consumption set for chlor-alkali industry sector. Therefore, it is suggested that a threshold limit of 12,000 MTOE per year is set for zinc sector and both major producers of zinc comprising 4 operating plants would be included as 'designated consumer' (DC). The benchmark energy consumption of zinc sector shows that there exists an energy saving potential of 8 to 13% in Indian zinc industries.

***Note:** The benchmark and world average figures have been referred from UNIDO's Global Industrial Energy Efficiency Benchmarking – A Energy Policy Tool Working Paper [20]5.0 References

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6.0 Appendices

Appendix 2.1

Table - 1 : Reserves/Resources of Lead & Zinc Ore as on 1.4.2010
(By Grades/States)

(In '000 tonnes)

Grade/State	Reserves				Remaining resources								Total resources (A+B)
	Proved STD111	Probable		Total (A)	Feasibility STD211	Pre-feasibility		Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
		STD121	STD122			STD221	STD222						
All India : Total Ore	**20215**	**87569**	**1196**	**108980**	**129**	**1077**	**3983**	**21433**	**221601**	**325051**	**3340**	**576614**	**685594**
By Grades													
Ore with (+)10% Pb & Zn	11055	64958	81	76094	-	-	-	-	24660	39095	-	63755	139849
Ore with 5-10 % Pb & Zn	9160	22611	1115	32886	-	961	3983	16827	59043	138602	-	219416	252302
Ore with (-)5% Pb & Zn	-	-	-	-	129	117	-	4606	137898	147354	3340	293444	293444
Metal													
Lead metal	398.42	1817.89	28.70	2245.01	-	34.32	50.95	472.37	2915.70	5831.04	-	9304.38	11549.39
Zinc metal	1938.37	10460.72	54.17	12453.26	5.20	4.71	86.91	1168.96	9607.12	13237.09	101.65	24211.64	36664.90
Lead & Zinc metals	-	-	-	-	-	-	-	-	-	118.45	-	118.45	118.45
By States													
Andhra Pradesh													
Ore	-	-	-	-	-	-	-	1000	4159	17530	-	22689	22689
Lead metal	-	-	-	-	-	-	-	28.70	119.53	688.65	-	836.88	836.88
Zinc metal	-	-	-	-	-	-	-	12.00	44.00	7.00	-	63.00	63.00
Bihar													
Ore	-	-	-	-	-	-	-	-	435	11000	-	11435	11435
Lead metal	-	-	-	-	-	-	-	-	-	24.00	-	24.00	24.00
Zinc metal	-	-	-	-	-	-	-	-	14.75	24.00	-	38.75	38.75
Gujarat													
Ore	-	4955	845	5800	-	-	-	129	-	200	-	329	6129
Lead metal	-	104.37	17.81	122.18	-	-	-	3.90	-	-	-	3.90	126.08
Zinc metal	-	224.04	39.37	263.41	-	-	-	1.10	-	-	-	1.10	264.51
Lead & Zinc metals	-	-	-	-	-	-	-	-	-	0.90	-	0.90	0.90
Madhya Pradesh													
Ore	-	-	-	-	129	117	-	1510	4006	5930	3150	14842	14842
Lead metal	-	-	-	-	-	-	-	26.12	5.13	5.04	-	36.29	36.29
Zinc metal	-	-	-	-	5.20	4.71	-	114.76	41.93	186.02	101.00	453.62	453.62
Maharashtra													
Ore	-	-	-	-	-	-	-	1967	6305	1000	-	9272	9272
Zinc metal	-	-	-	-	-	-	-	133.56	428.11	28.00	-	589.67	589.67

(Contd.)

Table - 1 (Concld.)

Grade/State	Reserves				Remaining resources								Total resources (A+B)
	Proved STD111	Probable		Total (A)	Feasibility STD211	Pre-feasibility		Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
		STD121	STD122			STD221	STD222						
Meghalaya													
Ore	-	-	-	-	-	-	-	-	880	-	-	880	880
Lead metal	-	-	-	-	-	-	-	-	16.50	-	-	16.50	16.50
Zinc metal	-	-	-	-	-	-	-	-	14.00	-	-	14.0	14.00
Odisha													
Ore	-	-	-	-	-	961	119	-	-	670	-	1750	1750
Lead metal	-	-	-	-	-	34.32	4.25	-	-	38.39	-	76.96	76.96
Rajasthan													
Ore	20215	82178	287	102680	-	-	3864	13157	200065	287576	190	504852	607532
Lead metal	398.42	1706.62	9.21	2114.25	-	-	46.70	272.54	2604.74	5055.46	-	7979.44	10093.69
Zinc metal	1938.37	10223.80	11.66	12173.83	-	-	86.91	741.17	8821.59	12950.20	0.53	22600.40	34774.23
Lead & Zinc metals	-	-	-	-	-	-	-	-	-	117.55	-	117.55	117.55
Sikkim													
Ore	-	436	64	500	-	-	-	300	-	150	-	450	950
Lead metal	-	6.90	1.68	8.58	-	-	-	-	-	-	-	-	8.58
Zinc metal	-	12.88	3.14	16.02	-	-	-	3.00	-	1.05	-	4.05	20.07
Tamil Nadu													
Ore	-	-	-	-	-	-	-	200	590	-	-	790	790
Lead metal	-	-	-	-	-	-	-	2.26	5.48	-	-	7.74	7.74
Zinc metal	-	-	-	-	-	-	-	11.76	24.76	-	-	36.52	36.52
Uttarakhand													
Ore	-	-	-	-	-	-	-	3170	1790	660	-	5620	5620
Lead metal	-	-	-	-	-	-	-	138.85	34.25	9.50	-	182.60	182.60
Zinc metal	-	-	-	-	-	-	-	151.21	87.99	27.63	-	266.83	266.83
West Bengal													
Ore	-	-	-	-	-	-	-	-	3371	335	-	3706	3706
Lead metal	-	-	-	-	-	-	-	-	130.07	10.00	-	140.07	140.07
Zinc metal	-	-	-	-	-	-	-	-	130.42	13.00	-	143.42	143.42

Figures rounded off.

Appendix 2.2

Yearly zinc metal production in India

Year	Zinc production (tonnes)
2000-2001	1,78,015
2001-2002	2,04,209
2002-2003	2,35,525
2003-2004	2,51,754
2004-2005	2,39,187
2005-2006	2,96,460
2006-2007	3,80,945
2007-2008	4,57,075
2008-2009	5,79,091
2009-2010	6,13,964
2010-2011	7,40,402*

* *projected*

Source: Market survey on lead and zinc (p. 41), Indian Bureau of Mines [1]

Appendix 2.3

Consumption trend of zinc at global level

Year	World	Europe	Africa	Asia	America
2001	8806.9	2768.8	189.2	3773.9	1847.2
2002	9330.7	2730.7	208.5	4066	2088.1
2003	9831.4	2758.3	191.1	4749.7	1870
2004	10237.9	2845.2	169.4	5017.5	1950.4
2005	10491.6	2643.6	178.7	5526.2	1890.4
2006	10823.9	2736.8	189.2	5667.5	1938.5
2007	11230.8	2897.5	184.1	6215.9	1801.8
2008	11556.2	2673.3	172.5	6736.1	1757.5
2009	11188.1	2041.3	166.4	7221.9	1579.7
2010	12376.5	2332.7	171.6	8109.1	1553.2
CAGR %	(+)3.91	(-) 1.33	(-)0.84	(+)8.94	(-)1.67

Appendix 2.4

Price trends of zinc slab

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

2011	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bombay metal market, Rs. Per Kg												
Zinc slab	126.15	133.83	133.8	131	124.58	123.92	126.28	124.61	123.46	119.29	123.04	124.26
2012	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bombay metal market, Rs. Per Kg												
Zinc slab	124.46	128	139.26	131.46	131.72	130.88	133.92	134.47	140.27	137.44	137.05	143.44
2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bombay metal market, Rs. Per Kg												
Zinc slab	146.77	150.22	145.8	140	140.78	143.84	148.84	150.22	158.35	159.77	160.08	

Appendix 2.5

Imports to India

Imports of zinc ores and conc.			Imports of zinc and alloys (including scrap)			Imports of zinc and alloys (worked bars, rods, plates, etc)		
Country	Quantity (tonne)	%	Country	Quantity (tonne)	%	Country	Quantity (tonne)	%
Peru	88171	63.33	Kazakhstan	20008	17.83	Malaysia	1628	12.58
Australia	50317	36.14	Iran	10725	9.56	Germany	1245	9.62
Congo	346	0.25	UAE	10878	9.69	Iran	1215	9.39
UAE	51	0.04	Korea, Rep of	9657	8.60	UAE	1164	8.99
Dkibouti	147	0.11	Australia	7789	6.94	Bangladesh	1768	13.66
Morocco	46	0.03	China	4530	4.04	Australia	431	3.33
Iran	48	0.03	Germany	3658	3.26	Korea	510	3.94
Ethiopia	74	0.05	Malaysia	3590	3.20	China	455	3.52
Japan	22	0.02	Namibia	3690	3.29	Belgium	335	2.59
			Belgium	2390	2.13	Finland	314	2.43
			Other countries	35313	31.47	Other countries	3879	29.97
Total	139222		Total	112228		Total	12944	

Appendix 4.1

Energy consumption details of HZL and BZL

(1) Specific energy consumption of Hindustan Zinc Ltd

Area	Specific energy consumption (GJ/tonne)			
	2009-10	2010-11	2011-12	2012-13
HZL mines	1.68	2.03	2.16	2.42
HZL smelters	18.2	17.3	17.09	17.31

(2) Energy consumption of Binani Zinc Ltd

	Energy consumption			
	2006-07	2007-08	2008-09	
Zinc Ingot production	32,697	31,903	30,441	
Electricity				
million kWh	146.4	147.7	141.7	
Equivalent toe	12,588	12,700	12,138	
Furnace oil (liters)	3,97,824	11,55,746	531,734	
toe	372	1,080	497	
SEC (toe/ MT)	0.396	0.432	0.415	

Source: Energy audit report of Binani Zinc Ltd, The Energy and Resources Institute

(3) Specific energy consumption of smelters of Binani Zinc Ltd

	Smelter SEC	
	2011-12	2012-13
SEC (kWh/ tonne)	4694	4542
SEC (toe/ tonne)	0.404	0.391

Source: Annual Report of Hindustan Zinc Ltd (2012-13)