Chapter - 9

Iron & Steel Industry

9.1 Introduction

Steel plays an important role for the development of infrastructure in the growing economy. With the economic growth rate of 8% - 9%, during the last few years, the demand for steel has touched new heights. In fact, with opening up of the economy in the early nineties, country experienced rapid growth in steel making capacity. Large integrated steel plants set up in private sector and capacity expansion of public sector plants has contributed to making India the 5th largest global crude steel producer in the year 2006. India is expected to become the second largest producer of steel in the world by the year 2015.

9.2 Present Capacity & Growth Potential

Data relating to production, consumption, import & export of finished steel (alloy & non-alloy) and crude steel from the year 2002-03 onwards is given in table 9.1 below:-

Table 9.1: Production, Consumption, Import, Export of Finished steel & crude steel production.

(in million tonnes)

		2002-03	2003- 04	2004 – 05	2005-06	2006-07	2007-08 (April – December)*
Finished Steel including Alloy Steel	Production	37.166	40.709	43.513	46.566	52.529	40.117
	Consumption	30.677	33.119	36.377	41.433	46.783	36.992
	Import	1.663	1.753	2.293	4.305	4.927	5.325
	Export	4.517	5.207	4.705	4.801	5.242	3.850
Crude Steel	Production	34.707	38.727	43.437	46.460	50.817	39.608

*Provisional

(Source : Annual Report of Ministry of Steel, GoI, 2007-08)

The projected total demand of finished steel by the end of XIth plan (i.e. year 2011-12) is 70.34 million tonne and production of crude steel is 80.23 million tonne. These figures of demand and production are likely to increase to 90 million tonne and 110 million tonne respectively by the year 2019-20.

9.3 Iron & Steel Manufacturing Process

The two main routes for the production of steel are :

- Production of primary steel using iron ore and scrap
- Production of secondary steel using only scrap.

9.3.1 Steel Production from Iron Ore

Steel production at an integrated steel plant involves the following four basic steps i.e,

i. Production of coke and sinter / pallets from iron fines - Material preparation
ii. Reduction of iron ore in blast furnace-Iron making

iii. Processing of molten iron to produce steel -Steel making
iv. Steel forming and finishing.

In addition, the alternative route of iron making is Direct Reduction of Iron Process (DRI)

9.4 Production of Crude steel in India through different processes

Traditionally, Indian steel industry were classified into Main Producers (also referred to as the integrated iron & steel plants for example SAIL (Steel Authority of India Ltd.) plants, Tata Steel and Vizag Steel / RINL (Rashtriya Ispat Nigam Ltd.) and the Secondary Producers. However, with the coming up of larger capacity Steel making units, of different process routes, the classification has been charcterised as Main Producers & Other Producers. Other Producers comprise of Major Producers namely Essar Steel, JSW Steel and Ispat Industries as well as large number of Mini Steel Plants based on Electric Furnaces and Energy Optimising Furnaces. Besides the steel producing units, there are a large number of Sponge Iron Plants, Mini Blast Furnace units, Hot & Cold Rolling Mills & Galvanising/Colour Coating units which are spread across the different states of the country. The following table 9.2 highlights the contribution of the private and public sector in crude steel production in the country:

Table 9.2: Sectorial Production of Crude Steel

(in million tonne)

	2003-04	2004-05	2005-06	2006-07
Public Sector	15.8	16.0	17.0	17.0
Private sector	22.9	27.5	29.5	33.8
TOTAL PRODUCTION	38.7	43.5	46.5	50.8
% Share of public sector	40.0	36.6	36.5	33.5

(Source: Annual Report of Ministry of Steel, GOI, 2007-08)

9.5 Energy Consumption in Steel Plants

9.5.1 Energy Intensity

Iron & Steel industry in India is highly energy intensive. Major energy inputs in the sector are coking coal, non-coking coal, coke & electricity.

Energy demand in this sector is expected to be nearly 28% of the total industrial energy demand in 2030, which is roughly between 20-22% at present. The demand for coal in steel sector is expected to grow by 5.2% per year (upto2030) and natural gas demand to grow by 6% a year. The electricity demand in the same period is likely to grow 8% per year.

9.5.2 Energy Consumption

The specific energy consumption in Indian Steel plants is quite high. It ranges between 25.5 GJ/ tcs to 34.2 GJ/ tcs (tonne of crude steel). On an average, the SEC (Specific Energy Consumption) is 30 GJ/ tcs in India, which is almost double of the World's best plants. There is variation of specific energy consumption in different steel plants. This is mainly because of different processes, quality of coal, types of products produced & energy efficiency measures adopted by the plants. The details of specific energy consumption by the Indian steel plants (GJ/ tcs) is given in table 3 below:-

Table 9.3: SEC of Indian Steel Plants (GJ/ tcs)

Plant	*2006-07*
Bhilai Steel Plant (BSP)	28.53
Durgapur Steel Plant (DSP)	29.58
Rourkela Steel Plant (RSP)	33.39
Bokaro Steel Plant (BSL)	29.66
IISCO Steel Plant (ISP)	34.26
SAIL (as a whole)	29.95
RINL	27.32
TATA Steel	28.07
JSW Steel	25.52

(Source : Annual Report of Ministry of Steel, GoI, 2007-08)

The major energy consuming process in iron making are coking, sinter making & blast furnace. They consume about 61.3% of the total energy. The slabbing mill, and hot strip mill together with others account for 36.5% energy consumption. The table 9.4 gives the major portion of energy consumption in iron making.

Table 9.4 : Major portion of energy consumed in iron making

Process	Energy consumed 10^6 kCal/tonne CS	% of total energy	
Coking	1.033	11.5	61.3% in iron making
Sinter making	0.967	10.7	
Blast furnace	3.519	39.1	
BOF (LD)	0.202	2.2	2.2% in steel making
Slabbing mill	0.483	5.4	36.5% in rolling and others
Hot strip mill	1.080	12.0	
Cold rolling mill	1.025	11.4	
Other (including losses)	0.91	7.7	
Total	**9.000**	**100.0**	

(Source : Handbook of Energy Conservation by H. M. Robert & J. H. Collins)

The details of specific energy consumption by process in an Indian Steel Plant is given in table 9.5 below:

Table 9.5 : Specific Energy Consumption

Description	Qty. of energy		Energy in heat values (10^6 kCal)	
	consumed	Produced	consumed	Produced
Coke oven (per tonne of coke)				
Coal (tonne)	1.489	-	10.423	-
BF coke (tonne)	-	1.0	-	7.000
Electricity (kWh)	27	-	0.067	-
COG (M^3)	208	416	0.853	1.706
Steam (kg)	100	-	0.087	-
Coke breeze (kg)	-	150	-	1.050
Crude tar (kg)	-	40	-	0.034
Total			11.430	9.790
Net energy consumed per tonne of BF coke			1.640	
Net energy consumed per tonne of CS (at coke rate of 700 kg and HM ratio of 900 kg)			1.033	
Sinter plant (per tonne of sinter)				
Coke breeze (kg)	100	-	0.700	-
Electricity (kWh)	100	-	0.250	-
COG (M^3)	20	-	0.082	-
BFG (M^3)	50	-	0.043	-
Total			1.075	-
Net energy consumed per tonne of sinter)			1.075	-
Net energy consumed per tonne CS (at sinter rate of 1000 kg and HM ratio of 900 kg)			0.967	
Blast furnace (per tonne of hot metal)				
Coke (kg)	700	-	4.900	-
Electricity (kWh)	30	-	0.075	-
BFG (M^3)	1000	2500	0.870	2.075
Steam (kg)	160	-	0.140	-
Total			5.985	2.075
Net energy consumed per tonne of HM			3.910	
Net energy consumed per tonne of CS (at HM ratio of 900 kg)			3.519	
Steel melting shop (per tonne of ingots)				
Electricity (kWh)	40	-	0.100	-
Steam (kg)	25	140	0.022	0.122
COG (M^3)	20	-	0.082	-
Oxygen (M^3)	70	-	0.120	-
Total			0.324	0.122
Net energy consumed per tonne of CS			0.202	
Slabbing mill (per tonne of ingots)				
Electricity (kWh)	45	-	0.112	-
BFG (M^3)	450	-	0.371	-
Total			0.483	
Net energy consumed per tonne of CS			0.483	
Hot strip mill (per tonne of slabs)				
Electricity (kWh)	150	-	0.375	-
COG	140	-	0.574	-
BFG (M^3)	420	-	0.366	-
Steam (kg)	-	50	-	0.043
Total			1.315	0.043
Net energy consumed per tonne of slab			1.272	
Net energy consumed per tonne of CS			1.080	
Cold rolling mill (per tonne of CR coils)				
Electricity (kWh)	250	-	0.625	-
Steam (kg)	250	-	0.219	-
COG	70	-	0.287	-
BFG (M^3)	210	-	0.183	-
Total			1.314	-
Net energy consumed per tonne of CRC			1.314	-
Net energy consumed per tonne of CS			1.025	

(Source :Handbook on Energy Conservation by H.M. Robert & J.H. Collins)

9.6Energy Efficiency in Steel Industry in India

In the journey of progress, the Indian Steel Industry has taken significant steps in improvement of productivity, conservation of natural resources, Research and Development, import substitution, quality upgradation and environment management. Some notable developments are:

1. Introduction of Stamp Charging and Partial Briqueting of Coal Charge (PBCC) for production of metallurgical coke - in this process, it has been made possible to replace part of the metallurgical coal requirements by non-coking/ semi-coking coal, with higher strength of the coke and less emission.

2. Installation of energy recovery coke ovens - in order to meet the power requirements as well as to reduce emission.

3. Use of non-coking coal in iron making - processes such as Corex have now been introduced in some of the steel plants to produce hot metal by predominantly using non-coking coal. Coal Dust/ Pulverised Coal Injection System has been introduced in several blast furnaces to partially substitute Coke. In addition, there has been large scale growth of sponge iron units based on non-coking coal.

4. Use of Direct Reduced Iron (DRI) / Sponge iron in steel making-earlier, only scrap could be used as a feed material in electric arc furnaces. With growing scarcity of scrap, a replacement could be found in the form of DRI produced from iron ore with reformed natural gas/ non-coking coal as reluctant.

5. Use of hot metal in electric arc furnaces - setting up of Basic Oxygen Furnace is capital intensive and successful only at a large scale.

6. Adoption of continuous casting - The first solidified form of steel in the melting shops used to be ingots. With the advent of continuous casting in late seventies and now the adoption of thin slab casting has resulted in energy saving. Today the continuously cast steel output is 66%.

7. Reducing coke consumption in blast furnaces and improving productivity - Indian blast furnaces used to consume as high as 850 kilograms of coke per tonne of hot metal and Blast Furnace productivity were hovering at less than one tonne per cubic meter per day. Introduction of modern technologies and practices viz. high top pressure, high blast temperature, pulverized coal injection, attention on burden preparation & distribution, and higher use of sinter in place of lumps have resulted in reduced coke consumption and improved productivity. Today, coke rate in some of the blast furnaces is less than 500 kg/ tonne hot metal & productivity exceeding 2 tonne per cubic meter per day.

8. Enhancing steel quality - Earlier the steel making furnaces used to complete the steel making within the furnaces itself. With the introduction of modern steel making technologies/practices and secondary refining technologies such as ladle metallurgy, vacuum degassing etc., it is now possible to produce steel of much lower inclusion and much lower content of oxygen, nitrogen and hydrogen. The ladle furnace technology has also made it possible to cut down the steel making time in converters or Electric Arc Furnaces and enable to produce steel of low sulphur and phosphorus content.

9. Efforts to reduce energy consumption and emissions - Iron and Steel making involves energy intensive processes. The international norm of energy consumption is 4.5 to 5 Giga calories per tonne of crude steel. With setting up of modern equipments and beneficiation of raw materials, Indian Steel plants have been able to achieve energy consumption at the level of 6.5 to 8.5 Giga calories only. Further, steps are being taken to achieve much lower energy consumption and corresponding lower Green House Gas (GHG) emissions by the end of 11^{th} Five Year Plan. With the growth of steel industry, increasing attention is being paid to environment management. Steps such as afforestation, installation of pollution control equipments etc. are likely to abate the pollution emanating from steel industry. Further, the Indian iron and steel industry is now taking the advantages of Clean Development Mechanism under the Kyoto Protocol thereby reducing pollution and energy consumption.

9.6.1 Directory of ENCON measures by the Indian Steel Industry

In Indian steel industry, the specific energy consumption ranges from 25.5 GJ/ tcs to 34.2 GJ/ tcs, depending on the process & product produced. Average SEC of Steel Industry in India is 30 GJ/ tcs as compared to 26 GJ/ tcs of US & 18 GJ/ tcs of Japan. Over the years, a number of energy conservation measures have been taken by each plant.

A Important energy conservation schemes implemented/under implementation are listed below :

1. Fabrication and erection of thyrister control for 800 tonnes shear in Blooming and Billet mill (BSP).
2. Installation of energy efficient dry fog dust suppression system in Blast Furnace stock house (BSP).
3. Installation of side burner in Furnace of Rail Mill (BSP).
4. On-line sealing of steam blast and gas leakage (DSP).
5. Insulation of steam lines and other hot surfaces (DSP).
6. Commissioning of alternate Blast Furnace gas line for Blast Furnace stoves (RSP).
7. Steam impingement on sinter bed introduced in both the strands of Sinter plant (RSP).
8. Commissioning of vapour absorption chiller in Coal Chemicals Department (RSP).
9. Change over from 9-2 pushing series to 5-2 pushing series(BSL).
10. Resumption of coal dust injection in Blast Furnace after capital repair (BSL).
11. Installation of 18 kW motors in place of 24 kW motors in 92 nos. of bases in Annealing Line of Cold Rolling Mill (BSL).
12. Installation of electronic belt weigh feeder at coal handling bunker (IISCO).
13. Conversion of four stroker type boilers at Power House from coal firing to By Product Gas firing thereby reducing the coal consumption in power generation (TISCO).
14. Increased recovery of LD gas from a level of 37 Normal cubic metre per tonne of crude Steel to a level of 56 Normal cubic metre per tonne of crude Steel. The recovered LD gas is mixed with BF gas for utilisation at Power Houses (TISCO).
15. Installation of variable frequency drive to reduce electrical energy consumption (TISCO).
16. Increase in high top pressure at E Blast Furnace, thereby increasing the blast furnace productivity and reduction in blast furnace coke rate (TISCO).
17. Installation of Top Recovery Turbine at H Blast Furnace (TISCO).
18. Modification in LD gas network to recover additional LD gas from another LD Shop (TISCO).
19. Split blowing at Blower Houses to reduce steam consumption for blast furnace blowing (TISCO).
20. Introduction of COREX Technology for Iron Making (JSW).
21. The first 1.2 MTPA non-recovery coke ovens with stamp charging and co -generation of 85 MW waste heat power (JSW).
22. Main gates and street lights are replaced by solar lights (JSL).
23. Installation of air-preheaters in waste heat recovery boilers (JSPL).

24. Installation of dual fired boiler (1×63 TPH) substituted coal by Blast Furnace Gas partially (JSPL).
25. Installation of non-recover type, environmental friendly coke oven plant(JSPL).
26. Replacement of petro-fuel by producer gas (JSPL).
27. Introduction of metallurgical coke fines in Electric Arc Furnace by coke injector as cheap substitute of CPC (JSPL).
28. Waste heat recovery boilers (WHRB) installed to utilise sensible heat of off-gas of DRI-Kilns to generate extra electrical power emission (JSPL).
29. Other conventional energy saving measures adopted are :
    a) LD Gas recovery,
    b) 100% Continuous Casting,
    c) Highest hot charging of slabs,
    d) Coal injection in Blast Furnaces,
    e) High Hot blast Temperature in stoves

9.7 Details of the World's Best Processes

9.7.1 Blast Furnace- Basic Oxygen Furnace (BOF) Route

During the ironmaking process, sintered or pelletized iron ore is reduced using coke in combination with injected coal or oil to produce pig iron in a blast furnace. Limese is added as a fluxing agent. Reduction of the iron ore is the largest energy-consuming process in the production of primary steel. The best practice blast furnace is a modern large scale blast furnace. Fuel injection rates are similar to modern practices found at various plants around the world. The highlights of the process are given below :-

Blast Furnace and BOF

- Fuel injection rate approx. 125 kg/t hot metal
- Oxygen is used for enrichment
- Pressurized operation for blast furnace at four bar
- Power recovery using Top Gas Power Recovery Turbine (wet type)
- Heating efficiency of hot gas stoves is maintained at around 85% using staggered parallel operation of 3 to 4 stoves per furnace.
- Scrap input typically 10% - 25% in BOF Process
- BOF gas and sensible heat recovery

Coke Plant

- Electrical exhausters are installed
- VFDs for motors and fans
- Coke Dry Quenching (CDQ) saves additional 1.44 GJ/t (49 kgce/t) coke (kgce = kilograms coal equivalent)

Sinter Plant

- Coke and breeze is used as fuel and gas as ignition furnace fuel
- Moving Grate technology is used
- Waste heat recovery from sinter exhaust cooler

9.7.2 Smelt Reduction - Basic Oxygen Furnace Route

Smelt reduction processes are the latest development in pig iron production and omit coke production by combining the gasification of coal with the melt reduction of iron ore. Energy consumption is reduced because production of coke is abolished and iron ore preparation is reduced.

Currently, the COREX process (Voest-Alpine, Austria) is commercial and operating in South Africa, South Korea and India, and under construction in China. The COREX process uses agglomerated ore, which is pre- reduced by gases coming from a hot bath. The pre-reduced iron is then melted in the bath. The process produces excess gas, which is used for power generation, DRI - production, or as fuel gas.

The best practice values for the COREX plant are based on the commercially operating plant at POSCO's Pohang site in Korea. The plant coal consumption is around 100 kgce/t (Kg Coal Equivalent), 75 kWh/t (9.2 kgce/t) hot metal electricity and 526 Nm^3/t hot metal of oxygen. It exports offgases with an energy value of 13.4 GJ/t (457 kgce/t) hot metal.

9.7.3 Direct reduced Iron (DRI) - Electric Arc Furnace (EAF) Route

DRI, Hot Briquetted Iron (HBI), and iron carbide are all alternative iron making processes. DRI, also called sponge iron, is produced by reduction of the ores below the melting point and has different properties than pig iron. DRI serves as a high-quality alternative for scrap in secondary steelmaking.

In the EAF steelmaking process, the coke production, pig iron production, and steel production steps are omitted, resulting in much lower energy consumption. To produce EAF steel, scrap is melted and refined, using a strong electric current. DRI is used to enhance steel quality or if high quality scrap is scarce or expensive. Several process variations exist using either AC or DC currents, and fuels can be injected to reduce electricity use.

The best practice EAF plant is state-of-the-art facility with eccentric bottom tapping, ultra high power transformers, oxygen blowing, and carbon injection. The furnace uses a mix of 60% DRI and 40% high quality scrap. The high DRI charge rate limits the feasibility of fuel injection. The best practice excludes scrap preheating, although this is used in large scale furnaces.

The best practice DRI-scrap-fed EAF consumes a mix of 60% DRI and 40% scrap. It consumes 530 kWh/t (65 kgce/t) liquid steel for the EAF and 65 kWh/t (8 kgce/t) liquid steel for gas cleaning and ladle refining, as well as 8 kg/t liquid steel of carbon. Installing a scrap preheater reduces power use in the EAF by 40 kWh/t (4.9 kgce/t) liquid steel, reducing total electricity use to 555 kWh/t (68.2 kgce/t) liquid steel.

9.7.4 Scrap - Electric Arc Furnace Route

In the EAF steelmaking process, the coke production, pig iron production, and steel production steps are omitted, resulting in much lower energy consumption. To produce EAF steel, scrap is melted and refined, using a strong electric current. Several process variations exist, using either AC or DC currents and fuels can be injected to reduce electricity use.

The EAF is equipped with eccentric bottom tapping, ultra high power transformers, oxygen blowing, full foamy slag operation, oxy-fuel burners, and carbon injection.

The "best practice" DRI-scrap-fed EAF consumes 100% scrap. It consumes 409 kWh/t (50.3 kgce/t) liquid steel for the EAF and 65 kWh/t (8 kgce/t) liquid steel for gas cleaning and ladle refining, as well as 0.15 GJ/t (5.1 kgce/t) liquid steel of natural gas and 8 kg/t liquid steel of carbon. Installing a scrap preheater would reduce power use in the EAF by 70 kWh/t (8.6 kgce/t), reducing total electricity use to 404 kWh/t (49.6 kgce/t) liquid steel.

9.7.5 Casting

Casting can be either continuous casting or thin slab/near net shape casting. Best practice continuous casting uses 0.06 GJ/t (2.0 kgce/t) steel of final energy. Energy is only used to dry and preheat the ladles, heat the tundish, and for motors to drive the casting equipment. Thin slab/near net shape casting is a more advanced casting technique which reduces the need for hot rolling because products are initially cast closer to their final shape using a simplified rolling strand positioned behind the caster's reheating tunnel furnace, eliminating the need for a separate hot rolling mill. Final energy used for casting and rolling using thin slab casting is 0.20 GJ/t (6.9 kgce/t) steel.

9.7.6 Rolling & Finishing

Hot Rolling

Rolling of the cast steel begins in the hot rolling mill where the steel is heated and passed through heavy roller sections to reduce the thickness. Best practice values for hot rolling are 1.55 GJ/t (53.0 kgce/t), 1.75 GJ/t (59.6 kgce/t), and 1.98 GJ/t (67.5 kgce/t) of steel of final energy for rolling strip, bars, and wire, respectively.

The best practice values assume 100% cold charging, a walking beam furnace with furnace controls and energy efficient burners, and efficient motors. Hot charging and premium efficiency motors may further reduce the rolling mill energy use.

Cold Rolling

The hot rolled sheets may be further reduced in thickness by cold rolling. The coils are first treated in a pickling line followed by treatment in a tandem mill. The best practice final energy intensity for cold rolling is 0.09 GJ/t (3.0 kgce/t) steam, fuel use of 0.053 GJ/t (1.8 kgce/t) and electricity use of 87 kWh/t (10.7 kgce/t) cold rolled sheet, equivalent to 0.47 GJ/t (13.7 kgce/t) cold sheet.

Finishing

Finishing is the final production step, and may include different processes such as annealing and surface treatment. The best practice final energy intensity for batch annealing is steam use of 0.173 GJ/t, fuel use of 0.9 GJ/t and 35 kWh/t of electricity, equivalent to 1.2 GJ/t (41.0 kgce/t). Best practice energy use for continuous annealing is assumed to be equal to fuel use of 0.73 GJ/t, steam use of 0.26 GJ/t, and electricity use of 35 kWh/t, equivalent to final energy use of 1.1 GJ/t (or 38.1 kgce/t). Continuous annealing is considered the state-of-the-art technology, and therefore assumed to be best practice technology.

While the data describes best practices in energy efficiency for key processes, the integration of these individual technologies is key to obtain the full benefits of these technologies. For example, combined heat and power would increase the efficiency of steam supply for the described processes, while by-product energy flows may also be used more efficiently by implementing more efficient technologies (e.g. use of blast-furnace gas in a combined cycle instead of a boiler). Tables 9.6 and 9.7 below summarize the Energy Intensity Values of the Best Plants based on International Iron & Steel Institutes (IISI) Eco Tech Plant & All Tech plants in U.S.

Table 9. 6 : Summary of World Best Practice "Final Energy Intensity Values" for Iron & Steel Sector

Iron and Steel	Unit	GJ/t	kgce/t
Technological Process			
Blast Furnace – Basic Oxygen Furnace –Thin Slab Casting Slab Casting	steel	14.8	504.5
Smelt Reduction – Basic Oxygen Furnace – Thin Slab Casting	steel	17.8	606.4
Direct Reduced Iron – Electric Arc Furnace – Thin Slab Casting	steel	16.9	576.2
Scrap - Electric Arc Furnace – Thin Slab Casting	steel	2.6	87.5

Source : LBNL; Environment Technologies Division; Feb'2008 by WorrellE., Price L., Neelis M., Galitsky C., Nan Z.)

Table 7 : Summary of World Best Practice "Primary Energy Intensity Values" for Iron & Steel Sector

Iron and Steel	Unit	GJ/t	kgce/t
Technological Process			
Blast Furnace – Basic Oxygen Furnace– Thin Slab Casting	steel	16.3	555.1
Smelt Reduction – Basic Oxygen Furnace– Thin Slab Casting	steel	19.2	656.8
Direct Reduced Iron – Electric Arc Furnace – Thin Slab Casting	steel	18.6	635.8
Scrap - Electric Arc Furnace – Thin Slab Casting	steel	6.0	205.1

(Source : LBNL; Environment Technologies Division; Feb'2008 by Worrell E., Price L., Neelis M., Galitsky C., Nan Z.)

9.8 World's Best Practices of Energy Efficiency

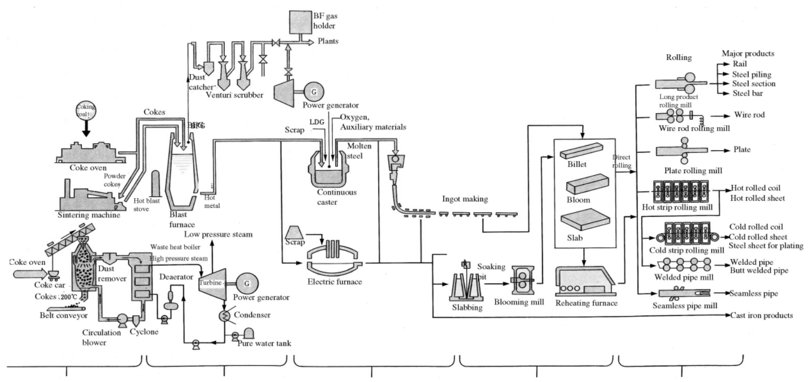
Some important measures of energy conversation in different processes taken by Steel Industry Internationally are highlighted in this section.

- **Sintering process**
  - Heat recovery from hot pallets is utilized to generate low temperature steam, which is used in turbo blower.
  - Waste heat is recovered from cooler boiler
  - VFD is used for speed control of dust collecting blower and boiler water feed pump
  - Steam vapour is used for preheating the sinter.
  - Complete heat balance is done in the sintering process.
- **Coking process**
  - Coal is converted to coke by nitrogen injection process
  - Coke dry quenching (CDQ) is done and the steam and CO gas is recovered.
  - Moisture in coke is controlled by tube type dryer utilizing low temperature steam recovered in CDQ.
  - Sensible heat of gas (CO) recovered from CDQ is used to generate steam, which is used in turbo - blower or moisture control equipment.
  - Moisture is reduced from 8% - 10% to 5% - 7% to increase the density. About 5°C difference moisture control in coal increases the productivity directly by +5%.
  - Exhaust gas heat is recovered from coke oven.
  - Complete heat balance of coke oven is done.
- **Blast furnace and Iron making process**
  - Electric power conservation of dust collector and blower by use of VFD.
  - High temperature and pressure of dust collector is used for generating power by top gas pressure recovery turbine (TRT).
  - Waste heat is recovered from hot stove and it is used for heating combustion air.
  - Granulated slag waste heat recovery is done.
  - Reuse of dust as raw material in blast furnace (reduction in energy consumption in 0.4%).
  - Prevention of molten iron temperature drop by using torpedo car.
  - Complete heat balance of blast furnace and hot stove is done.
- **DRI Process**
  - Optimization of fixed carbon / iron (C/Fe) in the range of 0.40 -0.42.
  - Consistency in ash percentage of coal.
  - Modification of equipments and reduction in motor rating.
  - Optimization of operating parameters.
  - Use Proper capacity shell air fan.
  - Control in Carbon percentage in char (By-product) by efficient combustion.
  - Control of Carbon % in fly ash through better combustion in After Burning Chamber.
  - Effective, Efficient & Close monitoring of operating parameters.
- **Steel Melting Process**
  - Exhaust gas heat recovery from torpedo car and ladle.
  - Heat recovery from converter slag.
  - LD Converter Gas (Linz and Donawitz) sensible heat recovery.

  - Gas recovery from converter is done.
  - Continuous casting instead of ingots (transport without re-heating).
- **Rolling Process**
  - In re-heating furnace, the following are energy conservation measures:
  - Extraction of slab at low temperature.
  - Improvement of heat pattern
  - Computer aided furnace temperature control.
  - Proper upkeep of recuperator
  - Improvement of heat transfer through proper design
  - Optimisation of combustion air fan capacity
  - Hot direct rolling through continuous casting
  - Complete heat balance of reheating furnace
- In hot rolling process, the following energy conservation measures are adopted:
  - Increase productivity by improvement of coiler and strip cooling
  - Replacement of plunger pump (de-scaling pump).
  - Waste water heat recovery
- In cold rolling process, the following energy conservation measures are adopted:
  - Optimisation of motor cooling fan capacity
  - Replacement of plunge pump (de-scaling pump).
- In annealing process, the following energy conservation measures are taken:
  - Air and fuel preheating
  - Continuous annealing and process line.

The summary of the technological ENCON measures is diagrammatically shown in Fig. 9.1 below

Iron making process	Steel making process	Rolling Process



Technology

Improvement in segregated charging of sintering materials.

Coal drying and moisture control equipment for coke oven.

Coke dry quenching

Exhaust heat recovery system for sintered ore cooling equipment.

Sensible heat recovery from main exhaust gas of sintering machine.

Automatic combustion control of coke oven.

Blast furnace operation control system.

Blast furnace hot blast valve control system.

Blast furnace burden distribution control.

Technology

Pulverized coal injection for blast furnace.

BF top – pressure recovery turbine.

Technology

DC arc furnace with water cooled furnace wall.

Continuous casting machine.

High frequency melting furnace.

Channel induction furnace for cast iron melting.

Ferroalloy furnace for effective energy utilization.

Hot stove exhaust heat recovery equipment.

BOF exhaust gas recovery device (including sealed BOF)

BOF gas sensible heat recovery apparatus.

Raw material preheater for electric arc furnace.

Heating furnace with regenerative burners.

Ladle heating apparatus with regenerative burners.

Energy saving operation of electric arc furnace.

Technology

Hot charging and direct rolling mill.

Channel induction furnace for cast iron melting.

Ferroalloy furnace for effective energy utilization.

Heating furnace with regenerative burners.

High performance heating furnace.

Recovery of sensible heat from skid cooling water in heating furnace.

Descaling pump (conversion to plunger pump)

Operation Improvement of heat treatment furnace.

Technology

Continuous annealing line.

Convection heating type heat treatment furnace for wire rod coil.

Low temperature forge welded pipe production method.

High efficiency gas separation apparatus.

Centralized energy management. (Energy centre)

Figure 1 : Iron & Steel : Production Process and Energy Saving Technology

Source : Directory of Energy Conservation Technology in Japan: ECCJ)

9.9 Energy Efficient Technologies being used in Iron & Steel Industry in Japan

Case Studies for different sections are given below for different areas of Iron & Steel Production to finishing and general utilities including Centralized Power Plant (CPP) in an integrated Iron & Steel Plant.

9.9.1 Case Studies in Iron Making Area

Case Study 1 : Coal drying and humidity control equipment for coke oven

Brief

It is the equipment which reduces the humidity in the coal to be charged into a coke oven by heating in order to reduce fuel consumption in the coke oven. It reduces the heat consumption for carbonization and utilises a large amount of non-coking coal.

The charging amount of coal in a coke chamber is increased, and coke quality is improved by the increased density of coal charging.

Productivity is increased by about 5.9% when the water content is reduced by 2.9%.

Fuel consumption in the coke oven is reduced by heating the coal and reducing the humidity. Mainly, steam is used for heating coal.

	Before Improvement	*After Improvement*
Water Content in coal	*7% - 11%*	*6%*

Energy Saving

Energy saving: 40,000-80,000 kcal/t-coal (18,000 kcal/t-coal per 1% of water-content reduction).

Investment amount : Rs 800 Million for charge coal of 3,200 kt/year
Annual Savings : Rs 400 Million
Payback Period : 2 years

Case Study 2 : Coke Dry Quenching (CDQ)

Brief

This improvement is to use equipment which cools red hot coke produced in a coke oven by exchanging heat with inert gas in a sealed vessel, and recovers the heat as steam or electricity.
Coke production consumes 7-8% of the whole energy consumed in an integrated steel plant. About 45% of it is the sensible heat of red heat cokes coming out of coke ovens. Conventionally the red heat cokes which have the temperature of 1,000-1,200˚C, are cooled by water spray, and the sensible heat is dissipated into the atmosphere. Coke dry quenching is to recover this waste heat by performing heat exchange with inert gas such as combustion exhaust gas in a sealed vessel, heating the gas to about 800˚C, and generate steam by a boiler

	Before improvement	***After improvement***
Reduction of energy consumption kcal/T pig	*Base*	*291 x 10^3*

(Specification: Coke treating capacity 150t/h, Coke temperature 1200˚C, boiler efficiency 80%, BF coke ratio 480kg/t-pig)

Energy Saving

Investment amount	*: Rs 2.3 Billion*
Annual Savings	*: Rs 0.813 Billion*
Payback period	*: 3 years*

Case Study 3 : Automatic combustion control of coke oven

Brief

Program heating adjusts and optimizes the heating condition in each coking chamber in accordance with the state of coal carbonization. It saves energy by reducing coking energy consumption. It also improves the coke quality.

1) *Measurements are carried out on the flue temperature, generated gastemperature, red-heat coke temperature, exhaust gas composition, etc.*
2) *Electric valve controllers are installed on each of the existing adjusting cocks at the branches of the gas and air distribution piping, and the drafting pressure regulating waist dampers.*
3) *Combustion in each chamber is separately controlled in accordance with the conditions of the charged coal (charged volume, moisture content, etc.) and the operation (target time to finish heating, etc.).*
4) *The operation control system is integrated, which covers heating pattern control, air-fuel ratio control, program heating, charge scheduling, etc.*

Energy Saving

Amount of carbonization energy reduced: 40,000 kcal/ t-coal at coke production of 1,500 kt/ year.

Investment amount	*: Rs 160 Million*
Annual Saving	*: Rs 60 Million*
Payback period	*: 3 years*

Case study 4 : Exhaust heat recovery system for sintered ore cooling equipment

Brief

In this, the red-heat sintered ore, just after sintering, is air- cooled in the cooler. Sensible heat of hot exhaust gas from the cooler is recovered.

Sintered ore discharged from the sintering machine has the temperature of 500-750˚C, and cannot be transported directly to the blast furnace. Therefore, the air-cooling-type cooler is installed at the exit of the sintering machine. The sensible heat of the high-temperature part (250 - 450˚C) of the cooler exhaust gas is recovered as steam. The power generation system using low-volatile flon-based medium (florinol) has been developed and put to practical use.

Energy Saving

Reduction in crude oil equivalent	*: 3,500 (kL/y)*
Reduction in calorific value	*: 60,000 kcal/t-sinter*

Investment amount	*: Rs 800 Million*
Annual Saving	*: Rs 200 Million*
Payback period	*: 4 years*

Case Study 5 : Sensible heat recovery from main exhaust gas of sintering machine

Brief

In a sintering machine, fine iron ore is mixed with fine coke, powdered limese, etc., heated, and agglomerated into sintered ore, which is used as a blast furnace raw material. In this improvement, the main exhaust gas heat recovery and circulation process was adopted in addition to the cooler exhaust heat recovery. The main exhaust gas, which was previously dissipated into the atmosphere once its heat was recovered, is now returned back to the sintering machine, further enhancing the heat recovery efficiency.

In this process, using the waste heat boiler, the heat is recovered from the gas of the temperature of about 380˚C exhausted from the sintering machine, and then the gas is returned back to the sintering machine. By this method, the heat recovery is increased by about 30% and at the same time, emission of NOx, SOx, etc., into the atmosphere is reduced.

Energy Saving

Reduction in crude oil equivalent: 8,430 kL/y Reduction of 30,000 kcal/t-sinter at sinter production of 2,600,000 t/year.

Investment amount	*: Rs 160 Million*
Annual Saving	*: Rs 60 Million*
Payback period	*: 3 years*
Steam generation from boiler is 10 t/h	

Case Study 6 : Improvement in segregated charging of sintering materials

Brief

This is an improvement of the charging device in the sintering process. By uniformly charging the materials along the width of the sinter bed and optimizing the size segregation along the height, the yield and quality are improved, resulting in energy saving.

The improvement of segregated charging is to optimize the size distribution along the height of the sinter bed.

By this, the permeability increases, and the quality of the sintered ores in the upper layer is improved, resulting in the overall yield improvement.
Further, the return ores are reduced. Accordingly, the coke consumption is reduced and the energy saving effect is achieved.

Energy Saving

	Before improvement	After improvement	Crude oil equivalent
Specific coke consumption (kg/T-sinter)	Base	(-) 2.8	6,600 kL/y
Coal addition rate (%)	Base	(-) 0.54	1,200 kL/y

Investment amount : Rs 75 Million
Annual Saving : Rs 40 Million
Payback period : 2 years

Case Study 7 : Pulverised Coal Injection (PCI) system for blast furnace:

Brief

This is a technology to inject pulverized coal directly into a blast furnace through tuyeres in place of using coke. Energy to produce cokes (coking energy) is reduced.

- *Pulverized coal is injected into a blast furnace through tuyeres by a pulverized coal injection device.*
- *The type, size, etc. of pulverized coal injected differs by injection device and blast furnace.*
- *By improving the equipment and operation technology, injection of 50-200 kg/t-pig is now possible, resulting in a large energy saving.*

Energy Saving

At the pig iron production of 3,000 kt/year,
Reduction in crude oil equivalent: 19,460 kL/year at pulverized coal injection of 100 kg/t-pig, plus longer coke-oven life.
Reduction of energy consumption per tonne of pulverized coal: 600,000 kcal/t-coal, coal injection 300,000 t-coal/year
Investment amount : Rs 1.25 Billion
Annual Saving : Rs 0.4 Billion
Payback period : 3.1 years

Case Study 8: BF Top-Pressure Recovery Turbine (TRT)

Brief

A device which utilizes the furnace top gas pressure of a high pressure blast furnace for generating electric power by driving gas turbine.

The pressure of the BF gas (B gas) generated in a blast furnace is 2-3kg/cm^2 at the furnace top in high-pressure operation. In order to effectively utilize this gas in the downstream processes, conventionally its pressure was reduced by the septum valve after the dust was removed.

A top-pressure recovery turbine (TRT) utilizes this pressure and temperature, and recovers them as electricity by a gas turbine.

Energy Saving

Reduction in crude oil equivalent:29,000 - 39,000 kL/y at power generation of 18 MW and hot metal production of 3,000 kt/y, wet type.
Investment amount : Rs 600 Million
Annual Saving : Rs 360 Million
Payback period : 1.7 years

Case Study 9 : Hot stove exhaust heat recovery equipment

Brief

This is the equipment which improves the combustion heat efficiency and saves energy by preheating combustion air and fuel gas for a blast-furnace hot stove by utilizing the sensible heat of combustion waste gas exhausted from the hot stove.

1) *There are two types: one has separate heat exchangers for heat receiving and heat radiating, and heat medium is forced to circulate between the two; the other uses a regenerative heat exchanger and directly preheats combustion air*
2) *When preheating fuel gas, the type which has the heat exchangers completely separated is advantageous in view of safety, because fuel gas does not come in contact with high-temperature gas, and there is no danger of explosion.*

Energy Saving

Reduction in crude oil equivalent : 9,700 kL/y
Reduction of 30,000 kcal/s-t at crude steel production of 3,000 kt/y
(40 - 50% of the sensible heat of waste gas is recovered)
Investment amount : Rs 200 Million
Annual Saving : Rs 70 Million
Payback period : 3 years

Case Study 10 : Blast furnace hot blast valve control system

Brief

To improve the circumferential balance, hot blast control valves and their control system were adopted to individually control the hot blast flow rate at each of the tuyeres, hence saving energy.

The continuous control in accordance with the furnace condition was done with the help of hot blast control valves. Also, change in the fuel rate injection could be made possible.

Energy Saving

Energy saving	*: 134,000 kcal/t*	*For Production 3000 kt/y.*
Reduction in crude oil equivalent	*: 4,300 kL/y*	
Reduction in SOx, NOx	*: 47%*	
Investment amount	*: Rs 80 Million*	
Annual Saving	*: Rs 20 Million*	
Payback period	*: 4 years*	

9.9.2 Case Studies in Steel Making Area

Case Study 11 : Continuous Casting Machine

Brief

The continuous casting machine achieves large energy saving by eliminating some of the process steps. Molten steel is continuously charged into the mold. It is control-cooled from outside, and withdrawn as it is solidified from the surface and formed into semis. This machine eliminates the ingot casting, soaking, and slab or billet rolling, and achieves large reduction in fuel and power consumption.

Energy Saving

Reduction in crude oil equivalent : 25,940 kL/y
Reduction of 200,000 kL/t-steel at production of 1,200,000 t/year.
Investment : Rs. 32.5 Million for casting capacity of 1,200,000 t/year
Annual Saving : Rs 203 Million by energy saving and Rs 813 Million by yield improvement
Payback period : 2 months

Case Study 12: High frequency melting furnace

Brief

1) Frequency and power are selected, and the high frequency induction current, with enhanced current density which is 2 ~ 5 times higher than that of the low frequency method, is generated. This current generates heat by internal resistance of the material, and performs melting.
2) Steel and alloy steel are melted by the resistant heat generated by the induction current that flows in the steel itself.
3) Nonferrous metals and nonmetals are heated and melted by the conduction heat from the induction heating element such as graphite and metallic crucibles.

Energy Saving

Comparison of High-frequency and low-frequency melting furnaces

Furnace capacity: 3t	Low-frequency Melting furnace	High-frequency Melting Furnace	Energy-saving effect
Specific consumption (kWh/t)	719	630	12.3%
Melting speed (kg/h)	910	1550	Total production of a plant: Increase by 19.5%
Electricity (kW)	750	1500	Annual Electricity savings : Rs 3.6 Million

Investment amount : Rs 40 Million
Annual Saving : Rs 4 Million year by energy saving and Rs 8 Million by quality improvement
Payback period : 3 – 4 years

Case Study 13 : BOF Exhaust gas recovery device (including sealed BOF)

Brief

Exhaust gas generated during a BOF (Basic Oxygen Furnace) refining process is high-temperature gas containing mainly CO. A large volume of gas is generated intermittently. Energy of BOF exhaust gas is recovered and utilized.

1) For cooling and dust removing of BOF gas, there are two types of systems: combustion type (full-boiler type, half-boiler type) and non-combustion type (OG type) In the past, the combustion-type gas recovery system was the mainstream. At present, the non-combustion type recovery system is mainly used due to the fact that small-sized facilities can cope with BOFs which are getting larger and it can collect the combustion gas as well.
2) The recovered gas has the CO content of more than 60% and the heating value of about 2,000 kcal/Nm^3. It can be used as the fuel for boilers, rolling mills, and power generation plants.
3) Recently, the sealed-type OG method has been developed and is getting widely used, where the section between the furnace throat and the skirt is sealed during refining, in order to reduce the recovery loss of BOF gas.

It has following advantages compared with the combustion-type exhaust gas treatment method:

a) It is compact.
b) The construction cost is low.
c) The operation cost is low.
b) The efficiency of dust collection from the exhaust gas is high.
c) Recovered gas can be used as a clean fuel of a negligible sulfur content.

Energy Saving

Recovered energy from BOF exhaust gas is 2,00, 000 - 2,70,000 kCal per tonne of crude steel. The increased amount of BOF exhaust gas recovery by the sealed-type OG method is about 20,000 kcal per tonne of crude steel.

Investment amount : Rs 800 Million (BOF capacity 250 t/h)
The investment per unit BOF capacity (t/charge) is Rs 4 Million.

Case Study 14 : Ladle heating apparatus with Regenerative burners

Brief

Large Energy is saved by incorporating Regenerative burners into the apparatus to heat the refractories of a ladle which receives molten steel. It also prolongs the life of the ladle refractories.

A Regenerative burner system comprises of a pair of burners which burn alternately for a determined time period and function as a exhaust duct while not burning. The heat of the high-temperature exhaust gas is stored in the regenerator installed just after the burner, and the stored heat is used for preheating the combustion air.

	Before Improvement	After improvement	Remarks
Fuel consumption during heating (Nm^3 /h)	200	120	Fuel saving of 56%
Fuel consumption during soaking (Nm^3 /h)	200	70-80	
Refractory life of ladles	Base case	10% extension	

Energy Saving

Fuel saving of 56% corresponds to monthly consumption of 573 x 10^6 kcal.
Increase of electric power consumption by auxiliaries : 23.9 x 10^6 kcal per month.
Investment amount : Rs 10 Million
Annual Saving : Rs 4 Million
Payback period : 2.5 years (excluding the refractory life extension)

Case Study 15 : DC Arc Furnace with water cooled furnace wall

Brief

Large energy saving is achieved in an arc furnace which melts and refines ferrous materials such as steel scrap by changing its power source from the conventional 3-phase alternating current (AC) to the direct current (DC).

a. *The largest advantage of the DC arc furnace over the 3-phase AC arc furnace is that it can melt the materials uniformly.*
b. *In the DC arc furnace, the metal is melted and agitated by the electric current flowing through it and the magnetic field.*
c. *By adopting the water-cooled furnace wall, high-efficiency operation is achievable*
d. *Furnace maintenance materials are reduced.*

Energy Saving.

1) *Reduction in Specific power consumption : 5-10%.*
2) *Specific electrode consumption reduction : 40-50%.*

Investment amount : Rs 400 Million
Annual Saving : Rs 100 Million
Payback period : 4 years

Case Study 16 : Channel Induction Furnace for cast iron melting

Brief

Induction furnaces are two types: crucible type and channel type. The channel type is more widely used because of its higher overall heat efficiency. It can perform continuous operation and save energy. Energy saving can be achieved by conversion to channel type.

Energy Saving

	Before improvement (crucible-type)	**After improvement (channel-type)**
1. Power efficiency	60% - 80%	95% - 97%
2. Overall efficiency	55% - 65%	75% - 85%
3. Specific power consumption	High	Low
4. Need of heel	Not needed	Needed
5. Intermittent operation	Arbitrarily possible	Principally 2 shifts or continuous operation

Investment amount : Rs 40 Million
Annual Saving : Rs 12 Million
Payback period : 4 years

Case Study 17 : Ferroalloy furnace for effective energy utilization

Brief

The electric furnace for smelting HC-FeCr (high-carbon ferrochromium) refines chromium ore using coke as a reducing agent. However, as the ratio of fine chromium ore increased in recent years, permeability in the electric furnace decreased, and specific consumption of electric power and coke increased. The system described here reduces energy consumption for producing HC-FeCr and recovers the combustible exhaust gas.

When fine chromium ore is agglomerated and calcined into pellets by the annular furnace and the pellets are charged to the electric furnace in place of fine chromium ore, permeability in the furnace increases, which increases the heat exchange rate among charged materials, and decreases specific power consumption. Exhaust gas from the furnace is used as a fuel of the burner for pellet calcination. Excess gas is converted into steam, and steam purchase from outside is reduced.

Energy Saving

Reduction in crude oil equivalent : 12,570 tonnes/y.
When applied to 7 electric furnaces of more than 10,000 KVA each, reduction in crude oil equivalent is 87,990 tonnes/y.
Investment amount : Rs 400 Million
Annual saving : Rs 100 Million
Payback period : 4 years

Case Study 18 : Raw material preheater for Electric Arc furnace

Brief

In this system, the heat efficiency of the electric arc furnace is improved by utilizing the sensible heat of high-temperature exhaust gas from the electric furnace to preheat the scrap. Hence, its electric power consumption is reduced.

1) *With the 1-power-source 2-furnace method, the furnace itself is used for preheating the scrap instead of a scrap-charging bucket. While one furnace melts charged material, the other preheats the scrap. Scrap is heated to a higher temperature than by bucket preheating.*
2) *With the shaft-furnace method, scrap is preheated in the shaft furnace installed above the furnace*

Energy Saving

	Before improvement	**After improvement**
Exhaust Gas Temp.	500-1000˚C	150-400˚C

Reduction of specific power consumption : 60,000-80,000 kcal/t (20% of the total heat of the electric- furnace exhaust gas is utilized.
Electric power saving : 25-50 kwh/t-s
Shortening of the steelmaking time : 5-8 min./charge
Investment amount : Rs 400 Million
Annual Saving : Rs 100 Million
Payback period : 4 years (in the case of a 150t/charge furnace)

9.9.3 Case Studies in Rolling / Finishing of Steel

Case Study 19: Hot Charging and direct rolling mill

Brief

High-temperature semi-finished materials (slab, bloom, or billet) just after continuous casting (CC) is charged into the heating furnace with the temperature maintained as high as possible, thus reducing the fuel consumption at the heating *furnace. Further, by improving the measures for preventing the temperature drop of the semis after CC, the semis are directly sent to the rolling mill without going through the heating furnace, eliminating the heating process and substantially reducing the fuel consumption.*

Energy Saving

Reduction in crude oil equivalent : 16,200 kL/t Reduction of $50x10^3$ kcal/t by coupling direct rolling with hot charging at rolling of 3,000 kt/y.
Investment amount : Rs 200 Million
Annual Saving : Rs 100 Million
Payback period : 2 years

Case Study 20 : Descaling pump (conversion to plunger pump)

Brief

A descaling pump is used to apply high – pressure water jet to remove the scale during steel rolling operation. In order to reduce power consumption, various measures were taken, such as pressure and flow rate reduction. To achieve further power saving, the turbine pump was converted to the plunger pump.

Since high-pressure jet is applied intermittently in short duration, a plunger pump, which can perform no-load operation at a low pressure, significantly saves power consumption during the time when high-pressure water jet is not applied.

Energy Saving

		Before improvement	After improvement	Savings/ Improvement
Power consumption	Loaded	1930 kW	1890 kW	40 kW
	Unloaded	1210 kW	180 kW	1030 kW
Annual energy consumption		9456 MWh/y	3948 MWh/y	5508 MWh/y
Reduction in crude oil equivalent				1,338 kl/y

Investment amount : Rs 80 Million
Annual saving : Rs 30 Million
Investment payback : 2.5 years at 2750 L/min x 175 kg/cm^2 x 1 unit

Case Study 21 : Convection heating type heat treatment furnace for wire rod coil

Brief

To shorten the time required for annealing of wire rod coils a forced circulation fan was installed. The outside of the wire rod coils is heated by the radiation from the radiant tube heat source as well as by the convection heat transfer by the forced circulation fan installed at the top cover. Hot air is forced into the inside of the coils by the fan. It passes through among the individual strands of the coils, and heats up the coils. Forced convection heat transfer by the fan improves the heat transfer efficiency, shortens the treatment time, and saves energy. At the time of cooling, an indirect gas cooler is employed for rapid cooling, instead of the radiant tubes.

Energy Saving

Heating time reduced by approx. 2.5 hours

Cooling time reduced by approx. 3 hours
Fuel saving : 25%
Investment amount : Rs 80 Million
Annual saving : Rs 20 Million
Payback period : 4 years

Case Study 22 : Low temperature forge welded pipe production method

Brief

Electro-magnetic induction heating (an edge heater) was introduced in forge-welded pipe production, and the temperature of steel hoops at the exit of a continuous heating furnace was reduced from the previous high temperature (1300˚C) to 1200˚C, the edge being locally heated. Accordingly, specific fuel consumption of the heating furnace was reduced

1) *The automatic control system is introduced to control the edge to the constant temperature (an electro- magnetic induction heating method).*
2) *A seam cooling device is installed to eliminate the temperature difference in the circumference direction of pipes. The prevention of beading and bending is made possible.*
3) *The forge welding roll in the mill has a motor driven screw down mechanism to control the forge welding stress.*

Energy Saving

Reduction in crude oil equivalent : 7,500 kL/y
Reduction of energy consumption : 115 x 10^3 kcal/t at the production of 50,000t/m.
Investment Amount : Rs 500 Million
Annual Saving : Rs 160 Million
Payback period : 3.5 years

Case Study 23 : Energy saving operation of Electric Arc Furnace

Brief

An example of the operation improvement which targets at the reduction of electric power consumption of small and medium size electric arc furnaces is as follows :

1) *Use of a basic melting furnace*
   - Electric arc furnaces are divided into two types by the lining refractories they use: acidic furnace (MgO-based refractories) and basic furnace (SiO_2 - refractories). The acidic furnace merits because of low power consumption and short melting time. On the other hand, it has a difficulty in removing harmful elements such as P and S, and therefore it has the limitation in the types of steel it can produce.
   - One of the furnaces was remodeled to an acidic type to deal with return scrap which contains relatively smaller amounts of P and S, and power saving was achieved.
2) *Shortened melting time by eliminating intermediate analysis*
   - Earlier, for the purpose of checking the compositional specification in the arc furnace, composition analyses were performed four times: at melt down, at oxidation finishing, at the intermediate time, and in the ladle. It was

confirmed that the elimination of the intermediate analysis does not cause quality problems. The elimination shortened the melting time by about 5 minutes, and saved energy consumption by about 20 kWh/t.

Energy Saving

Annual energy consumption	*: 2,460 x 10^3 kwh*
Annual Reduction in crude oil equivalent	*: 600 kL*
Investment amount	*: Rs 4 Million*
Annual Saving	*: Rs 4 Million*
Payback period	*: 1 year*

9.9.4 Case Studies in General Utilities and CPP

Case Study 24 : Heating furnace with Regenerative burners

Brief

A regenerative combustion system uses a pair of Regenerative burners, in each of which a burner for combustion and a regenerator for heat storing are incorporated. Each of the pair is used for combustion and heat storing alternately. It is a highly efficient combustion system which can recover more than 85% of the waste heat. A system is so constructed that one burner performs combustion and the exhaust gas from the combustion is led to the opposite side burner.

Energy Saving

Reduction of specific fuel consumption	*: 10-30%.*
Investment amount	*: Rs 12 Million per pair of burners*
Annual Saving	*: Rs 4 Million*
Payback period	*: 3 years*
Combustion volume	*: 5,000 x 10^3 kCal/piece*

Case Studies 25 : Recovery of sensible heat from skid cooling water in heating furnace

Brief

Skid beams in a heating furnace are cooled by passing water through their insides. Previously the cooling water was sent to a cooling tower and circulated. This improvement is to supply pure water as cooling water in place of previous industrial water, and recover the heat as steam of 12 kg/cm^2.

The inner temperature of the furnace is about 1300˚C. Skid beams are used as heat transfer tubes of a boiler. A steam – water separation drum is installed outside the furnace, where steam is generated, recovering the heat.

Energy Saving

Recovery amount of steam	*: 9 t/h x 12 kg/cm^2*
Annual Recovered heat in crude oil equivalent:	*23,000 kL at operation of 7900 tonne*
Investment amount	*: Rs 750 Million*
Annual Saving	*: Rs 280 Million*
Payback period	*: 3 years*

Case Study 26 : Control of excess air by installing O_2 monitoring system in high-pressure boiler of CPP in a steel plant.

Brief

Presently, there is no monitoring of O_2 in flue gases of this boiler, which is used, in captive power plant of steel plant. Without this, optimization of efficiency of boilers is not possible, especially when quality of coal and boiler load is also changing.

By continuous monitoring & controlling the excess air & maintaining the % O_2 below 6%, the efficiency of boiler can be improved from 79.1% to 83.5%. Further improvement of boiler efficiency is possible by taking care of the unburnt carbon in ash.

Energy Saving

The following table summarizes the overall effect of O_2 monitoring & control effect on boiler performance :

Parameter	***Existing condition***	***After installing O_2 monitoring & control system***
%O_2	*13.7*	*6*
Excess air, %	*189.6*	*40*
Boiler efficiency, %	*79.1*	*83.5*
FD Fan airflow, Nm^3/h	*264607*	*127558*
ID fan airflow, Nm^3/h	*317528*	*153069*

Annual hours of operation HP-1 boiler = 4350 hours
Average steam generation = 73.6 TPH (average during trials)
Annual saving in fuel input =

$$\frac{\text{Steam flow x Enthalpy of steam}}{\text{GCV of coal}} \times \left(\frac{1}{Eff_1} - \frac{1}{Eff_2}\right) \times \text{Annual operating hours}$$

Where Eff_1 = Existing efficiency of boiler, Eff_2 = Likely efficiency of boiler after modifications in control

$$\text{Annual saving in coal} = \frac{73.6 \times 639 \times (1/0.79 - 1/0.84) \times 4350 \text{ tonne}}{3825}$$

$$= 3563 \text{ tonnes}$$

(Price of Coal : Rs. 1000 per tonne)

Annual Saving	*: Rs 3563 x 1000 = 3.56 Million*
Investment amount	*: Rs 0.5 Million*
Payback period	*: 2 month*

Case Study 27 : Use of variable frequency drives on FD fans and ID fans in place of existing inlet

Brief

It was recommended to install VFDs in FD & ID fans for energy saving. After implementing the O_2 monitoring system as explained above, the following operating parameters observed on FD and ID fans on boiler – 1 are given below :

	Before improvement	After improvement
Rating of FD fans kw)	275x2	250x2
Rating of ID fans (kw)	310x2	250x2
FD fan air flow (Nm^3/h)	264607	127558
ID fan air flow (Nm^3/h)	317528	153069

Energy Saving

Assuming 25% time operating each at 60%, 70%, 80% and 90% of rated flow, energy savings are calculated as shown below:

Annual Saving per fan= 2,20,000 kWh/ year : Rs 0.55 Million
Total energy cost saving for 4 nos. fans : Rs 2.2 Million
Investment : Rs 6 Million (for 4 nos. motors):
Payback period : 3 years

Case Study 28: Reduction of number of stages of pump from existing 7 stages to 5 nos. stages

Brief

By reducing the number of stages of feed pumps (2 nos) from 7 stages to 5 stages, there will be a drop of head by 30 kg/cm^2, which is still higher than the rated one by 15 %. This will reduce the power by about 400 kw.

Energy Saving

	Before improvement	After improvement
No. of stages of pumps	7	5
Head (mwc)	750	450
Power input (kw)	1900	1500
Pump efficiency (%)	72	72
Flow (m^3/h)	490	490

Annual Saving : 32,00,000 KWh (at 8000 hrs. operation)
Annual monetary saving : Rs 8 Million
Investment amount : Rs 1.2 Million
Payback period : 1 month

Case Study 29 : Installation of appropriate/ smaller capacity CW pumps in CPP of steel plant

Brief

At present, the throttling valves are used to throttle the flow upto 50 %. By installing the pumps of smaller capacity, a lot of power can be saved.

Particulars	TG-4	TG-5
Design cooling water flow requirement for condensers	6800 m^3/hr	6800 m^3/hr
Cooling water flow rate at present (combined for two pumps)	5340 m^3/ hr	5188 m^3/ hr
Rated flow rate of the proposed individual pump	3500 m^3/ hr	3500 m^3/hr
Actual power drawn by two pumps at present	725 kW	700 kW
Estimated power drawn by each pump	327 kW (654 kW for two pumps)	327 kW (654 kW for two pumps)
Reduction in the power drawn	71 kW	46 kW
Combined efficiency of the proposed pump/ motor	70%	70%

Energy Saving

Annual energy saving : 93,6000 kWh
Annual Saving : Rs 1.872 Million
Investment amount : Rs 1.5 Million
Payback period : 10 months

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