cKinetics
Accelerating Sustainability

State of Sector:

GHG Emissions in Indian SMEs

Steel Re-Rolling

Ceramics

Forging

Foundry

This State of Sector Report has a two-fold aim:

- Take stock of the current level of GHG emissions in the small and medium enterprises (SME) sector to inform policy-making and for framing pathways for a low carbon future
- Inform and spread awareness about the best practices and energy efficiency measures in the SME sector

Produced by

cKinetics is a mission driven Sustainability Insight, Innovation & Capital Advisory Firm. It leverages thought processes for accelerating sustainable business and investing practices that include: (a) Closed loop systems, (b) Decentralized production and consumption, and (c) Resource conservation.

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Outreach by

Sustainability Outlook creates online and offline interactions to drive conversations around the topic of resource management in the business operations of the firms and their extended value chains. With a focus on emerging markets, Sustainability Outlook brings together business, policy, consumer advocates and other stakeholders.

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Index of Abbreviations

- ✓ **INDC**- Intended Nationally Determined Contribution
- ✓ **SEC**- Specific Energy Consumption
- ✓ **MMtCO2**- Million Metric tons CO2
- ✓ **MSME**- Micro, Small and Medium Enterprises
- ✓ **BEE**- Bureau of Energy Efficiency
- ✓ **NMCC**- National Manufacturing Competitiveness Council
- ✓ **BAU**- Business as usual
- ✓ **UNFCCC**- United Nations Framework Convention on Climate Change
- ✓ **NMCC**- National Manufacturing Competitiveness Council
- ✓ **GHG**- Greenhouse gas
- ✓ **ZED**- Zero effect Zero defect
- ✓ **TMT**- Thermo- mechanically treated
- ✓ **MJ**- Mega Joule
- ✓ **SG**- Spheroidal Graphite
- ✓ **SRRM**- Steel re-rolling mill
- ✓ **PNG**- Piped Natural Gas
- ✓ **UNDP**- United Nations Development Program

Source: Pixabay

Executive Summary

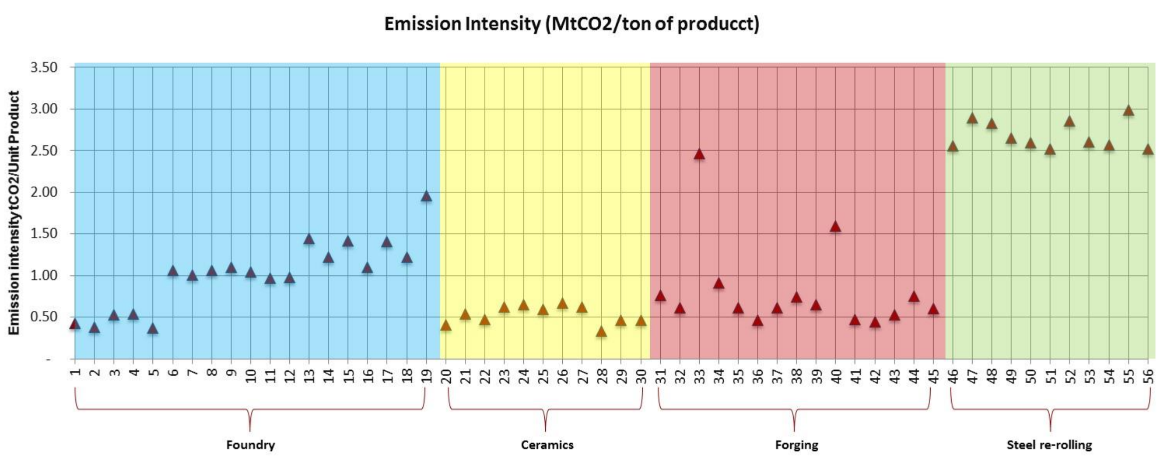
In India, the Small and Medium enterprise sector is of high importance for attainment of the emission reduction targets set as a part of the INDC's. Therefore, taking stock of the current level of GHG emissions is a pre-cursor to informed policy-making and for framing pathways for a low carbon future. In that direction, this study attempts to carry out a bottom-up modelling exercise aimed at studying the prevalence of best practices and energy efficiency measures in a few shortlisted sectors. The choice of sectors was determined by multiple factors which included current market size, energy costs in overall cost model, distribution of units and clusters etc. The four sectors chosen for the analysis were: **Ceramics, Foundry, Forging & Steel re-rolling.**

The choice of clusters for undertaking the study was made on the basis of production volume, type of products and level of engagement with the industry associations.

The chosen clusters were: Morbi and Khurja for Ceramics, Ludhiana and Rajkot for Forging and Foundry and Mandi Gobindgarh for Steel re-rolling.

Data gathering was done through secondary research as well as extensive engagements with industry associations as well as factory owners. **cKinetics' in-house tools** were used for analyzing the data and generating actionable outcomes.

Below graphic gives a bird's eye view of emission intensity across various sectors as also variations within a sector.



Some of the observations (in some cases reasons) from the above graph are:

1. Steel re-rolling sector has the highest emission intensity per unit product
2. The emission intensity for ceramics is relatively less compared to other sectors (even though the overall quantum of emission from the ceramics is significant)
3. Foundry and forging has relatively high variability in emission intensity due to the different furnace technologies and additional processes like machining, heat treatment etc.

The key insights that have emerged through the analysis for different sectors are provided below:

CERAMICS

- In spite of the obvious energy savings and consequent cost savings for factories associated with switching from coal to natural gas, the penetration of gas based systems has been limited due to the availability of PNG, relatively higher prices and volatility as compared to coal
- The type of tiles produced and production volume have a major bearing on the specific energy consumption. Vitrified tiles in general, fare better in terms of SEC.
- Broadly, there is a definite negative correlation between the level of implementation of Best Management practices and Specific energy consumption.
- In the business as usual scenario, if the units continue performing the way they are currently performing, the total emissions will reach 33.4 MMtCO_2 per annum by 2020.
- The key levers identified to enable a transition to a low carbon future are energy efficient manufacturing (with a reduction potential of 2.5 MMtCO2 per annum) and shift to natural gas (with a reduction potential of 4.68 MMtCO2per annum).

FOUNDRY

- Out of the two main technologies for melting of metal namely Cupola and Induction furnace, Cupola fares better in terms of both emissions and cost per Kg of production which explains the high penetration of cupolas in the clusters visited. However, Cupolas are limiting in terms of the diversity of products that can be manufactured vis-à-vis induction furnaces. Therefore there is a clear trade-off that a factory owner has to make between energy efficiency and expansion of sales.
- Factories that reported a higher yield were also found to have lower specific energy consumption. Therefore, productivity related interventions also have a significant role in reducing the GHG footprint indirectly.
- The surveyed units were broadly observed to have relatively lower adoption of the best management practices as compared to some of the other sectors studied. Barring a few units, there was a definite negative correlation between the level of adoption of best management practices and the reported specific energy consumption
- In the business as usual scenario, if the units continue performing the way they are currently performing, the total emissions will reach 11.8 MMtCO2e per annum by 2020.
- The key levers identified to enable a transition to a low carbon future are energy efficient manufacturing (with a reduction potential of 1.8 MMtCO2e per annum) and yield enhancement (with a reduction potential of 0.8 MMtCO2e per annum).

FORGING

- In forging, the choice of heating technology has a major bearing on the energy consumption. While oil furnaces are in-efficient in terms of energy as well as productivity (oil fired furnaces follow batch firing unlike induction furnaces that follow continuous firing), the cost of fuel is lower for oil furnaces as compared to induction furnaces. The scope for debottlenecking of operations is high but often overlooked by forging units and can be a low hanging fruit to increase profits with minimal investments.
- Forging units are also faced with the choice of deciding whether the heat treatment for the manufactured components is done in-house or outsourced to a 3rd party based on investment considerations, space constraints and share of the heat treated products out of the total sales. Addition of a heat treatment section to a factory adds to the specific energy consumption due to additional energy requirements as well as added system inefficiencies.
- The level of adoption of best management practices is at a moderate level. While the operational best practices are observed to have a high level of penetration, the technology- related best practices which are capex intensive have lower adoption.
- In the business as usual scenario, if the units continue performing the way they are currently performing, the total emissions will reach 1.82 MMtCO_2 per annum by 2020.

- The key levers identified to enable a transition to a low carbon future are energy efficient manufacturing (with a reduction potential of 0.19 $MMtCO_2$ per annum) and fuel switch to natural gas (with a reduction potential of 0.14 $MMtCO_2$ per annum).

STEEL RE-ROLLING

- In the steel re-rolling sector, the furnace performance of most of the units is far below the national benchmark, which has been the result of poor maintenance practices coupled with unwillingness to invest in measurement and monitoring systems.
- The issue of poor maintenance practices has arisen because management apathy towards technical matters has led to the entire operations being handled by non-technical staff, i.e foremen and firemen, who rely on their experience to manage issues. These persons are mostly uneducated and consequently highly resistant to any new technology being introduced.
- The poor throughput at the reheating furnace creates a bottleneck in the operations and leads to high values of specific electricity consumption apart from the expected high specific thermal energy consumption.
- In the business as usual scenario, if the units continue to perform the way they are currently performing, the total emissions will reach 82.87 $MMtCO_2$ per annum.
- The appetite for making investments is very minimal. The key levers identified to enable the transition to a low carbon future are minor changes in operational practices to increase yield (which would entail greater monitoring of operational performance and control of fuel quality) and better inventory management practices (both of which are included in the best management practices). These can lead to significant cost savings which can then create cash flows desirable for enabling further investments. It is estimated that adoption of energy efficient manufacturing practices can reduce the emissions by 3.18 $MMtCO_2$ per annum to lower the emission to 79.69 $MMtCO_2$ per annum. Yield improvement projects, which would involve reduction of process losses are estimated to have the potential to reduce the emissions by 4.36 MMtCO2 per annum as compared to the business-as-usual scenario (absolute emission by 2020 being estimated to be 78.51 $MMtCO_2$ per annum).

Source: Pixabay

Source: Pixabay

Introduction

Context

India, in its INDC submitted to UNFCCC, has committed to reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level. Aside from increasing the renewable capacity in its energy mix (175 GW by 2022), energy efficiency constitutes a major component of India's mitigation strategy to achieve its targets. India launched its flagship program for energy efficiency, the National Mission for Enhanced Energy Efficiency, under its National Action Plan on Climate Change, to create a framework for fostering innovative and sustainable business models to scale up energy efficiency.

The MSME sector forms the backbone of India's industrial sector. It contributes to about 8%[1] of India's GDP and over 45% of overall Industrial output. The total greenhouse gas emissions from manufacturing industries are 300.62 million MMtCO_2 per annum[2], out of which the MSME sector is broadly projected to contribute to around 135 MMtCO_2 per annum.[3]

Around 60 million people are employed in the SME manufacturing sector thus any body of work feeding into building resilience for SMEs positively impacts a large number of people directly and indirectly.

As enhancement of resource efficiency and productivity within MSME segment will be key to India meeting its INDC's goals, several initiatives have been launched – key ones being: Zero Effect Zero Defect (ZED) as also Make in India campaign that covers over one million Small and Medium enterprises over the next 3-5 years[4] for rating them on quality, energy efficiency, enhanced resource efficiency, pollution control etc. among various other parameters.
Given the Indian government's intent to benchmark the SME sector on different operational level indicators, it is essential that a bottom-up approach be taken for estimating the GHG emissions from different SME clusters across the country. This will not only help establish the true state of emissions for the industrial sector but also help facilitate appropriate implementation of India's overall climate change plan.

Scope of this study

The purpose of this study is mainly to understand the energy and GHG performance of key SME sectors, specifically:

(a) measure the current status of GHG emissions from these sectors
(b) study the prevalence of best practices and energy efficiency measures
(c) identify potential pathways for a low carbon growth for these sectors

In order to frame a focused study, the initial scope has been limited to 4 energy intensive SME industries in India- ceramics, foundry, forging and steel re-rolling. These industries together contribute to over 99.08 million MtCO2e emissions per annum[5].Specific details of the industrial clusters covered during the study are provided in Section 4.

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[1] http://dcmsme.gov.in/msme_pdf/MSME%20February-2016/index.html#p=24
[2] Data for the year 2010. http://www.moef.gov.in/sites/default/files/indbur1.pdf
[3] Assuming 45% emissions are taking place from the MSME sector (pro-rata with Industrial output)
[4] ficci.in/events/22333/ISP/R-P-Singh.ppt
[5] cKinetics estimates for the year 2015-16

The study provides an overall view of these sectors from energy/carbon lens and is relevant for central and state policymakers; government agencies like BEE, NMCC as also several multilaterals and catalyst agencies working in the SME space.

Audience for the report

This report is targeted towards industry analysts, catalysts and policy makers for identifying potential intervention methodologies to develop frameworks and identify and scale up appropriate energy efficiency measures and policies. It also presents latest trends on energy consumption patterns, current adoption of best practices and potential pathways for low carbon growth.

Methodology

In order to carry out a focused study, 4 industrial sectors were shortlisted based on specific criteria, namely, a) Overall market size of the sector; b) Energy as a percentage of product manufacturing cost; c) Geographic dispersion (i.e. distribution of units and clusters); d) Extensive ongoing engagement by other agencies[6]; e) Emissions intensity. The key data for the selected clusters is presented in the table below.

Parameters	Ceramic	Foundry	Forging	Steel Re-rolling
No. of SME units in the country	1000[7]	5000[8]	3810[9]	1526
No. of clusters	2	21[10]	11[11]	12
% energy cost in overall production cost	25-30%[12]	20-25%[13]	10-12%	25-30%
Total market size of the industry	INR 282.5 Billion	INR 1000 Billion	INR 280 Billion[14]	INR 873 Billion

Table 1 Parameters for selecting focus sectors

Pursuant to identification of 4 energy intensive SME oriented sectors, a representative set of cluster/s and factories for the initial pilot were identified. This was done through a combination of primary and secondary research – the assessment led to identification of different kinds of products (and value chains), raw materials, technologies and processes.

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[6] Applied Inversely
[7] 479 units in Morbi and 494 units in Khurja as per http://www.cgcri.res.in/page.php?id=81
[8] http://www.foundryinfoindia.org/Energy_Conservation_Opportunities%20%E2%80%93%20Foundry_Industry.asx
[9] https://www.sidbi.in/files/Cluster%20Profile%20Report%20-%20Pune%20%28Forging%29%20Cluster.pdf
[10] http://www.foundryinfo-india.org/profile_of_indian.aspx
[11] http://www.indianforging.org/indian-forging-industry/
[12] Manual on energy conservation measures in ceramic cluster, Morbi
[13] http://www.indiasavesenergy.in/Uploads/Documents/635955347178241524.pdf
[14] http://auto.economictimes.indiatimes.com/news/auto-components/forging-production-in-india-to-grow-9-5-by-2018/55745779

Building off this categorization, a few clusters, representative of the industry at large, were shortlisted. Key criteria being:

a) cluster size being large in size in terms of production/turnover
b) cluster having a cross-section of factories with variety of product ranges thus enabling a mapping of a comprehensive product range

For example, in case of Foundries sector, Rajkot foundries cluster has amongst the highest number of foundries (over 1000 foundries) with an aggregate annual turnover of over INR 4.5 bn[15] (against overall sectoral turnover of approx. INR 1 trillion). In addition, the cluster has a good mix of both cupola foundries and induction melting foundries. Similarly, in case of ceramics, Morbi cluster represents over 90% of India's overall ceramics production[16], and it has both tile manufacturing units as well as sanitary-ware manufacturing units; and thus has been chosen.

Subsequent to the cluster identification, extensive industrial visits were undertaken by project team(s) to engage with local association as also factories and other influencers and stakeholders. See list of associations and institutions engaged in Annexure 2.

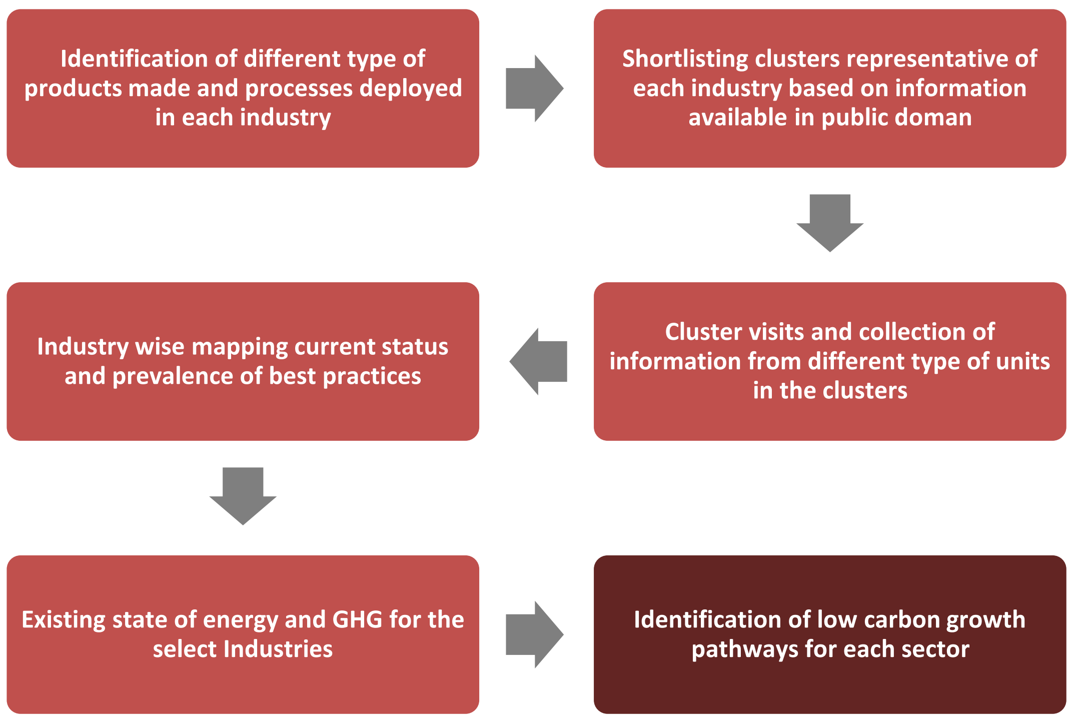

Figure 1 Methodology Adopted

Visits to the factories were undertaken to collate data on their specific energy and production patterns, high level mapping of their practices to identify best management practices across the units and also to conduct comprehensive discussions with top management to understand their priorities and offer thoughts on role of energy efficiency in their planning.

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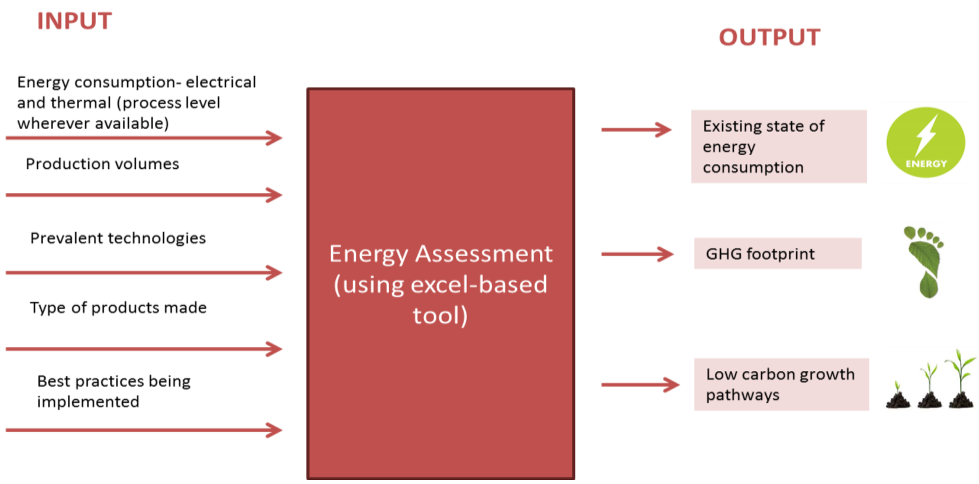
[15] Primary research carried out by cKinetics
[16] http://www.vibrantceramics.com/uploads/downloads/Report-Ceramic-and-Sanitaryware-Focus-Morbi-2016.pdf

The following infographic represents the parameters around which data was gathered and the output of the analysis carried out



Existing state of energy consumption and GHG footprint were established for the select Industries and low carbon growth pathways were also identified for each industry factoring in different scenarios /circumstances specific to each industry.

Understanding the geographic reach and scale

It is crucial to understand the geographic footprint of the selected industrial sectors to identify key focus geographies as also the characteristics of each cluster. An overview is presented in the table below.

Industry	Clusters	Number of units	Production (tpa)	Turnover (billion INR)	Avg turnover per unit (Million INR/year)
Foundry	Belgaum[17]	160	360,000	20	125.0
	Coimbatore[18]	535	600,000	34	63.6
	Kolhapur[19]	300	600,000	51.8	103.3
	Ludhiana	200	180,000	9	45.0
	Rajkot	1000	600,000	45	45.0
Ceramics	Morbi	635	1600 million square metre-tiles	280	440.9
	Khurja	200	NA	2.5	12.5
Forging	Pune	50	500,000	6	120.0
	Ludhiana[20]	300	1551428[21]	96	322
	Rajkot	200	NA	7.5	37.5
Steel Re-rolling	Mandi Gobindgarh	275	1,050,000	31.5	80
	Raipur	180	1,200,000	36	155
	Bhavnagar	120	1,500,000	45	261

Table 2 Major clusters[22] and total production

As is clear, foundry sector comprises of multiple SME clusters spread across the country. It can be observed that average turnover per unit is higher in Kolhapur indicating larger factory sizes whereas average price per unit production is highest in Rajkot indicating higher value products being made. Most of these clusters have developed in a way that each of the clusters specializes in a particular type of product which represents the majority of the production in the cluster. e.g. Coimbatore cluster is the hub of castings production for the pump-set industry; Ludhiana and Batala predominantly make machinery parts/agricultural implements etc.

In case of ceramics, 90% of the production in India takes place in one cluster i.e. Morbi. With a turnover of over INR 28,000 crore and production accounting for 12.9% of the overall ceramics production in the world, it is one of the fastest growing clusters in the country. Key focus products for morbi are tiles and sanitary ware. On the other hand, Khurja is a fairly small cluster that specializes in, Insulators, handicraft ceramics products and pottery.

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[17] http://sameeeksha.org/pdf/clusterprofile/Belgaum_Foundries_Karnataka.pdf
[18] http://sameeeksha.org/pdf/clusterprofile/coimbatore-foundry-cluster.pdf
[19] https://www.sidbi.in/files/Cluster%20Profile%20Report%20-%20Kolhapur%20%28Foundry%29%20Cluster.pdf
[20] http://www.inspirenetwork.org/act_proj_ene_forging_cluster.htm
[21] Indicative estimates
[22] Criteria was set to represent atleast one-third of the sector through identified clusters

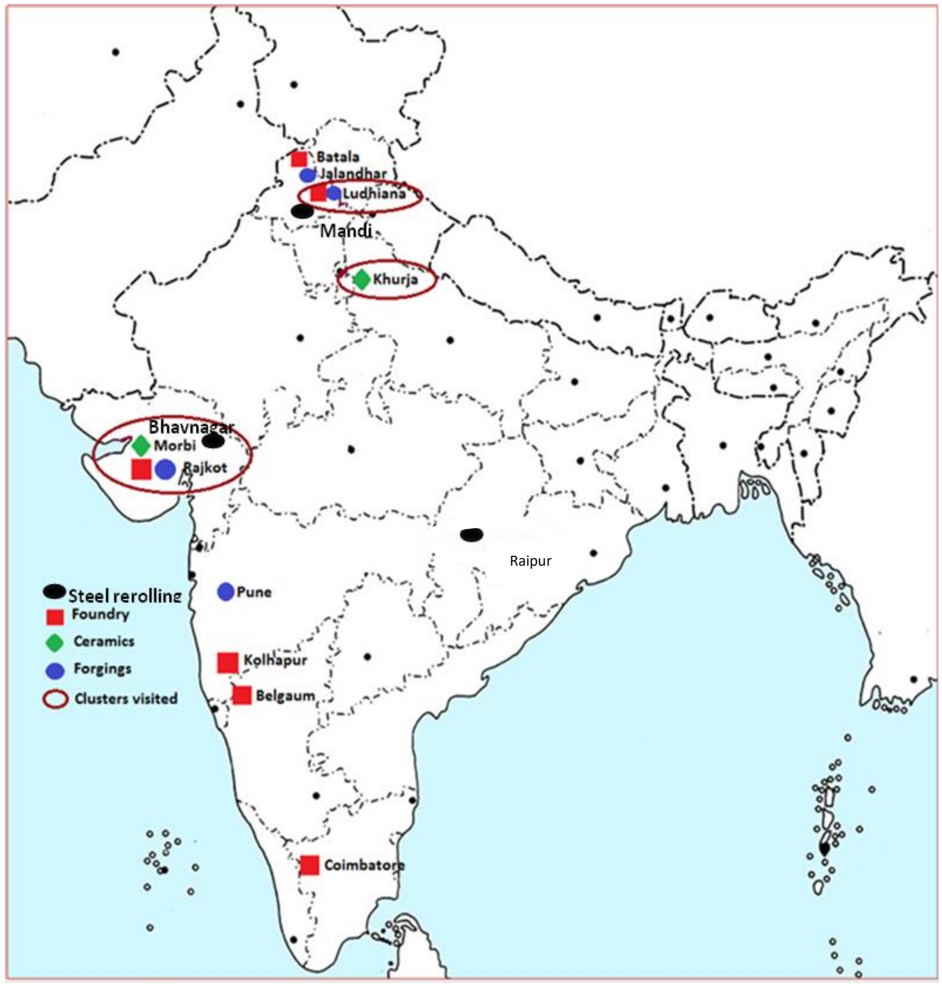

Figure 2 Major MSME clusters of the selected industries (also highlights clusters visited)

Among the steel re-rolling clusters, Mandi Gobindgarh, Raipur and Bhavnagar form the largest clusters in terms of number of units as well as production capacity. Raipur and Bhavnagar, owing to their locational advantage have a competitive advantage over Mandi Gobindgarh, which is far away both, from the raw materials as well as markets. However, irrespective of the geography, the sectoral rate of growth has been dismal since the past 5 years at <5%. The major products manufactured in all of these clusters are TMT bars which have a market both within and outside the country.

Source: Wikimedia


CERAMICS
Source: Pixabay

Ceramics: Current state and way forward

Industry overview

The ceramic industry comprises of ceramic tiles, sanitary ware and tableware. In India, the ceramic industry falls in both the organized and un-organized sector. The unorganized sector has 53% share in the total energy consumption of the ceramic industry.

The key characteristics of the different sub-categories of ceramic industry are as follows:

- **Tiles:** Indian tiles industry production is at 1600 Million sq.m per annum as of 2016. The share of un-organized sector in the production of tiles is 65%. It is highly export oriented and employment generating.
- **Sanitary-ware:** In the unorganized sector, around 250 companies produce basic sanitary-ware under various brand names which are majorly concentrated in Gujarat. This concentration has been due to low raw material costs and low overheads.
- **Tableware:** 50% of the tableware market is in the unorganized sector but the rate of market growth has been slow. However, the size of the tableware market is relatively much smaller than that of tiles and sanitary-ware.

Indian ceramics industry is the second highest in the world followed by China. In 2015-16, the industry saw a growth of 20% with an investment of Rs. 5000 crore[23]. As shown in Figure 2, Morbi and Khurja are the two key clusters for ceramic production in India. Out of the two, Morbi cluster accounts for 90% of the total ceramics production of the country. It employs over 1.3 million people, out of which 350,000 people are directly employed and others are indirectly employed in auxiliary area. It consists of a total of 635 units (370 wall tiles units, 125 vitrified tiles units, 60 floor tiles units and 80 sanitary ware units). Therefore, it has been chosen as the cluster of focus for the ceramic industry in this study. Additionally, more than 85% factories in Morbi region are tile manufacturing factories as also energy footprint of tiles is much higher compared to sanitary-ware due to complexity of manufacturing process. Hence, our ground team focused more on tile manufacturing factories.

Morbi- Cluster at a glance

- **Products manufactured:** Wall tiles, Floor tiles, Vitrified tiles, Polished glazed vitrified tiles, twin charged tiles, multi-colored charged tiles in various formats starting from 20X30 cm to 120 X180 cm; sanitarywares, industrial ceramics and technical ceramics
- **No of units** 700 tiles manufacturing units (wall tiles 370+, vitrified tiles 125, floor tiles 60 and sanitary ware 80) manufacturing units in the cluster
- **Production:** 1600 Million square meters
- **Cluster turnover**: INR 26,000 crore
- **Industrial growth**: 30% in 2015-16
- **Other key observations**
  - Tile manufacturing process is mostly automated, with the entire process running on conveyer belts with minimum human intervention required. Sanitary ware on the other hand is a more labour intensive process.
  - Due to fluctuating price of natural gas, a lot of factories have coal gasifiers in-house to produce coal gas and use that as fuel for kiln.

eProcess flow chart

An illustrative process flow chart for a ceramics tiles unit is shown below.

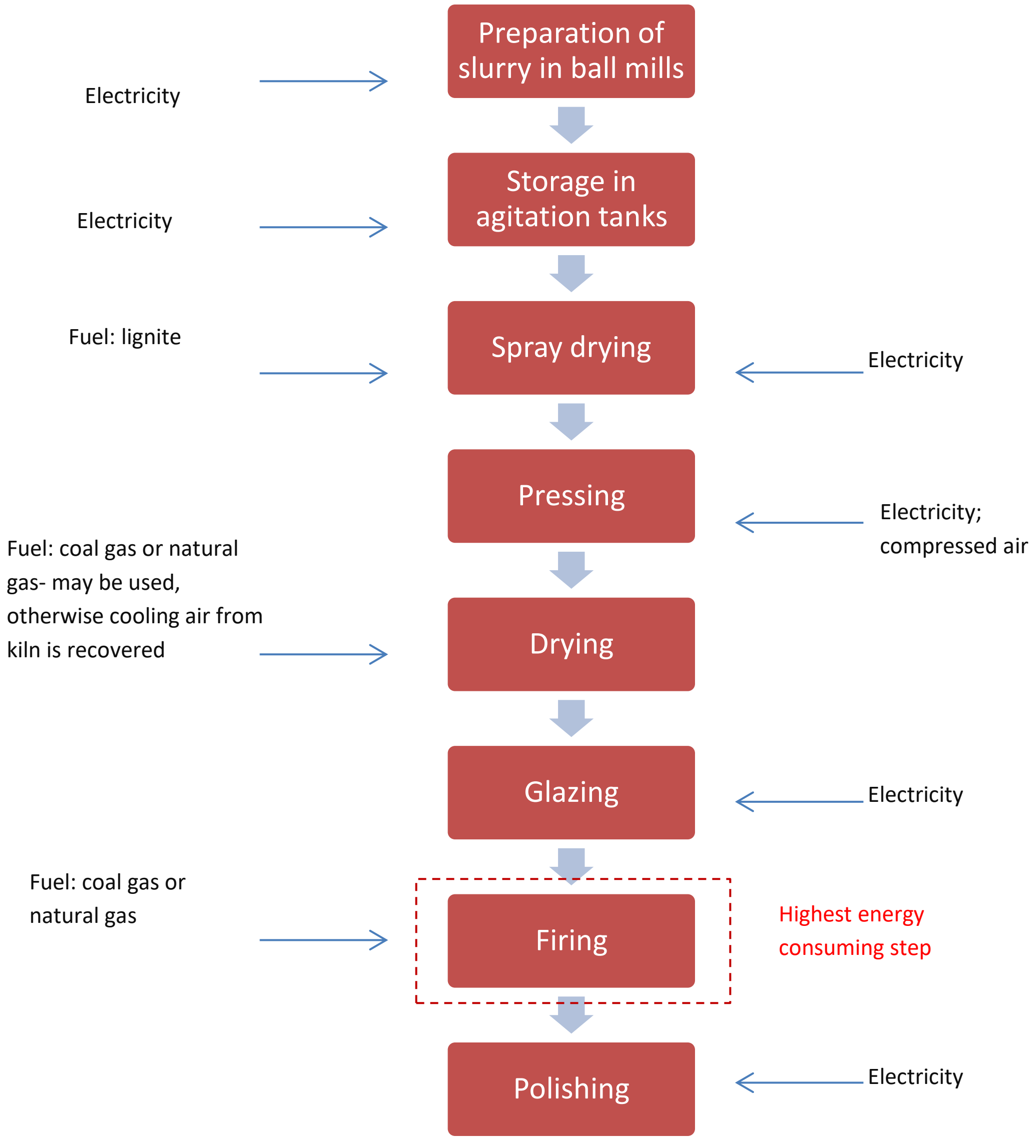

Figure 3 Process flow diagram for a ceramics tile unit

Energy and GHG footprint: current state

Nature of factories visited

Morbi cluster has 2 types of products - tiles manufacturing units and sanitary ware manufacturing units. These units can be further categorized into product sub-categories and technologies as indicated below.

Type of Unit	Coal gas fired furnace	Natural Gas fired furnace
Wall Tiles	✓	✓
Vitrified Tiles	✓	✓
Floor Tiles	✓	
Sanitary ware		

This categorization has been done keeping in mind the variation in energy consumption and GHG emissions in the sub-categories. During the visits, representatives units across these were covered

Overall energy consumption pattern

Wall and floor tiles (commonly known as ceramic tiles) are relatively thin plates made of ceramics. Wall and floor tiles are long-lasting, fire-resistant and relatively easy to clean, yet fragile when exposed to shocks. Vitrified tiles have a glassy texture and are known for their non-porous and stain resistant nature.

Both vitrified and floor tiles are single fired. In single-firing, both the slab and the glaze are fired simultaneously. Wall tiles are double-fired, that is, first biscuits are prepared by firing, followed by glazing and printing, after which the tiles are fired again in the kiln. This method of firing imparts the ability of the tile to be given sharp colours. However, electricity consumption in a vitrified tiles unit is higher than a wall tiles unit.

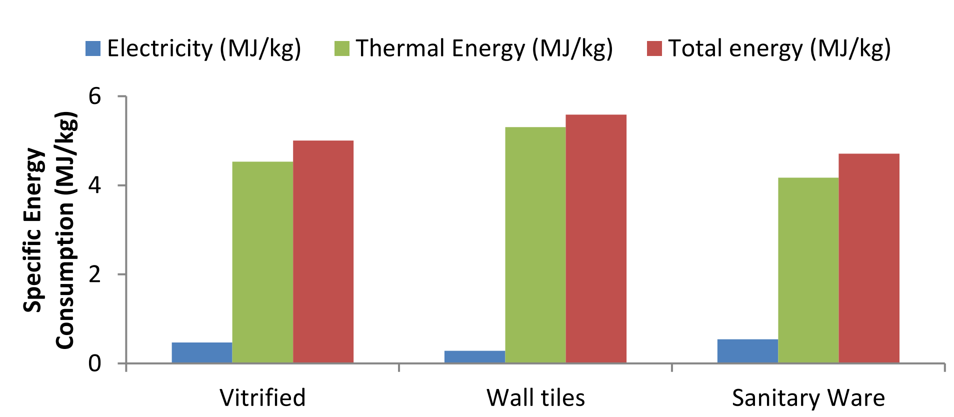

Figure 4 Energy consumption break up- vitrified tiles unit vs. wall tiles unit

As is clear from above, thermal energy accounts for lion's share in overall energy distribution and higher electricity consumption in a vitrified tiles unit doesn't significantly impact the overall energy consumption vis-à-vis other types of tiles.

Energy benchmarks

Based on our in-depth analysis, benchmarks have been classified based on the below mentioned parameters in order to compare units with similar requirements:

- Product type
- Type of fuel used

Product type	Type of fuel used	Specific Energy Consumption (MJ/kg)		
		Min	Average	Max
Wall tiles	Coal gas fired	5.65	6.09	6.51
	Natural Gas fired	4.36	5.06	5.76
Vitrified tiles	Coal gas fired	-	5.0	-
	Natural Gas fired	4.93	5.65	6.36
Floor tiles[24]	Coal gas fired	-	-	-
	Natural Gas fired	-	6.04	-
Sanitary ware	Coal gas fired	-	-	-
	Natural Gas fired	4.5	4.7	4.8

Table 3 Range of specific energy consumption assessed at the visited units

Tiles manufacturing primarily entails continuous production and therefore the productivity is higher, leading to lower specific energy consumption.

In-depth analysis and key observations

- CO2 emissions for coal fired wall tiles are greater than other type of units. Units that use coal for spray drying also have higher emissions.

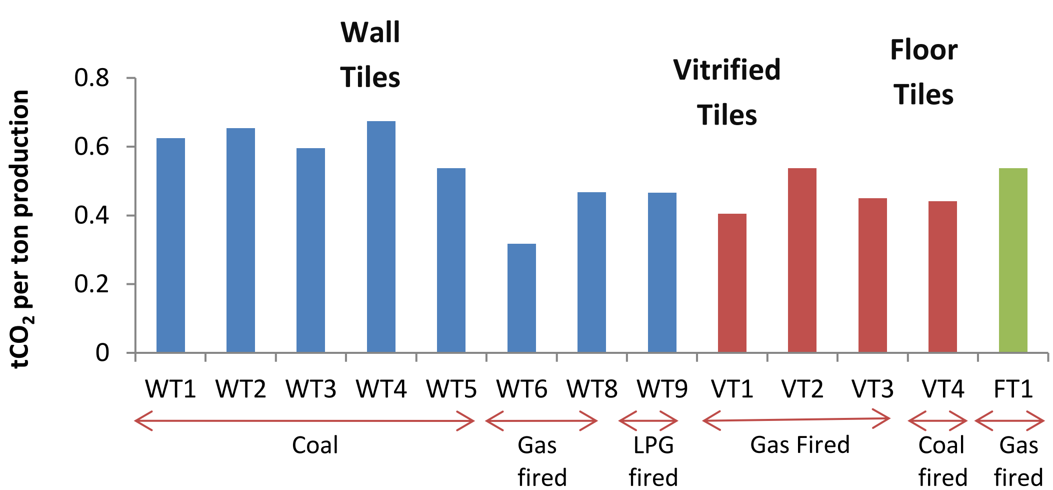

Figure 5 Metric tons CO2 per ton production for various ceramics units

[24] One unit was visited in the floor tiles category which was a natural gas fired unit.

- While the average firing cycle time is 55 mins for Vitrified tiles and wall tiles, cycle time for floor tiles is typically low: 38-40 mins, thus explaining the low SEC for FT1 Separately, fluctuation in natural gas and coal prices results in people shifting between the type of fuel used in furnaces, thus impacting:
    - GHG footprint of factory/cluster
    - Energy efficiency business case

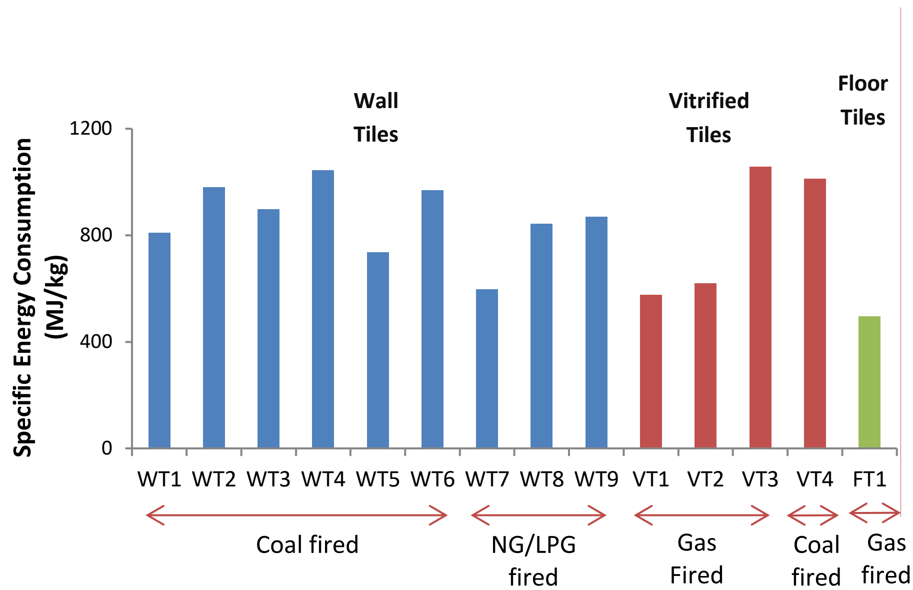

Figure 6 Specific Energy consumption pattern for various ceramics units

- Since wall tiles are double fired, the specific energy consumption in wall tiles is higher than vitrified tiles; electricity consumption of vitrified tiles is almost twice the electricity consumption of wall tiles. As the share of thermal energy consumption in the total energy consumption is significantly higher than that of electrical energy consumption, doubling of electricity consumption in vitrified tiles vis-à-vis wall tiles doesn't lead to a significant disadvantage in terms of specific energy consumption.

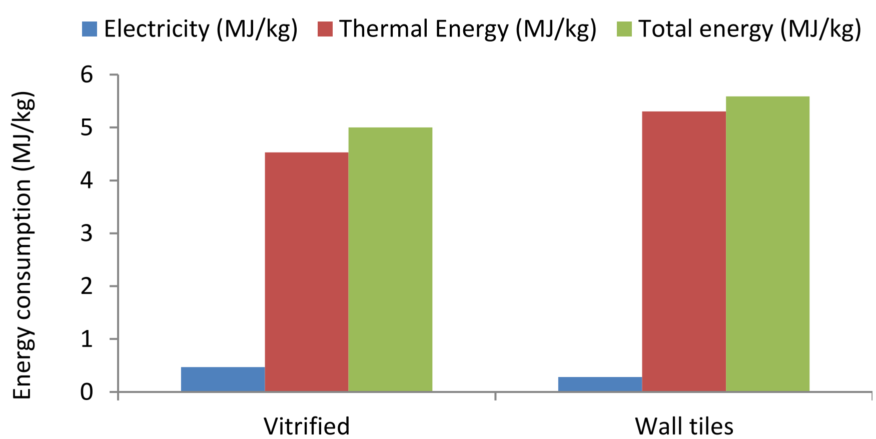

Figure 7 Electrical and thermal energy consumption for different type of ceramics units

- SEC decreases as production volume increases. This can be due to multiple reasons, as follows:
    - Higher width of kiln thus allowing more number of tiles to pass through in one batch
    - Lower cycle time for a batch (i.e., greater speed of belt) thus increasing productivity

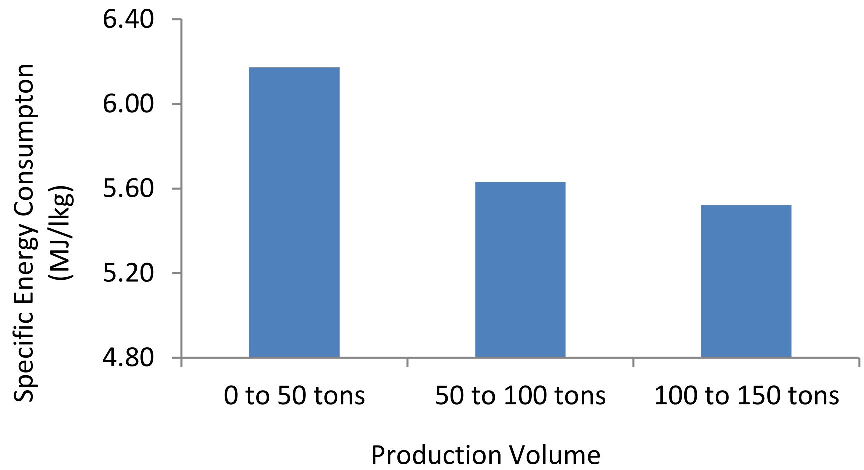

Figure 8 Specific Energy consumption vs. Production volume

Prevalence of best practices and way forward

Best Management Practices [25]	% Penetration[26]	Nature of project
Installation of Variable Frequency Drive (VFD) In Ball Mills, agitator tank motors etc.	100%	Tech
Regularly checking and maintaining proper kiln insulation	100%	Tech
Maintain power factor at 0.99	90%	Operational
Reuse cooling air from rapid cooling zone	89%	Tech
Preheating of combustion air by smoke air through recuperator	43%	Tech
Replacement of Existing Standard Efficiency Motors by Energy Efficient Motors	20%	Tech
Install automatic air-fuel ratio system in kiln	20%	Tech
Reducing speed of ball mills as cycle time progresses	0%	Operational
Implementation of ON - OFF Controller (10 minutes ON and 5 minutes OFF) for Agitation Motors	0%	Operational
Preheating of input slurry of spray dryer through solar energy up to 60 DegC	0%	Tech

Table 4 Prevalence of best practices

Low carbon growth path

Ceramics industry has been the fastest growing industries as compared to the other two industries in the last 4 years. I In case of Business as usual (BAU) scenario, Ceramics SME sector will be emitting 33.40 MtCO2/Annum by the year 2020 considering current energy consumption patterns and Industrial rate of growth. There are two identified independent approaches to avoid BAU scenario.

a. Energy efficient manufacturing practices

A second scenario has been considered, whereby if the units shift to energy efficient manufacturing, the emissions would be at 30.90 MMtCO$_2$ per annum by 2020. This would entail implementation of best practices by all factories to reach the current base case in India. These best practices would involve technology installations (which would entail investments with less than 3 years payback) as well as improvements in operational practices to achieve better process control. The adoption levels of different best practices for the ceramic sector show that there should be an equal level of focus on both these type of project/s. As industries tend to prioritize projects based on investment and payback, the logical first choice for them is the operational intervention. However, as illustrated in the analysis section, a few operational interventions have zero adoption, which necessitate demo projects to be implemented to build credibility.

Adoption of other known energy efficient manufacturing practices can significantly reduce the emission intensity of the sector. A total of 2.5 MtCO2/Annum emissions can be avoided by 2020 compared to BAU scenario.

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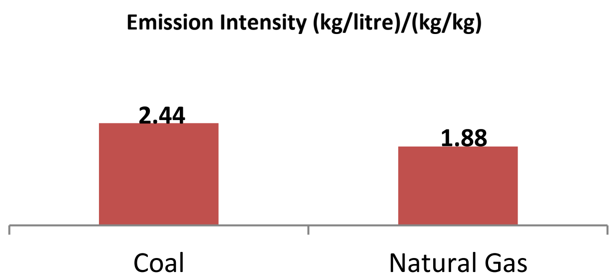
[25] cKinetics primary and secondary research (BEE Manual of energy conservation measures in Ceramics cluster Morbi)
[26] cKinetics' analysis

b. Shift to Natural Gas

In addition to above, if the units shift towards natural gas, by 2020, the emissions would be at 26.22 million MT per annum- that is, there exists a carbon footprint reduction potential of 21%. Currently 58 percent of the units are using coal as a major source of fuel. Coal is a cheaper but highly emission intensive source of fuel.



A total of 4.68 $MtCO_2$/Annum can be avoided by 2020 compared to BAU scenario by just shifting from coal to Natural gas.

Comparison of the two alternatives against Business as Usual Scenario

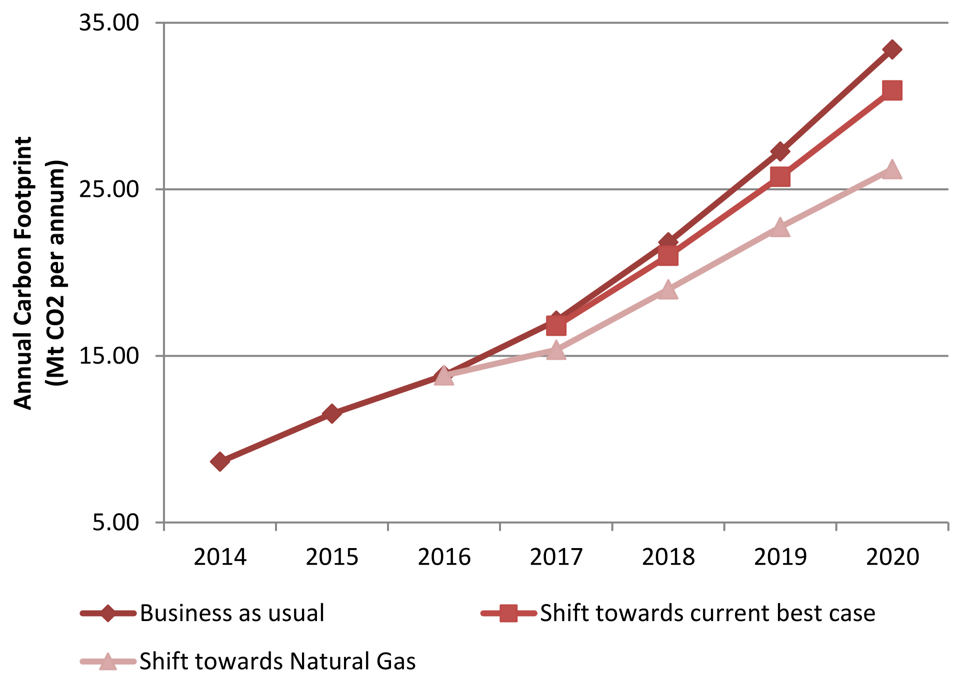


Figure 9 Low carbon growth paths for Ceramics Industry in India

Further, there may be scope for improving the yield as well which will have indirect impact through reduction of per unit CO_2 footprint. However, this has to be studied further as and when more information is gathered which may necessitate deep dive studies.

Source: Pixabay


FOUNDRY

Foundry: Current state and way forward

Industry overview

Indian foundry industry has a total production of over 10 million metric tons per annum, which is the third highest in the world after China (46.2 million metric tons) and USA (11.9 million metric tons).[27] The casting industry of India manufactures castings for a wide range of applications like auto, pumps, agriculture implements, machine tools, textiles, railways etc. The industry employs 2 million people, out of which 0.5 million are directly employed and 1.5 million people are indirectly employed.[28] The foundry industry in India is geographically clustered. There are several foundry clusters in India. Some of the major clusters include Howrah, Coimbatore, Rajkot, Kolhapur, Ahmedabad, Batala, Jalandhar, Ludhiana, Belgaum, Shimoga, Agra, Hyderabad, Bangalore, and Vijayawada.

Primarily, two types of melting technologies are used in foundries: induction heating and cupola furnace. Cupolas are only applicable for producing grey iron castings. Induction furnace, on the other hand, can be used for producing castings of grey iron, SG Iron, steel etc.

Rajkot- Cluster at a glance

- **No. of foundries** ~1200 (700 induction furnace based and 500 are cupola based foundries)
- **Turnover** ~5000 crore
- **Power availability situation**: Reliable
- **Commonly used fuel in Cupola based units:** Low ash coke
- **Primary products manufactured:** Diesel engines (42% production share), Automotive components/Textile components (15%) and machine tools (11%)
- **Key customer industries and their location:** Local diesel engine industry in Gujarat (90% share) and Electrical motor companies catered to by export oriented foundry units (10%)

Other key observations

- A local cupola design called "Rajkot Cupola" is popular in the cluster.
- Although there is a good prevalence of induction furnaces, not all units are separately monitoring the energy performance of their induction furnaces
- Best practices like keeping the crucible lids closed while melting operation, adoption of energy efficient motors etc. are not widely prevalent in the cluster

Ludhiana- Cluster at a glance

No of foundries: 200 (Majority of the units are cupola based)
Turnover: INR 9 Billion
Power availability situation: Reliable
Commonly used fuel in Cupola based units: Low ash coal from Dhanbad and Gujarat
Primary products manufactured: Agricultural implements, Machine tools
Key customer industries and their location: 85% are local industries and 15% are catered by export oriented industries
Other key observations

- The Ludhiana cluster produces mainly SG Iron castings and Cast Iron castings
- The raw material i.e pig iron is procured from Odisha at ¬INR 26000/tonne
- National Institute of Design Ahmedabad has worked in Ludhiana at cluster level.

[27] As per the 49th Census of the World Casting Production
[28] http://www.foundryinfo-india.org/profile_of_indian.aspx

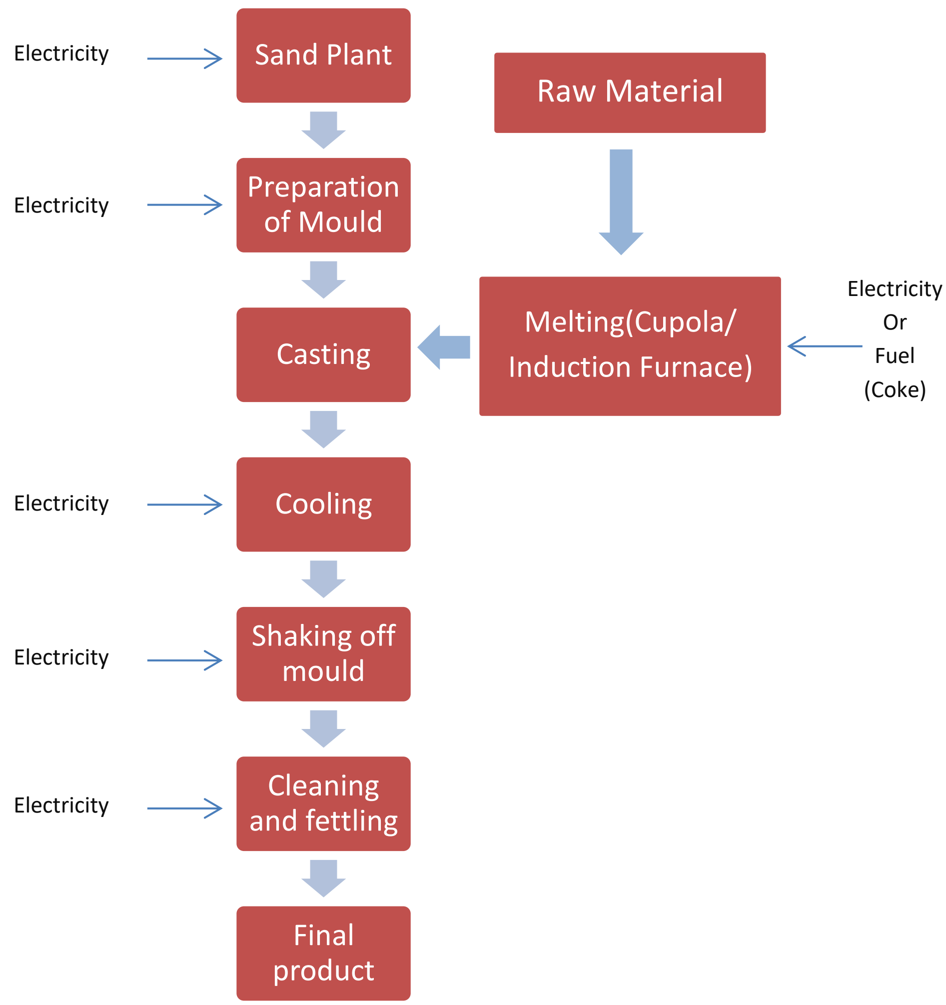


Figure 10 Illustrative process flow chart for a sand casting unit

Any foundry operation involves two main processes- mould preparation of melting of metal. Raw material (scrap) is prepared and fed into the induction furnace or cupola for melting. Simultaneously, moulds are prepared in the required shape and size so that once the molten metal is prepared, it can be immediately poured into the mould. The melting step is the highest energy consuming process, accounting for over 75% of the total energy consumed in a foundry.

Energy and GHG footprint: current state

Nature of factories visited

Most of the foundry units visited are situated in Rajkot. Figure below describes the nature of units in Rajkot and the units that have been covered in the study.

Type of Casting	Induction Furnace	Cupola
Grey Iron	✓	✓
SG Iron	✓	NA
Steel	✓	NA

Figure 11 Type of factories visited in foundry sector

Energy Benchmarks

The melting temperatures of different types of castings are different; steel requires a temperature range of 1450°C-1600°C; grey cast iron requires a temperature range of 1200°C-1300°C; therefore the energy consumption would vary based on the type of casting produced as well. For the purpose of comparing different units, benchmarks have been classified based on the following parameters:

- Type of casting produced
- Melting technology

Type of casting produced	Melting technology	Specific Energy consumption (MJ/kg)		
		Min	Average	Max
Cast Iron	Induction furnace	3.57	3.78	4.05
	Cupola	3.05	3.79	4.86
SG Iron	Induction furnace	4.50	4.91	5.32
Steel	Induction furnace	4.05	4.74	5.22
Cast Iron and SG Iron (hybrid units)	Induction furnace	-	3.66	-

Table 5 **Energy consumption pattern for different type of foundry units**

NOTE: Development of benchmarks for hybrid units in progress at the time of writing this report

In-depth analysis and observations

In-depth analysis of the data collected from different type of foundry units has been carried out to study trends in specific energy consumption and GHG emissions. Certain takeaways for the same have been highlighted in this section.

- Emissions from cupola are fairly lower than Induction furnaces although Cupola is coke based as compared to electricity based Induction furnace. Most of the recommendations suggest factories to shift from cupola to induction furnace

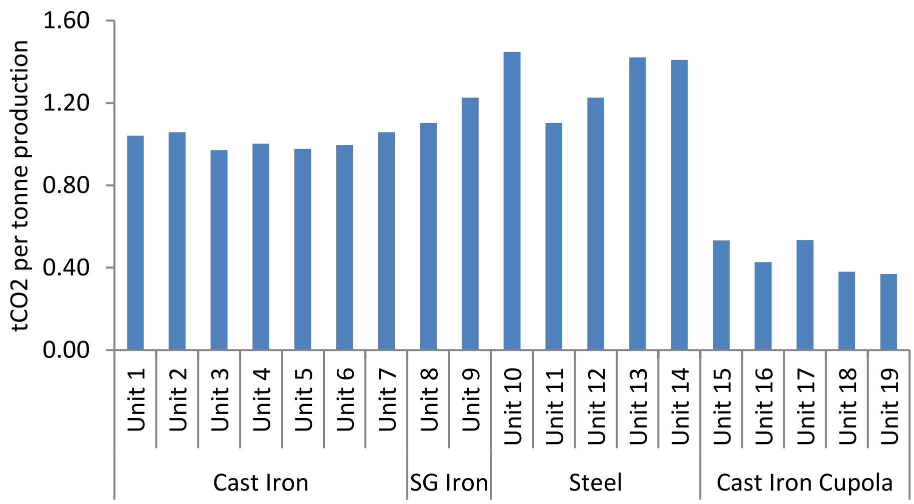


Figure 12 tCO_2 emissions per ton production for foundry units

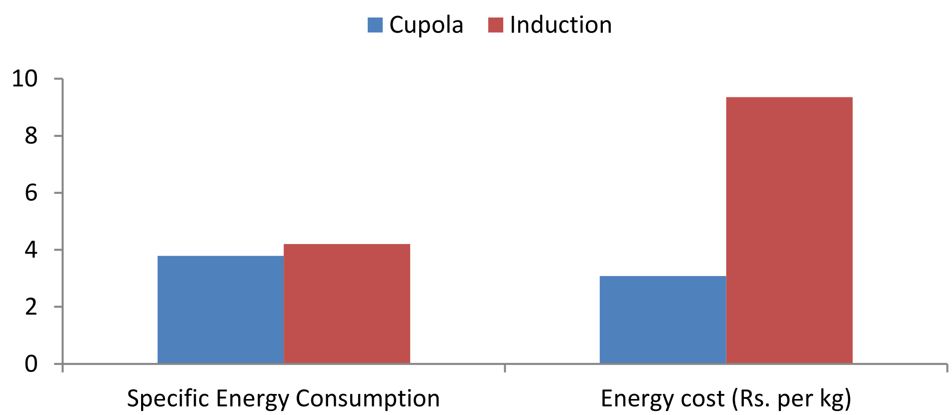


Figure 13 Specific energy consumption vs. energy cost for different types of melting practices

- SEC remains same irrespective of the technology used for melting. However, the cost of energy per kg production for cupola is much lower than Induction furnace
- SEC reduces as yield increases, thus there may be a case for productivity related interventions

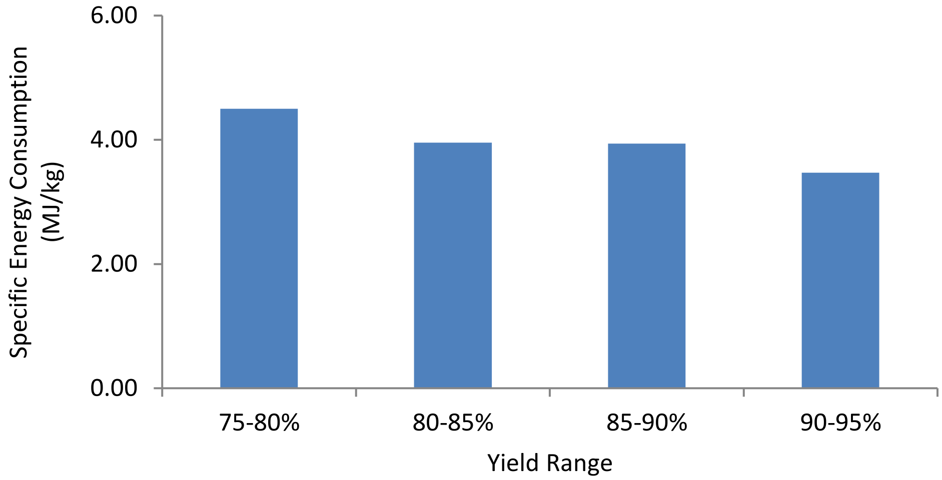


Figure 14 Specific energy consumption variation vis-à-vis yield range

- Revenue for SG Iron casting is greater by Rs. 1.5/MJ vis-à-vis Cast Iron
- The yield improvement measures that can be taken are:
    - Mould preparation and casting process synchronization
    - Riser and Runner optimization of metal loss
    - Optimizing holding time of molten metal

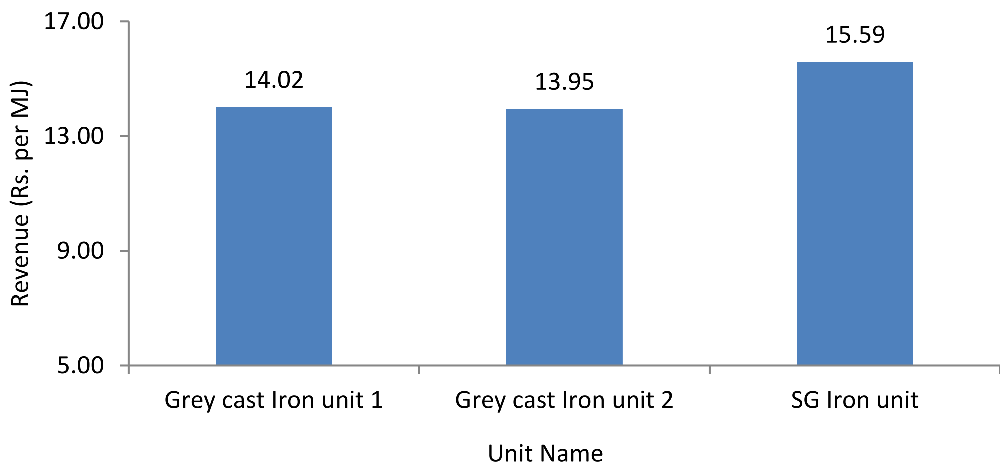


Figure 15 Typical revenue for grey iron and SG iron units (Rs./MJ)

Prevalence of best practices

Best Management practices	Penetration	Nature of project	Applicability
Installation of automatic air flow controller/flue gas monitoring to check excess air	16.7%	Tech	Cupola
VFD drive for blower motor to check excess air	16.7%	Tech	Cupola
Install lid cover on crucible for reducing energy loss	25%	Tech and Operational	Induction
Install energy efficient motors (IE3/IE4) in the unit	31%	Tech	Both
Replace conventional cupola with Divided blast cupola	50%	Tech	Cupola
Install separate electricity meter for Induction furnace	58.3%	Operational	Induction
Install LEDs/magnetic lamps in place of conventional lights	60%	Tech	Both
Install APFC panel	61.5%	Tech	Induction
Maintaining a record of operating temperature and time taken for one melt for Induction furnace	69%	Operational	Both
Maintain power factor at 0.99	66.7%	Operational	Induction
Regularly checking and maintaining insulation of furnace	91.2%	Tech	Both

Table 6 Best practices prevalence in foundry industry

Low carbon growth path

Foundry industry is the backbone of many manufacturing sectors and plays an anchor role in infrastructure development and Make in India campaign. In case of Business as usual (BAU) scenario[29], Foundry SME sector will be emitting 11.67 $MtCO_2$/Annum by the year 2020 considering existing energy consumption patterns and Industrial rate of growth. There are two identified independent approaches to avoid BAU scenario.

a. Energy efficient manufacturing practices

A second scenario has been considered, whereby if the units shift to energy efficient manufacturing within their particular class. The emissions would be approximately 10 million $MtCO_2e$ per annum by 2020. This would entail implementation of best practices by all factories in India. As can be seen in the analysis section, presently the factories are lagging behind in terms of both technology implementations as well as following operational practices. While capital intensive technology installations can be enabled using instruments such as low cost finance, improvements in operational practices would entail capacity building of management as well as the skilled and unskilled staff through training programs to sensitize them on topics of significance.

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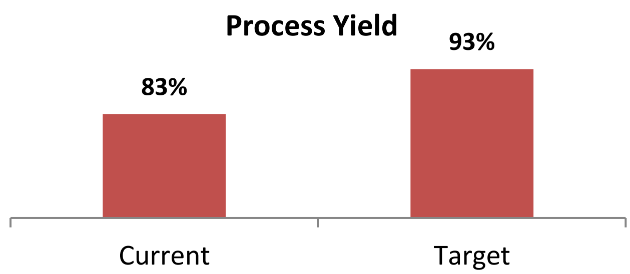
[29] Assuming 60% of national production using induction furnaces

Adoption of other known energy efficient manufacturing practices can significantly reduce the emission intensity of the sector. A total of 1.67 MtCO2/Annum emissions can be avoided by 2020 compared to BAU scenario.

b. Improve process yield

In addition to above, if the units shift towards higher productivity and higher yield trajectory by 2020, the emissions would be at 9.2 million MtCO2e per annum- that is, there exists a carbon footprint reduction potential of 22% against current baseline.



A total of 0.8 MtCO2/Annum can be avoided by 2020 compared to BAU scenario by improving process yield to industry best.

Comparison of the two alternatives against Business as Usual Scenario

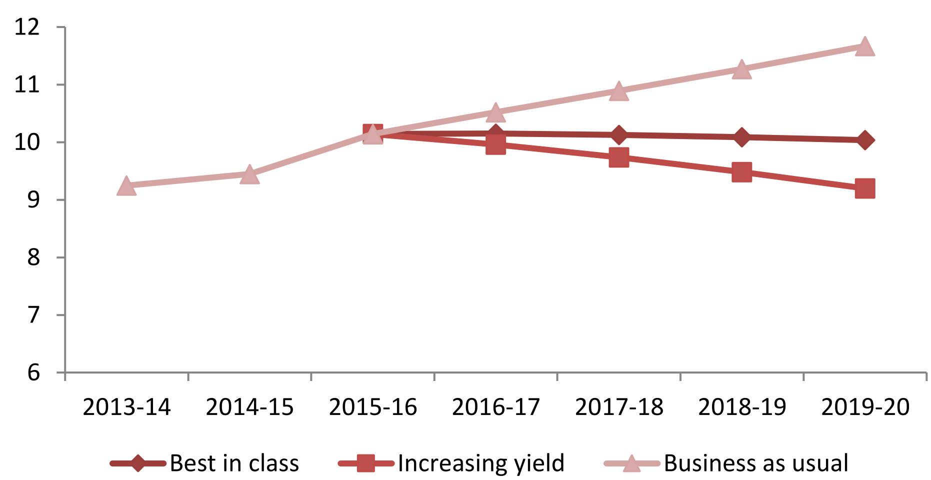


Figure 16 Low carbon growth paths for Foundry Industry in India

Further, there may be scope for switching fuels as well which will have indirect impact through reduction of per unit CO2 footprint. However this may necessitate deep dive studies.


Source: Pixabay


FORGING
Source: Pixabay

Forging: Current state and way forward

Industry Overview

Indian forging industry has a total production of over 2.45 million MT per annum, with an overall capacity of 37.7 million MT per annum. Over 70% of the total production in India is by closed-die/impression-die forging, 15% is open-die forging and the rest is precision forging products.[30] Geographically, the Indian forging industry is highly fragmented. The unorganized forging industries occupy a relatively smaller share (30%) of the total production and majorly comprise of micro, small and medium enterprises. These small and medium enterprises are either tier 3 or tier 4 component manufacturers or cater to the replacement market.

Indian forging industry primarily caters to the automobile sector, with the auto sector accounting for over 61% of the total forging production Automobile components like Gear box components, steering parts, connecting rods, camshafts etc., earthmoving components like bucket tooth, track links, drill bits, track roller shafts etc., machine tool components, electrical components etc. are produced. Forging industry in India provides direct employment to over 95,000 people.

Rajkot- Cluster at a glance

- **No of forging units**: 200
- **Associations in the cluster:** Rajkot Engineering Association, Rajkot district forged parts forging association
- **Major products:** Forged parts and back of bearing, auto parts connecting rod, gear crank shaft and nut bolt
- **Major markets:** Jaipur, Pune, Maharashtra within India and USA, Germany, Iran, Iraq and Africa continental and European countries outside India

Other key highlights

- Cluster has seen inadequate investment in technology up-gradation
- Training needs for coping with the demands of the export market
- Inadequate testing and validation facilities for smaller forging companies

[30] http://steelworld.com/focpot.pdf

Process flow chart

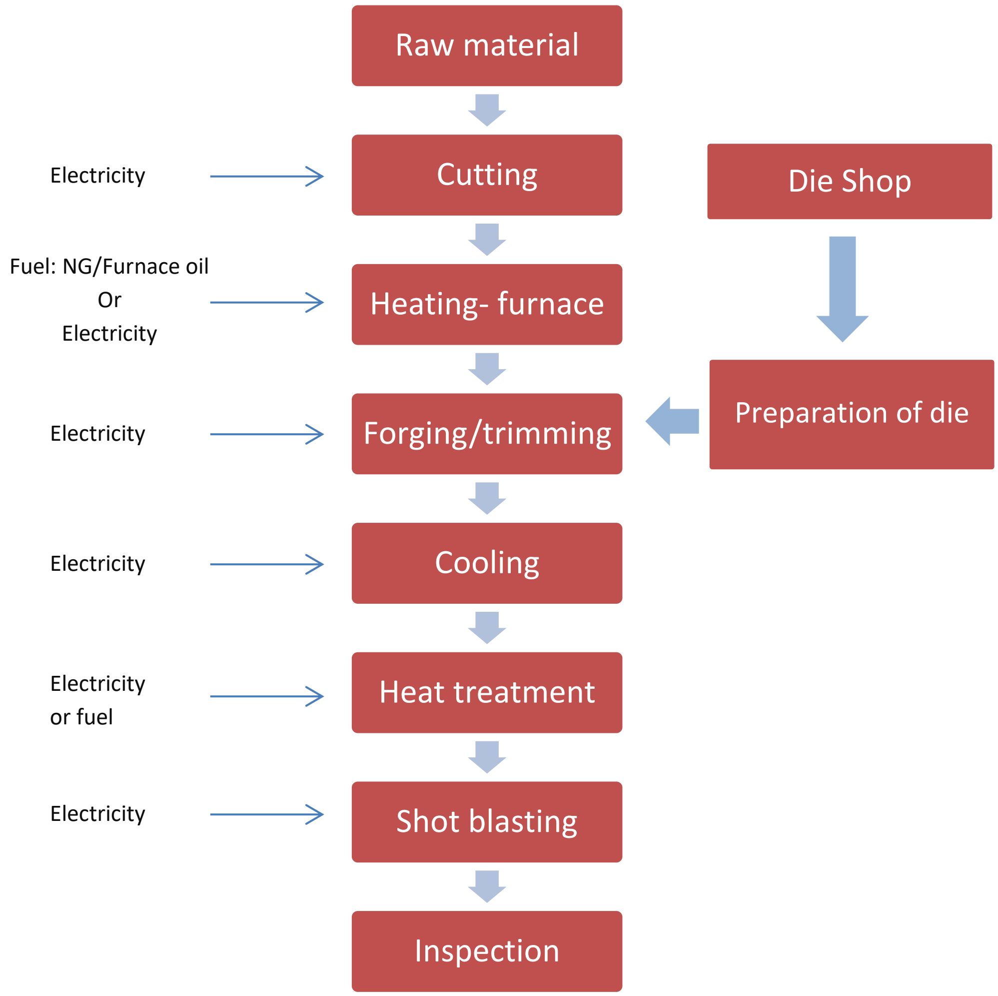


Figure 17 Process flow chart of a hot forging unit

Forging is the process that involves shaping of metal using compressive forces. Raw material (billets) is heated up to a temperature of 950 C till the metal is red hot using induction furnaces or fuel-fired furnaces. It is then pressed in forging hammers and/or forging presses that give it the desired shape. This is followed by subjecting the job to heat treatment. Heat treatment may or may not be carried in-house depending on the scale of operation of the unit. Heating accounts for a major share of energy consumption (around 80-85%).[31]

[31] https://www.sidbi.in/files/Cluster%20Profile%20Report%20-%20Pune%20%28Forging%29%20Cluster.pdf

Energy and GHG footprint: current state

Nature of factories visited

Forging has multiple types of processes and technologies used. The clusters visited mainly had hot forging units, mainly closed-die forging units and ring-rolling. Apart from this, there were a few open die forging units as well. The figure below describes the type of units in forging industry and the type of units that were visited.

Type of Forging	Oil-Fired Furnace	Induction Heating
Cold Forging		
Closed-die Forging	✓	✓
Open-die Forging	✓	
Ring Rolling		✓

Figure 18 Different types of ceramics factories and visited factories

Overall energy consumption pattern

For heating purposes, in closed-die forging, either electric heating is used or oil-fired furnaces are used. Ring rolling units are continuous in nature, and induction furnaces are used there to heat the billets. After the forging process, heat treatment may be carried out depending on the grading required in the products. Some units may have heat treatment in-house, others outsource it.
For facilitating comparisons based on benchmarks, classification has been done based on the following parameters:

- Type of forging
- Heating technology
- Presence of in-house heat treatment[32]

Type of forging	Heating technology	In-house heat treatment	Specific Energy Consumption (MJ/kg)		
			Min	Average	Max
Closed Die	**Induction**	With Heat Treatment	2.25	3.09	3.54
		Without Heat treatment	2.25	2.53	2.81
	Oil-fired	With Heat Treatment	-	6.44	-
		Without Heat treatment	4.36	4.53	4.70
Ring Rolling	**Induction**	With Heat Treatment	2.38	2.55	2.73

Table 7 Range of Specific Energy consumption for forging units

In addition to using different fuels for oil fired vs Induction furnace, oil-fired forging units are batch fired and Induction furnaces are continuous thus further contributing to lower specific energy consumption.

[32] Heat treatment is an additional process step which can be outsourced or done internally affecting SEC

In-depth analysis and key observations

- Oil-fired closed-die forging have higher specific energy consumption as compared to forging units that have induction furnaces, whereas ring rolling units and closed-die forging units with induction furnaces have similar Specific Energy Consumption.

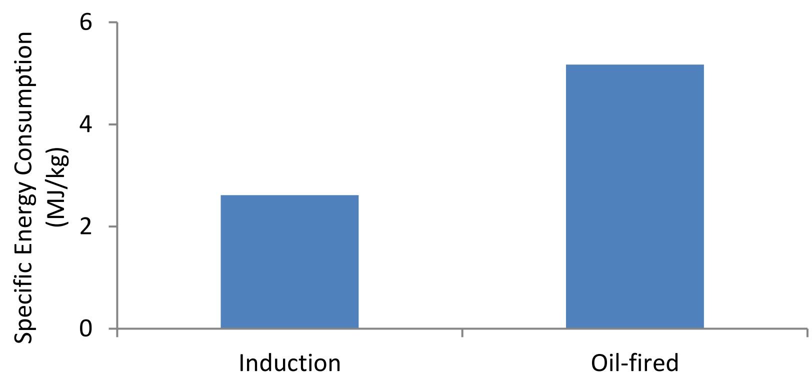


Figure 19 Total Specific Energy consumption of Induction and Oil fired furnaces

Prevalence of best practices and way forward

Best practices prevalence	Penetration	Nature of project
Energy efficient motors like IE3/IE4	0%	Technology intervention
Separate energy meter for Induction furnace	17%	Operational practices
Replace oil-fired heat treatment furnace with gas-fired/induction	50%	Technology intervention
Automation for temperature control in furnaces	50%	Operational practices
Replace oil fired furnace with induction furnace	55%	Technology intervention
Install Air pre heater/recuperator in furnace	60%	Technology intervention
Maintain correct amount of furnace draft	75%	Operational practices
Maintain power factor at 0.99	88%	Operational practices
Regularly checking and maintaining furnace insulation	94%	Technology intervention

Table 8 Best practices prevalence in forging industry

Low carbon growth path

In the last 4 years, the Indian forging industry has seen a 5% growth rate (CAGR). Prior to that, there was a slump in production output because the automotive sector had slowed down, however, it has recovered well. If the current trend continues as Business as usual (BAU) scenario, Forging SME sector will be emitting 1.82 MtCO2/Annum by the year 2020 considering existing energy consumption patterns and Industrial rate of growth. There are two identified independent approaches to avoid BAU scenario.

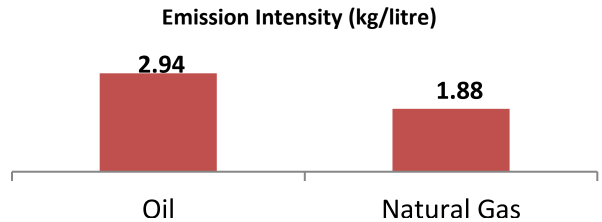
a. Energy efficient manufacturing practices

If all the units shift towards the adoption of energy efficient manufacturing, the industrial emissions will reach a value of 1.63 million MT per annum by 2020. This would be the case if all units start implementing manufacturing best practices listed above. As the implementation of capital intensive BMPs such as switch-over to induction furnace involve complicated trade-offs for the management, debottlenecking of operations could be a low cost and effective method to achieve the desired results through minimal investments. This would require undertaking detailed assessments to evaluate the potential for productivity and profit enhancements.

Adoption of other known energy efficient manufacturing practices can significantly reduce the emission intensity of the sector. A total of 0.19 MtCO2/Annum emissions can be avoided by 2020 compared to BAU scenario.

b. Shift towards Natural gas

In addition to above, if all oil-fired units shift towards natural gas, the emissions by 2020 will reduce to 1.49 million MT per annum, thus resulting in 18% reduction against current baseline.



A total of 0.14 MtCO2/Annum can be avoided by 2020 compared to BAU scenario by just shifting from coal to Natural gas

Comparison of the two alternatives against Business as Usual Scenario

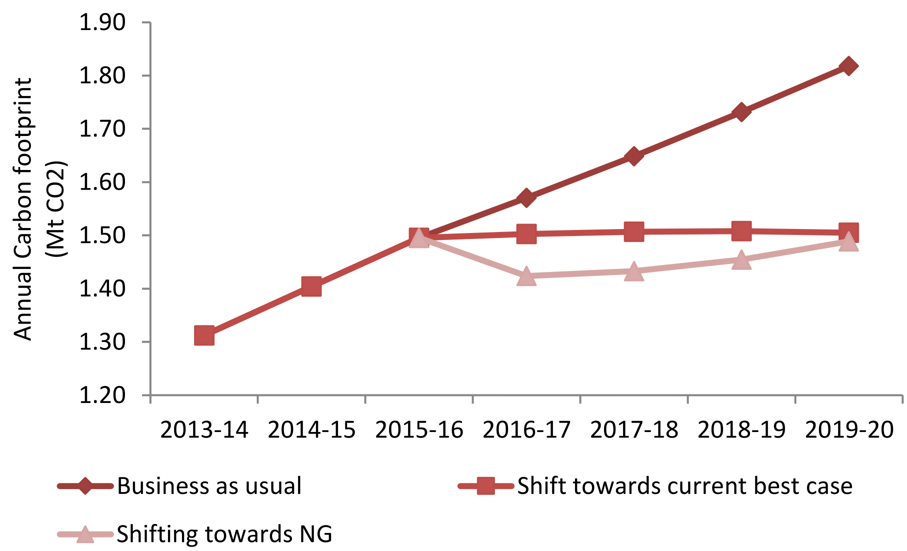


Figure 20 Low carbon growth paths for Forging Industry in India

Further, there may be scope for improving the yield as well which will have indirect impact through reduction of per unit CO2 footprint. However this has to be studied further as and when more information is gathered which may necessitate deep dive studies.

Source: Pixabay


STEEL
RE-ROLLING
Source: Wikimedia

Steel Re-rolling: Current State and way forward

Industry overview

Steel re-rolling industry falls under the secondary steel sector in India. The secondary steel production constitutes approximately 55% of the total steel production in India33. Out of 1710 steel re-rolling units in India, 1526 units (89%) fall in the Small and Medium enterprises sector34. The major Item of production in the Steel re-rolling industry are Re-bars/TMT constituting 54% of the total production, the other items being flats, squares, special window sections, thinner size HR strips, hexagons, wire rods, angles, channels, H-beams, I-beams, tele-channels etc.
The steel re-rolling sector has capital employed to the tune of INR 46,615 Cr35. The annual production capacity as on 2011-12 was 47 million tonnes against which the industry was found to be producing 32 million tonnes[36].
Steel re-rolling mills (SRRM) usually are family-run small and medium enterprises (SMEs) whose value proposition lies in flexibility in production for meeting low-tonnage requirements in various grades, shapes and sizes to serve niche markets. The key customer industries being served by the steel re-rolling sector are construction, infrastructure, automobiles, pipes and tubes, telecommunications etc.

The steel re-rolling industry caters to 68% of the domestic demand and has a share of 80% in the exports of rounds and bars37 and thus constitutes a vital part of the steel industry in India.

Based on their hourly production capacities, steel re-rolling units are classified into

- Small scale:3-14 tonnes per hour
- Medium scale 15-49 tonnes per hour.
- Units with an annual production capacity of 50 TPH or greater count as large scale industries

Steel re-rolling industries of Small and Medium scale supply finished products either to the customer industries directly (Government/Semi Government and other big projects and companies) or to the local markets. In the former case, they are usually required to have their own quality control arrangements so as to produce products complying to relevant standards as well as ensure the requisite physical and chemical properties demanded by the customer. Typically, the direct energy costs in small and medium scale steel re-rolling mills is estimated at 25-30% of the total production cost. Therefore, energy efficiency and operational effectiveness in steel re-rolling industries can be a vital tool to achieve profitability and scale up.

[33] Source: FICCI
[34] Executive Summary of Joint Plant Committee report 2013-14 released by Ministry of Steel
[35] Executive Summary of Joint Plant Committee report 2013-14 released by Ministry of Steel
[36] Executive Summary of Joint Plant Committee report 2013-14 released by Ministry of Steel
[37] Report on Standard Maintenance Practices for Re-heating furnace- UNDP GEF programme

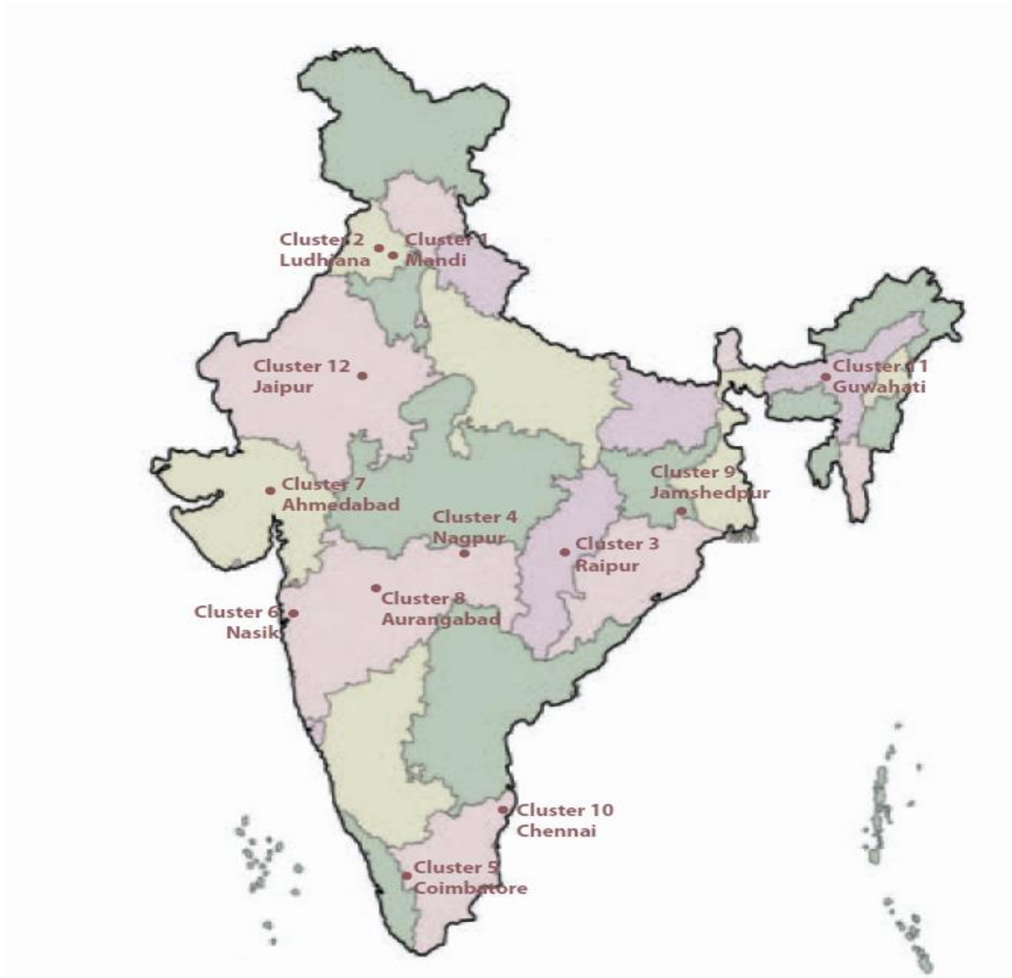


Figure 21 Key steel re-rolling clusters of India (Figure source: UNDP report on upscaling energy efficient production in the secondary steel sector in India)

Figure 21 shows the clusters where steel re-rolling units are situated in India. Some of the larger clusters (in terms of the number of units) among the ones depicted above are Mandi Gobindgarh (275 units[38]), Bhavnagar (120 units[39]) and Raipur (180 units[40]), the remaining clusters having less than 70 units individually.

[38] Source: All India steel Re-rollers association
[39] Source: Bhavnagar Steel re-rollers association
[40] Source: http://csraraipur.in/about_us.php#

Cluster	Production-TPD (Indicative figures only)	Range of Installed capacities of units	Major product	Proximity to raw materials and markets
Mandi Gobindgarh	3500	10 TPD to 150 TPD	Rounds, Squares, TMT Bars, Strips	No
Bhavnagar	5000	20 TPD to 300 TPD	TMT bar, H section	Yes
Raipur[41]	4000	10 TPD and upwards	MS Angles/Rounds/TMT, Channel, Wire Roll, MS beam	Yes

Table 9 Profile of India's largest steel re-rolling clusters

Mandi Gobindgarh is one of the oldest and largest steel re-rolling clusters in India which has a dominance of non-mechanized pusher furnaces and hence is highly labour intensive. The labour intensive nature of operations, apart from resulting in inherent inefficiencies, also leads to issues of migration of semi-skilled/skilled labour to relatively higher paying clusters such as Raipur. In addition, as mentioned in **Table 9**, unlike other major clusters, Mandi Gobindgarh is situated far from the sources of raw material as well as markets. This has put the Steel re-rolling industry in Mandi Gobindgarh at a competitive disadvantage, which makes cost cutting through energy efficiency highly invaluable. Mandi Gobindgarh has a combination of units using ingots/billets and scrap as the raw material, with the scrap

-based units at a production capacity ranging between 10-30 TPD (relatively much lower than the ingot/billet based units). Due to its unique set of challenges, which make it a rightful candidate for demonstrating the impact of energy efficiency and productivity related interventions, Mandi

<u>Mandi Gobindgarh – Cluster at a glance</u>

- **Most commonly used type of furnace**: Pusher furnace
- **Type of raw materials:** Steel Ingots, Billets, Blooms, Scrap from Ship breaking, Imported scrap
- **Source of raw materials:** Procured from open market, ship-breaking scrap is procured from Gujarat
- **Major products manufactured:** Rounds, Squares, TMT bars
- **Nature of operations:** Mostly manual or semi-automated
- **Cost of electricity:** INR 7.55 per unit
- **Types of coal used:** Imported from US through traders, procured from Local market, Steel grade coal procured from Coal India Ltd.
- **Cost of coal:** INR 9000 to 14000 per tonne
- **Previous Interventions:** 15-20 units have participated in UNDP's programme titled "Removal of Barriers to Energy Efficiency in the Steel Re-Rolling Mill Sector in India". In addition there also has been participation of units under MSME umbrella program of GIZ.

Gobindgarh has been chosen as the cluster of choice for the purpose of this study.

[41] Source: http://csraraipur.in/about_us.php

Process flow chart

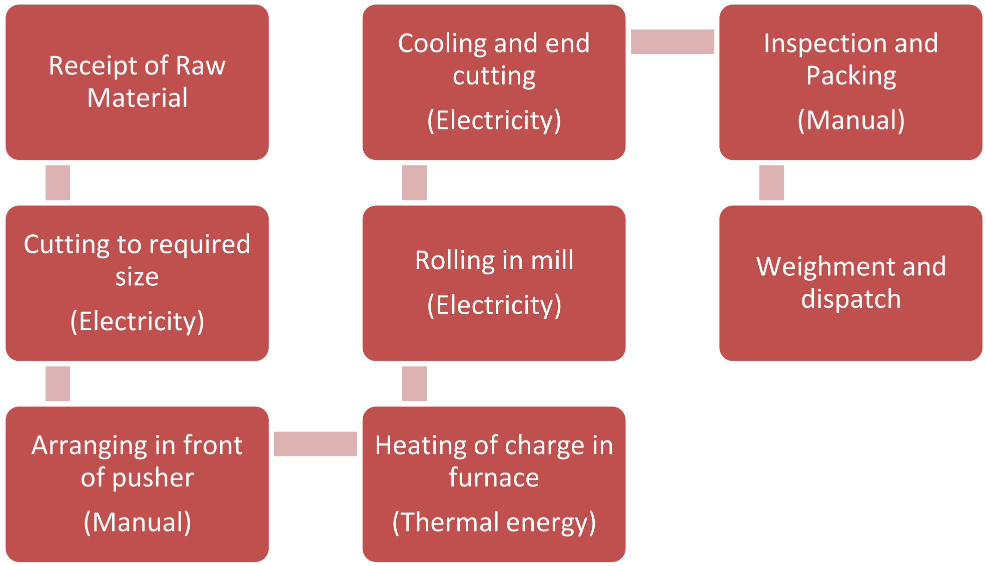


Figure 22 Process flow in a typical steel re-rolling mill with Pusher furnace

As a first step, the raw material (ingot/billet/bloom/scrap) enters the factory and is stored in the storage yard. It is then cut into the required dimensions (based on the dimensions of the product being manufactured) which can be done using gas cutting machines or using shearing machines. The cut pieces are arranged in lots and pushed into the furnace using a pusher (of mechanical/hydraulic type)

The charge fed into the furnace is heated by using burners. Heat transfer inside the furnace occurs through conduction, convection and radiation out of which radiation from the furnace roof is the most effective form of heat transfer. The heated charge is removed from the furnace either manually or using ejectors and is sent to the milling section. The milling section typically comprises of the roughing mill (high reduction in cross section), intermediate mills and finishing mills (relatively lower reduction in cross section). A mill stand has an arrangement of rotating rolls driven by motors which draw the heated charge in and reduce its cross section, resulting in increase in length. The rolls experience jerks and impact loading and transfer this impact load to the bearings and mill housing. The system of transfer of the stock between different stands can be manual or automated. The finished product is cooled in cooling beds and sent for quality testing and packaging where after, it is weighed and dispatched to the customer.

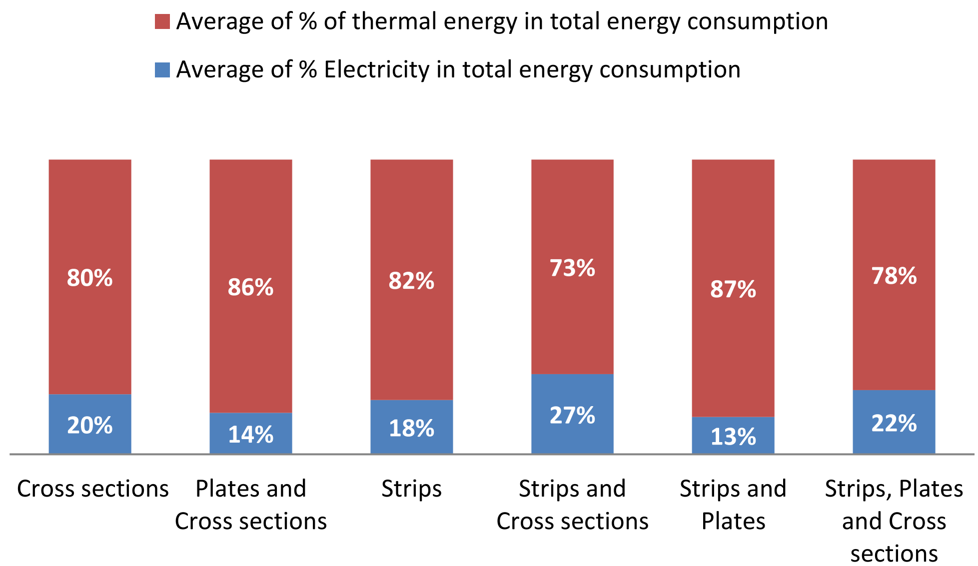


Figure 23 Share of thermal and electrical energy in total consumption based on product groups

As shown in the above figure, thermal energy accounts for a major portion of the energy consumed by a steel re-rolling mill. Low thickness products typically require greater pressure to be exerted by motors and contribute greatly to increasing the specific electricity consumption and thereby the share of electricity in the total energy consumed per tonne.

Energy and GHG footprint

Nature of factories visited

Figure 24 and Figure 25 show the profile of the units visited in Mandi Gobindgarh. It can be observed that the scale of operations greatly influences the choice of product that the factories manufacture and thus the raw material that is required for the product. Larger units are seen to be manufacturing plates and cross sections rather than strips (relatively low value items). Cross sections include girders, beams, and rounds squares and other heavy products of thickness greater than 5mm.

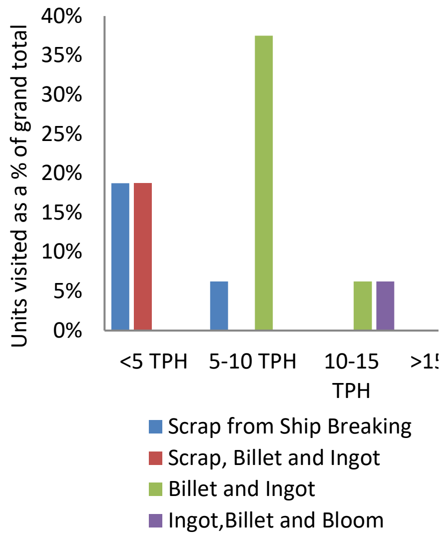


Figure 24 Distribution of peer groups in the cluster

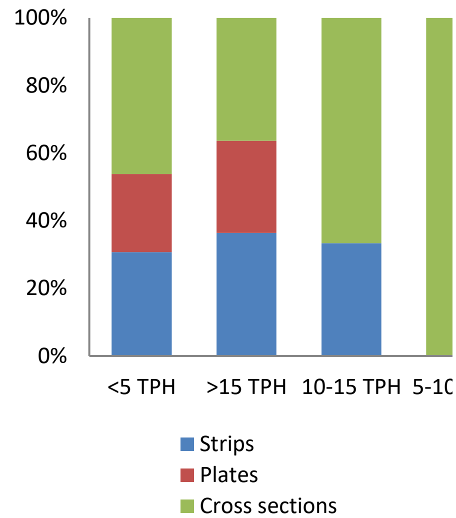


Figure 25 Products being manufactured by different peer groups

Figure **26** shows the magnitude of losses which are seen to be affecting yield of the different units surveyed. As against a benchmark yield of 95%, most of the units are seen to be having high value of losses and there is a scope of increasing their yield in the range of 1-3%. These losses are seen to be directly impacting the specific energy consumption as observed in the correlation between magnitude of losses and specific energy consumption.

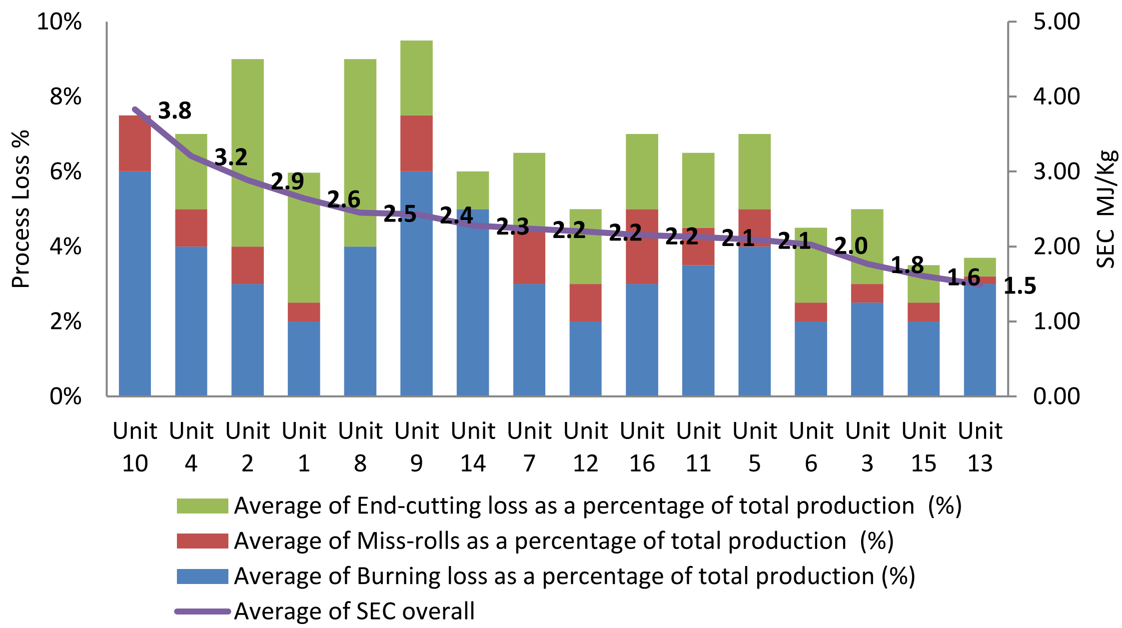


Figure 26 Correlation between process loss and specific energy consumption

The general observations through conducting factory visits in the Mandi Gobindgarh cluster are as follows:

- There is a de-prioritization of energy efficiency as compared to production. In the absence of cooperation/knowledge sharing among members of the Steel rolling association, hand-holding approach sorely needed for implementing energy efficiency projects
- Although the earlier interventions pertaining to energy efficiency in the cluster have created awareness about the technologies as well as best management practices, they have witnessed limited participation. Consequently, over 50% of the units are still unaware of the impact of incorporating new technologies and best-in-class practices on their operations.
- The unskilled and semi-skilled manpower is unstable (high attrition to other clusters) and uneducated. Industry management is found to focus only on the commercial aspects and have off-loaded the management of technical aspects of the factory to firemen and foremen who are non-technical persons relying on their experience to address operational issues. These workers are also highly averse to new technology, thereby preventing any effort towards a positive change.
- Sub-optimal yield
    - Inability to control oxygen percentage and temperature inside furnace leading to high burning loss
    - Improper operating practices and lack of automation in process compounding yield issue.
- High fluctuation in cost of fuel and lack of ability to keep track of fuel quality is an uncontrollable factor for the factory management

Energy benchmarks

Figure 28 shows the specific energy consumption per Kg of product for 16 steel re-rolling mills visited as a part of this study. It can be observed that the SEC is in the range of 1.5 to 3.8 MJ/Kg. Few factories are found to have relatively higher values of thermal SEC which contributes to high overall SEC.

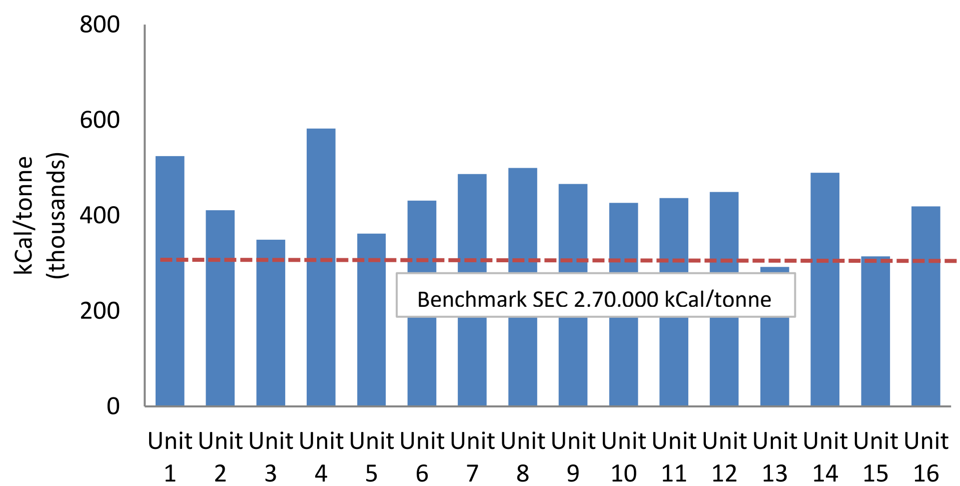


Figure 27 **S**pecific thermal energy consumption vis-a-vis benchmarks

As against a benchmark thermal energy consumption of 2,70,000 kCal/tonne[42] which is achievable for small and medium scale steel re-rolling mills, the actual values are found to be much higher as can be observed in the figure above. This has been the case due to lack of focus on furnace maintenance and monitoring which has resulted in high losses and most importantly a glaring lack of attention on monitoring of coal quality which is seen to have spillover effects in the process by improper combustion and poor calorific values.

Unlike thermal energy consumption, which primarily depends on the proper operation of the furnace, the specific electrical energy consumption depends on multiple factors such as the amount of reduction in cross section from raw material to finished product, number of passes, uniformity of reduction across different passes, temperature of rolling, mill utilization, furnace throughput etc. Variation in these factors explains the electrical energy consumption in some of the units shown in Figure 28 being much higher than the others. For instance, Unit 2 has a high electricity consumption because it manufactures strips of thickness as low as 0.4mm whereas Unit 4 and 10 were observed to roll ship breaking and other types of scrap of highly variable sizes (such as TMT bars, automotive scrap) into strips and cross sections at a lower rolling temperature and with highly uneven reduction across different rolling stands, resulting in high electrical SEC.

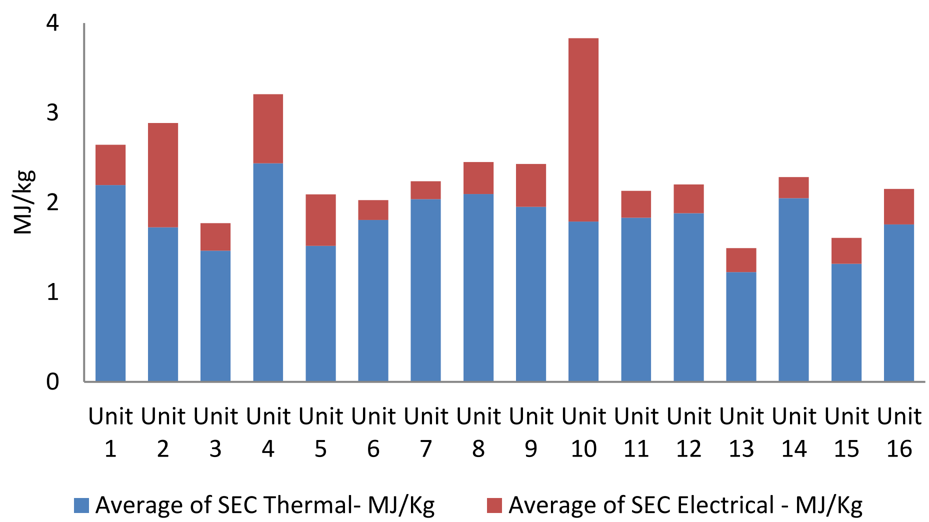


Figure 28 Specific Energy Consumption- Share of thermal and electrical energy consumption

In-depth analysis and observations

[42] Figure arrived at through expert consultations

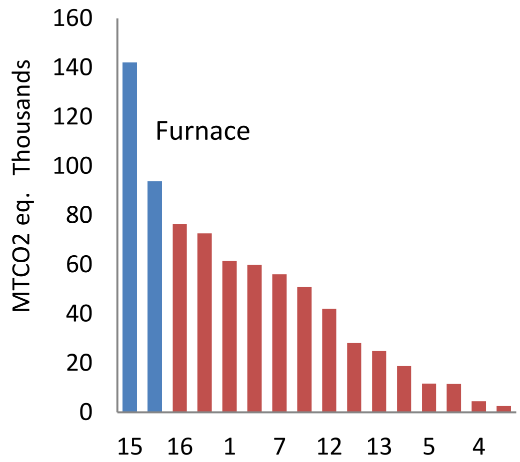


Figure 29 Annual emission profile of surveyed factories

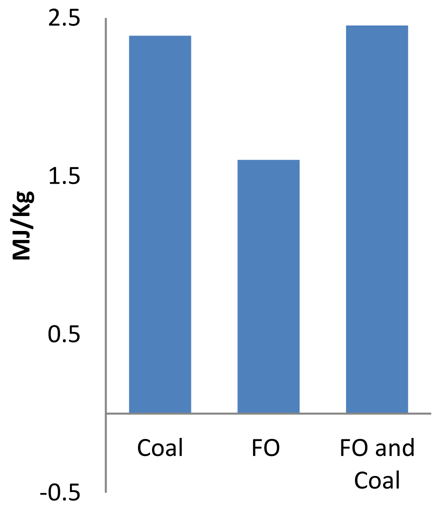


Figure 35 Specific Energy consumption based on type of fuel

In Mandi Gobindgarh cluster, the factories were seen to be using coal as well as furnace oil as the fuel. It can be observed in the figures shown above that although the factories using furnace oil had a distinctive advantage over the coal based factories in terms of the thermal SEC, the absolute quantum of carbon dioxide equivalent emission caused by these factories was on the higher end because of relatively higher production of these units as well as higher emission intensity (2.63 tonnes of CO2 per tonne product for Furnace oil based units as against 2.59 tonnes of CO2 eq. of coal based units). Only the larger units which produce heavy sections typically use furnace oil, which has higher costs of thermal energy per tonne of production (INR 1100 per tonne as against INR 500~800 for coal based units).

Prevalence of best practices

In Mandi Gobindgarh, there is a low level of prevalence of industry best practices both in terms of technology installations as well as operational best practices. A few of the BMPs (such as recuperator and VFD installation) found relatively higher percentage of takers as there is a pressure from the State Pollution control boards to adopt these measures which lead to improved combustion and heat utilization and consequently less pollution. Discussions with the management of these units also reflects a lackadaisical attitude towards tracking inventory and energy consumption in spite of the units being aware of the obvious monetary benefits of carrying out the implementation of the 'low hanging fruit' kind of projects. Overall, compliance is seen to be a major driver for the adoption of energy efficient technologies.

On the productivity front, the key performance indicator on which the units were evaluated is yield, which represents the percentage of material throughput that happens in a unit when the process losses such as burning loss, miss-roll and end-cutting are accounted for. The ideal figure of yield for small and medium enterprises is 95%. It was observed that only 25% of the factories visited had reached or crossed this benchmark figure, which indicates a high scope of improvement in yield. The practices that lead to increase in yield include better control of furnace parameters such as temperature and pressure and ensuring uniformity in feed dimensions.

Best practices prevalence	Penetration	Nature of project
Use regenerative burner system in reheating furnace	0.00%	Technology installation
Use recuperator for heat recovery	100.00%	Technology installation
Use Oxy fuel combustion system	0.00%	Technology installation
Use top and bottom firing system for optimum heating	0.00%	Technology installation
VFD in combustion fans to control excess air	100.00%	Technology installation
Improved insulation and refractories in re-heating furnace	50.00%	Operational improvement
Maintain optimum furnace pressure (draft) and temperature using automatic monitoring system	18.75%	Technology installation
Minimum waste-crop length minimization	0.00%	Technology installation
Anti-friction roller bearing	31.25%	Technology installation
Use of cast-in carbide rolls	0.00%	Technology installation
Maintain power factor at 0.99	100.00%	Operational improvement
Presence of energy efficient electric motors	12.50%	Operational improvement
Coal quality measurement instruments	0.00%	Operational improvement

Low carbon growth path

In case of Business as usual (BAU) scenario, Steel Re-rolling SME sector will be emitting 82.87 $MtCO_2$/Annum by the year 2020 considering existing energy consumption patterns and Industrial rate of growth. There are two identified independent approaches to avoid BAU scenario.

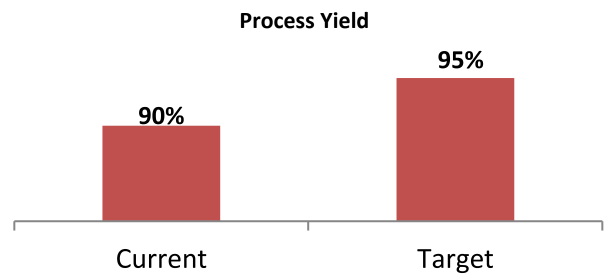
a. Energy efficient manufacturing practices

However, if the industry resorts to adoption of best management practices which improve the operational performance, the impact can be reduced to 79.69 Million tonnes of CO_2 eq.

Adoption of other known energy efficient manufacturing practices can significantly reduce the emission intensity of the sector. A total of 3.18 $MtCO_2$/Annum emissions can be avoided by 2020 compared to BAU scenario.

b. Improve process yield

There is another trajectory namely increasing the yield to the best practice figure of 95% which holds the potential to reduce the sectoral emission to 78.51 Million tonnes of CO_2 eq. As the industry is traditionally averse to investing in projects with high investment and low payback requirements, the approach for energy efficiency in these units needs to be through making low or minimal investments to achieve continual improvement over a period of time and setting easy to achieve and realistic targets. This would require continuous handholding and enabling the skilled and unskilled labour, who control the process to manage the change through programmatic interventions.



A total of 1.18 $MtCO_2$/Annum can be avoided by 2020 compared to BAU scenario by improving process yield.

Comparison of the two alternatives against Business as Usual Scenario

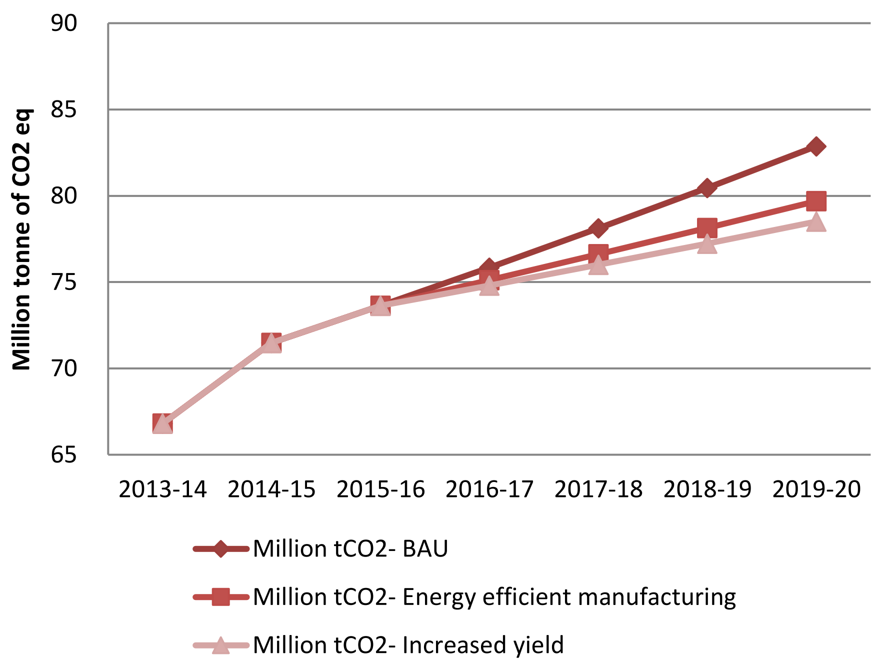


Figure 30 Low carbon growth path

Total emissions vs. emissions intensity

It may be worthwhile studying the 4 industries together not just based on total GHG footprint but also in terms of emissions intensity.

Total annual carbon dioxide emissions of ceramics industry at 13.8 million MtCO2e are higher than foundry at 10.14 million MtCO_2e. However, the energy emissions intensity is higher in case of foundries.[43]

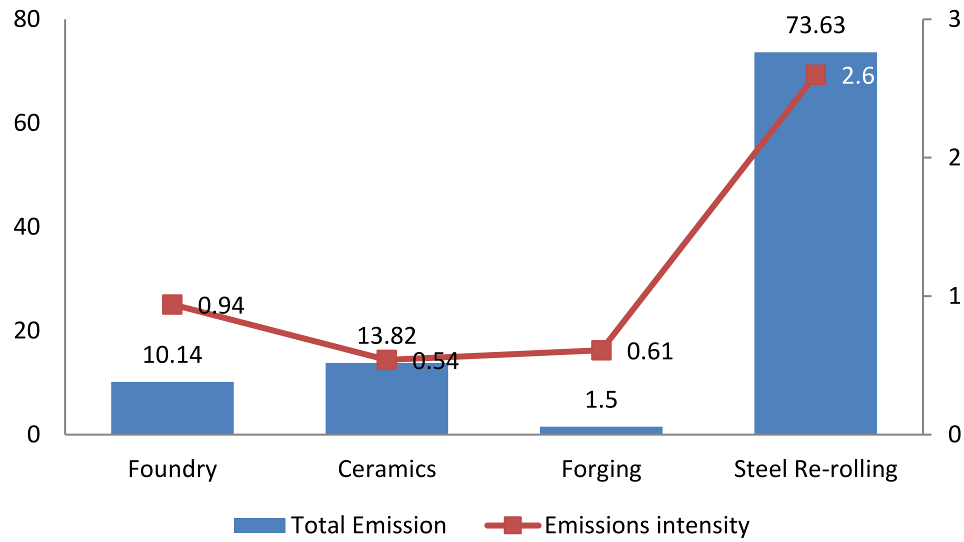


Figure 31 Total emissions vs. emissions intensity for different industries

As can be observed in above graph, emissions intensity of ceramics is the lowest, even lower than forging even though forging process requires a relatively lower temperature.

[43] SIDBI cluster profile reports and cKinetics' analysis

Fuel type-wise emissions of shortlisted industries

Various types of fuels are used across the shortlisted industries. In foundries, electricity is used for melting as well as for auxiliary electric load (pumps, grinders, drilling machines, molding machines etc.) whereas coke is used in cupola operations.

Forging units use either oil fired furnaces or Induction (electricity) furnaces. Ceramics industry has the option of using both natural gas or coal gas, industry keeps switching the fuel type based on price competitiveness.

S. No.	Industry	CO2 Emissions (million MtCO2)					Total Emissions (Million Mt CO_2 eq.)
		Electricity	Natural Gas	Coal	Coke	Oil	
1	Foundry	9.05	-	-	1.09	-	10.14
2	Ceramics	1.52	2.21	10.09	-	-	13.82
3	Forging	1.15	-	-	-	0.39	1.5
4	Steel Re-rolling	2.21	-	64.28	-	7.14	73.63

Table 8 Fuel-type wise CO_2 emissions- current state

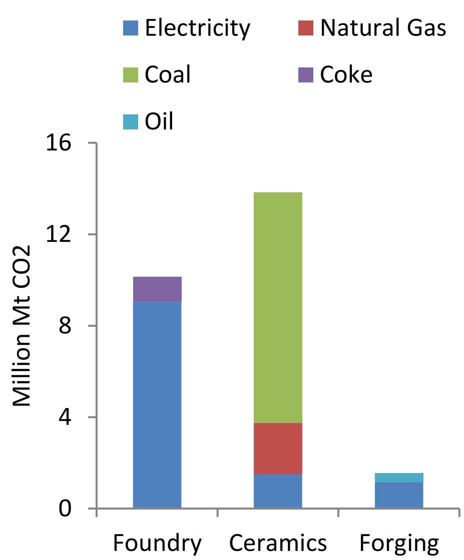


Figure 32 Fuel-wise contribution to GHG emissions in the industries

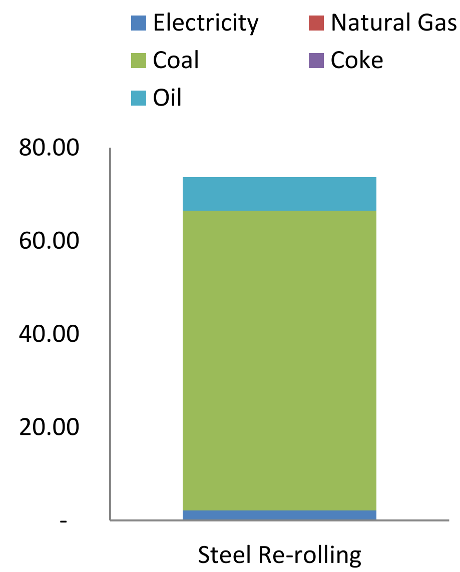


Figure 33 Fuel wise contribution to GHG emissions in Steel re-rolling industry (Figure shown separately due to high value)

Appendix

1. Methodology adopted for GHG calculation

Approach taken: framework

The methodology adopted was based on the approach developed by ckinetics' in the past for the programs undertaken in other industrial clusters. After understanding the industry and its processes, questionnaires were developed broadly capturing data around the following parameters from a unit in a given industry:

- Energy consumption- electrical and thermal (process level wherever available)
- Production
- Plant machinery
- Type of products made
- Best practices being implemented

With this information, benchmarks were created for the purpose of comparing one unit with another. The above parameters allow for benchmarking comparisons of units making similar grade of products and having similar operations.

Assumptions taken for calculations

Foundry

For projecting CO_2 emissions, it has been assumed that 40% of all grey iron castings are being produced in cupola, and the rest using induction furnaces. This assumption is based on the data collected on ground from Rajkot as well as from cluster profiles of other clusters. The scenarios have been projected by taking the growth rate as the CAGR for the last 6 years, that is, 3.5%.

For the Business as usual scenario, average CO_2 emissions per ton production for Rajkot has been taken as the number for calculating emissions nationally (separately for cupola foundries and induction furnaces). In the case of best in class, this number has been taken as the CO_2 emissions of the unit that is currently performing best within its class amongst the units visited. Similarly for the third scenario, yield percentage has been taken as the yield percentage of the unit currently with the best yield (95%) and that number has been used to project the emissions in this case.

Ceramics

In the case of ceramics industry, it has been assumed that 43% of the tiles production will be vitrified tiles; 700 MSM out of 1600 MSM produced currently are vitrified tiles. Moreover, it has been assumed that 50% of the units are coal-fired and 50% are natural gas fired, based on information collected from the study. The scenarios have been projected by taking the growth rate as the CAGR for the last 5 years, that is, 23.3%.

For the Business As usual scenario, the average for coal-fired and gas-fired units has been taken separately for different type tiles to project CO_2 emissions for 2020. For projecting the current best in class value, the best performing unit in both the classes has been taken as the benchmark. A third scenario has been taken where the emissions have been projected if all units shift to natural gas. Natural gas is a cleaner fuel both in terms of GHG emissions as well as air pollution.

Forging

For forging industry, projections have been calculated by classifying units based on type of furnace used; electric-based or fuel-fired. Based on information collected from ground, it has been considered that 60% of the units use induction furnace and the rest use furnace oil.

Similar to the above two, the business as usual has scenario has been projected by taking the growth rate as the CAGR for the last 4 years, that is, 5.1% and the average value of emissions per ton production of the units visited so far has been used for the projection. Similarly, the current benchmark value has been taken to arrive at the current best in class projections. Additionally, a third scenario has been considered to projects emissions if all oil-fired units shift to natural gas.

Steel Re-rolling

For steel re-rolling industry, the projections have been made by classifying units based on the type of fuel being used i.e pulverized coal-based units or Furnace oil based units. Based on the information collected on ground, approximately 10% of the units are Furnace oil based and 90% of the units are pulverized coal based. The business-as-usual scenario has been projected by considering the CAGR as 3%. The average value of emissions per tonne for Furnace oil based units has been taken as 2.65 tonnes CO2 eq. and that of pulverized coal based units has been taken as 2.6 tonnes CO2 eq. Current benchmark value of emissions per tonne production considered for coal based units is 2.5 tonnes CO2 eq and that of Furnace oil based units is 2.55 tonnes of CO2 eq. These values have been used to arrive at the current best-in-class projections.

Emission factors used for GHG calculations

Fuel	CO2 Emission	Unit
Gasoline/ Petrol	2.27	kg/ litre
HFO	2.94	kg/ litre
LPG	1.61	kg/ litre
Petcoke	3.17	kg/ kg
Coal	2.44	kg/ kg
Wood	1.75	kg/ kg
CNG/ PNG	1.88	kg/ m^3
Diesel (Stationary combustion sources)	2.68	kg/ litre

Table 10 Emission factors

Data validity

All information shared is based on self-reporting by the unit's senior / top management or secondary research from reliable data sources.

2. List of key institutions and associations engaged

1. All India Steel Re-rollers Association
2. Auto Parts Manufacturing Association
3. Chamber of Industrial and Commercial Undertakings
4. Foundation for MSME clusters
5. Indian Institute of Foundrymen
6. Khurja Pottery Manufacturers Association
7. Ludhiana Foundry Cluster Association
8. Morbi Ceramics Association
9. Morbi Sanitary Ware Manufacturers Association
10. Punjab State Council for Science and Technology
11. Punjab Forging Industries Association
12. Rajkot Engineering Association
13. Shapar Veraval Industries Association
14. SIDBI (Ludhiana Circle and Morbi circle)
15. TERI
16. Vithal Udyognagar Industries Association

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