Tables & Figures

Table 7.1.1. *Industrial Sector Final Energy, Primary Energy, and Energy-Related Carbon Dioxide Emissions, 10 World Regions, 1971-2002.*
Source: Price *et al.*, 2005a.

	Final Energy (EJ)			Primary Energy (EJ)			Energy-Related Carbon Dioxide ($MtCO_2$)		
	1971	**1990**	**2002**	**1971**	**1990**	**2002**	**1971**	**1990**	**2002**
Pacific OECD	6.02	7.44	10.08	8.40	10.57	13.27	529.3	639.1	798.7
North America	20.21	19.18	22.05	25.90	26.17	31.58	1,532.5	1,492.9	1,692.7
Western Europe	14.78	14.89	16.07	19.71	19.61	21.68	1,404.0	1,176.1	1,150.7
Central and E. Europe	3.78	4.62	2.62	5.29	6.72	4.72	397.5	484.8	311.6
Former Soviet Union	11.22	18.59	9.36	13.87	22.98	16.36	962.6	1,464.7	1,004.4
Centrally Planned Asia	5.12	14.17	16.93	6.58	18.86	27.09	572.2	1,559.2	2,274.1
Other Asia	2.21	5.48	9.24	2.74	7.52	14.59	138.1	448.0	963.6
Latin America	2.78	5.94	7.45	3.43	7.43	12.91	170.2	325.8	644.5
Sub Saharan Africa	1.25	2.13	2.40	1.86	2.95	4.75	117.7	179.7	305.9
Middle East and N. Africa	0.83	3.60	5.66	1.05	4.31	9.99	62.7	237.6	575.6
World	68.20	96.04	101.87	88.83	127.12	156.94	5,886.7	8,007.8	9,721.7

Note: Biomass included

Table 7.1.2. *Projected Industrial Sector Final Energy and Energy-Related Carbon Dioxide Emissions, Based on SRES Scenarios, 2000-2030. Source: Price et al., 2005a.*

A1 Scenario

	Final Energy (EJ)			Primary Energy (EJ)			Energy-Related Carbon Dioxide ($MtCO_2$)		
	2000	**2010**	**2030**	**2000**	**2010**	**2030**	**2000**	**2010**	**2030**
Pacific OECD	9.95	8.50	8.10	13.72	11.50	11.39	774.3	896.5	681.1
North America	23.09	26.18	29.55	31.36	32.43	33.76	1661.0	1,819.4	1,585.4
Western Europe	16.21	17.62	21.25	21.03	24.31	29.94	1107.7	1,322.7	1,216.9
Central and E. Europe	2.76	6.68	8.76	3.83	8.28	11.75	256.4	532.3	553.9
Former Soviet Union	9.41	23.82	31.24	13.03	29.68	42.12	800.5	1,820.0	1,893.7
Centrally Planned Asia	15.67	28.60	46.32	24.57	37.14	63.88	2012.2	3,321.7	4,483.3
Other Asia	8.66	16.27	36.26	12.75	21.95	45.67	765.5	1,755.9	3,274.3
Latin America	7.54	19.98	35.57	9.72	25.69	42.86	429.3	1,505.0	2,326.1
Sub Saharan Africa	2.28	6.85	13.62	3.26	10.71	21.15	194.6	750.8	1,296.3
Middle East and N. Africa	5.38	16.17	32.17	6.79	22.78	44.97	364.1	1,421.2	2,454.0
World	100.96	170.67	262.83	140.06	224.47	347.50	8365.7	15,145.7	19,764.9

Note: Biomass included

B2 Scenario

	Final Energy (EJ)			Primary Energy (EJ)			Energy-Related Carbon Dioxide ($MtCO_2$)		
	2000	**2010**	**2030**	**2000**	**2010**	**2030**	**2000**	**2010**	**2030**
Pacific OECD	9.95	9.00	8.17	13.72	12.89	10.97	774.3	926.5	650.4
North America	23.09	19.54	21.06	31.36	27.46	27.01	1,661.0	1,836.1	1,652.8
Western Europe	16.21	13.98	13.39	21.03	18.35	16.54	1,107.7	1,248.6	1,066.0
Central and E. Europe	2.76	3.06	4.48	3.83	4.00	5.59	256.4	294.2	382.1
Former Soviet Union	9.41	11.49	15.41	13.03	14.18	18.97	800.5	985.3	1,088.7
Centrally Planned Asia	15.67	25.55	37.81	24.57	31.50	47.58	2,012.2	2,549.2	3,301.7
Other Asia	8.66	12.91	26.01	12.75	16.77	32.43	765.5	1,135.0	1,862.9
Latin America	7.54	10.45	16.62	9.72	13.93	22.14	429.3	839.8	1,107.8
Sub Saharan Africa	2.28	2.54	9.25	3.26	3.75	12.21	194.6	243.5	622.3
Middle East and N. Africa	5.38	7.66	11.77	6.79	11.13	16.80	364.1	714.0	975.1
World	100.96	116.18	163.96	140.06	153.96	210.25	8,365.7	10,772.2	12,709.9

Note: Biomass included

Table 7.1.3. *Projected Industrial Sector Emissions of Non-CO_2 Gases, $MtCO_2$-eq.*
Source: US EPA, 2006.

	1990	**2000**	**2010**	**2020**
Industrial sector				
Pacific OECD	38.7	83.0	106.0	128.9
North America	145.0	178.0	248.0	369.7
Western Europe	156.4	114.7	145.0	173.1
Central and Eastern Europe	27.4	16.0	20.7	24.9
Former Soviet Union	39.0	22.8	29.9	38.1
Centrally Planned Asia	19.8	24.3	48.9	68.6
Other Asia	4.3	9.9	16.0	23.0
Latin America	2.6	6.7	23.4	36.6
Sub Saharian Africa	28.3	85.9	156.9	222.3
Middle East and North Africa	16.7	28.7	53.7	71.8
World	478.2	570.1	848.6	1,157.1

Table 7.2.1. *Industrial Technology for Reducing Greenhouse Gas Emissions*

Sector	Energy Efficiency		Fuel Switching		Power Recovery	Renewable Energy		
	Sector-wide	Process Specific	Sector-wide	Process Specific	Sector-wide	Process Specific	Sector-wide	Process Specific
Iron & Steel	Motor systems (compressed air, pump, fan), efficient boilers, efficient burners, heat recovery, efficient lighting, efficient HVAC, efficient office equipment, energy management systems and practices	Smelt reduction, near net shape casting, scrap preheating, efficient furnace, dry coke quenching	Coal to Natural Gas	Natural Gas, Plastic Injection BF	Cogeneration	Top-gas pressure recovery, coke oven gas Combined Cycle	Biomass boiler fuel, biogas from anaerobic digestion or gasification, PV on roof, wind turbines	Charcoal
Non-Ferrous Metals		Inert anode, efficient cell designs						
Chemicals		Efficient furnaces, process integration, membranes, reactive distillation		Natural gas		Pre-coupled gas turbine, pressure recovery turbine		
Cement		Precalciner kiln, roller mill, fluidized bed kiln		Natural gas, waste fuels, biogas, biomass		Drying with gas turbine fluegas, bottom cycle using kiln exhaust		Biomass fuels, biogas
Glass		Oxyfuel furnace		Natural gas in furnace		Pre-coupled gas turbine		n/a
Pulp & Paper		Efficient pulping technology, efficient drying, condebelt drying, shoe press		Biomass, landfill gas		Black liquor gasification combined cycle		Biomass fuels (bark, black liquor)
Electronics		Continuous melt silicon growth				RT-power recovery		n/a
Food		Efficient drying, membranes				Anaerobic digestion, gasification		Biomass, by-products, solar drying
Non-metallic minerals		Roller kiln		Landfill gas		n/a		Biogas, wood

Table 7.2.1 continued

Sector	Feedstock Change	Product Change	Material Efficiency	Non-CO_2 GHG	CO_2 sequestration
Iron & Steel	Scrap	High Strength steel	Recycling, high strength steel, reduction process losses	n/a	CO_2/O_2 combustion of blast furnace and BOF-gas
Non-Ferrous Metals	Scrap		Recycling, thinner film and coating	PFC-controls	
Chemicals	Recycled plastics, bio-feedstock	LLDPE, high-performance plastics	Recycling, thinner film and coating, reduction process losses	N_2O controls (nitric acid, nylon), PFC, CFC, HCFC controls	Ammonia, ethylene oxide
Cement	Slags, fly-ash, ground limestone	Geo-polymers			CO_2/O_2 combustion in kiln
Glass	100% cullet for glass container, recycling flat glass	high-strength thin containers	Re-usable glass containers		CO_2/O_2 combustion
Pulp & Paper	Recycling, non-wood fibers	Fiber orientation to increase strength, thinner paper	Reduction cutting and process losses		
Electronics				PFC, SF6 controls	
Food			Reduction process losses, filtering waste water		
Non-metallic minerals	wood chips in clay	Hollow bricks			

Table 7.4.1. *Emission Reduction Potential for Major Energy Conservation Technologies in the Iron and Steel Industry*

($Mt\text{-}CO_2$/Yr.)	**CDQ**	**TRT**	**CC**	**BOF recovery**	**Total**
North America	3	5	0	2	10
Europe	5	5	1	4	15
FSU	4	3	8	2	17
South Korea	0	0	0	1	1
China	17	25	2	7	51
India	1	3	1	1	7
Other Developing	4	8	1	3	16
Total	34	49	13	20	117

CDQ = Coke dry quenching
TRT = Blast furnace top gas pressure recovery turbine
CC = Continuous casting
BOF recovery = Basic oxygen furnace process gas recovery

Potential: + = 0-0.1 MtC/yr; ++ = 0.1-03. MtC/yr; +++ = 0.3-1 MtC/yr; ++++ = >1 MtC/yr

Table 7.4.2. *Emission factors and estimated global emissions from electrode use and reductant use for various non-ferrous metals.* ***Indirect emissions and non-CO_2 greenhouse gas emissions are not included.*** *After: Sjradin (2003).*

	Specific CO_2-emissions (tCO_2/t product)[4]	World CO_2-emissions (kt CO_2)	Comment
Primary aluminium [1]	1.55	44,700	Not considering significant electricity consumption and PFC emissions
Titanium dioxide	0.49	900	
Ferrosilicon	2.92	10,500	
Silicon metal [2]	4.85	3,500	
Calcium silicon	2.71	n.a.	
Ferromanganese [2]	1.79	1,205	
Silicomanganese [5]	1.66	5,800	
Ferrochromium	1.63	9,500	
Ferrochromiumsilicon	2.82	(incl. in FeCr)	
Lead	0.64	3,270	
Nickel	0	0	Exothermic reduction process from sulfide ores - some fossil fuel use
Ferronickel	1.36	1,150	
Magnesium	0.05	4	Not considering significant electricity consumption and SF_6 emissions
Tin	1.12	280	
Zinc	0.43	3,175	
Copper	0.18[4]	2,480	Indicative estimate – range of processes and fuels. USGS-Production data
Chromium	0	0	Alumino-themic reduction using aluminium metal dominates – limited
Calcium carbide	1.10	4,475	
Silicon carbide	2.30	n.a.	
TOTAL:		91,000	

[1] Production values taken from BREF, 2001 (World value is only: Russia, US, Poland and South Korea)
[2] Silicon metal is usually about one-fifth of world production of ferrosilicon (Jones, 1998)
[3] ImnI, 2002
[4] All emission factors (except for copper) are NEAT values as reported by Sjradin (2003). n.a. – production data not available.

Table 7.4.3. *Greenhouse gas emission from production of various non-ferrous metals*

Metal	Global Annual Emissions, Mt CO_2-eq./yr.	Source and Year
Aluminium		
CO_2-Mining and Refining	109	IEA GHG, 2001 for 1995
CO_2-Electrodes	45	Sjardin, 2003 for 1995
PFC-Emissions	50	IAI, 2001 for 2000
CO_2-Electricity	300	IEA GHG, 2001 for 1995
Magnesium		
CO_2-Electrode and Cell-Feed	4	Sjardin, 2003 for 1995
SF_6-Casting	16	US-EPA, 2001 for 2000
CO_2-Electricty	unknown	
CO_2-Other steps of production process	unknown	
All other Non-Ferrous-Metals		
CO_2-Process	40	Sjardin, 2003
CO_2-Electricty	unknown	
CO_2-Other steps	unknown	
All non-ferrous-metals	560 (lower bound)	

Table 7.4.4. *Technical Potential for CO_2 Emission Reduction in the Paper and Pulp Industry*

Region	Production in 2000	Projected Production in 2030	Estimated Reduction Potential in 2030
Pacific OECD	+++	+++	++
North America	++++	+++	+++
Western Europe	+++	+++	+++
Central and Eastern Europe	+	+	+++
Former Soviet Union	+	+	+

Centrally Planned Asia	+++	+++	++++
Other Asia	++	+++	++++
Latin America	++	+++	++++
Sub-Saharan Africa	+	+	+
Middle East and North Africa	+	+	+

Production: + = 0-10 Mt/yr; ++ = 10-30 Mt/yr; +++ = 30-100/yr; ++++ = >100 Mt/yr
Potential: + = 0-1 MtC/yr; ++ = 1-3 MtC/yr; +++ = 3-10 MtC/yr, ++++ = > 10 MtC/yr

Table 7.5.1. *CO_2 Emissions Reduction Costs and Potential for the Industrial Sector*

Region or Country	Sector	Total Potential Abatement ($MtCO_2$/yr)	Total Potential Abatement (% below baseline)	Net Direct Costs (US$(2000)/ tCO_2 avoided)	Model Type	Baseline	Discount Rate Used	Potential Type	Source
2030									
World	Total industry	573	10%	n/a	BU	BAU	n/a	Enhanced market	IEA, 2004
OECD	Total industry	133	7%	n/a	BU	BAU	n/a	Enhanced market	IEA, 2004
Transition	Total industry	76	12%	n/a	BU	BAU	n/a	Enhanced market	IEA, 2004
Developing	Total industry	364	12%	n/a	BU	BAU	n/a	Enhanced market	IEA, 2004
APEC	Steel	945	19%	n/a	TD	BAU	n/a	Enhanced market	Heaney *et al.*, 2005
2025									
U.S.	Total industry	235	10%	n/a	BU*	BAU	n/a		US EIA, 2005
2020									
U.S.	Total industry	414	22%	n/a	BU*	BAU	n/a	Enhanced market	IWG, 2000
U.S.	Total industry	167	8%	n/a	BU*	BAU	n/a		US EIA, 2005
China	Total industry	1283	30%	n/a	BU	BAU	n/a		State Council, 2004
South Africa	Total industry	24		-8	BU**	BAU	10%	Enhanced market	Howells *et al.*, 2005
U.S.	Steel	24	18%		BU*	BAU	~14%	Enhanced market	IWG, 2000
China	Steel	15	3%	n/a	BU	BAU	n/a		Zhou, 2003
China	Aluminum	7	21%	n/a	BU	BAU	n/a		Zhou, 2003
U.S.	Paper	41	41%	n/a	BU*	BAU	n/a	Enhanced market	IWG, 2000
China	Paper	25	21%	n/a	BU	BAU	n/a		Zhou, 2003
U.S.	Cement	15	20%	n/a	BU*	BAU	n/a	Enhanced market	IWG, 2000
India	Cement	21	14%	n/a	BU	Frozen	n/a	Enhanced market	Sathaye *et al.* 2005
China	Bldg materials	53	14%	n/a	BU	BAU	n/a		Zhou, 2003
U.S.	Non-energy-	345	30%	n/a	BU*	BAU	n/a	Enhanced	IWG, 2000

int	market

Notes: * = U.S. EIA's National Energy Modeling System, ** = Markal model

Table 7.5.1. *Continued*

Region or Country	Sector	Total Potential Abatement ($MtCO_2$/yr)	Total Potential Abatement (% below baseline)	Net Direct Costs (US$(2000)/ tCO_2 avoided)	Model Type	Baseline	Discount Rate Used	Potential Type	Source
2014									
South Africa	Total industry	20		-34	BU**	BAU	10%	Enhanced market	Howells *et al.*,2005
2012									
India	Total industry	57						Tech/econ	TERI, 2005
India	Steel	14						Tech/econ	TERI, 2005
India	Cement	5						Tech/econ	TERI, 2005
India	Fertilizer	14						Tech/econ	TERI, 2005
2010									
Europe	Total industry	395	22%		BU	Frozen	4%	Economic	EC, 2001
U.S.	Total Industry	392	20%		BU*	BAU	~14%	Enhanced market	IWG, 2000
U.S.	Total industry	99	5%	n/a	BU*	BAU	n/a		US EIA, 2005
China	Total industry	480	15%	n/a	BU	BAU	n/a		State Council, 2004
Mexico	Total industry	38.1		-27.3 to -33.6 (1994US$)	BU	Frozen	n/a		Scheinbaum *et al.*, 2000
U.S.	Steel	22	16%		BU*	BAU	~14%	Enhanced market	IWG, 2000
China	Steel	11	2%		BU	BAU			Zhou, 2003
China	Aluminum	4	13%		BU	BAU			Zhou, 2003
U.S.	Paper	43	40%		BU*	BAU	~14%	Enhanced market	IWG, 2000
China	Paper	17	19%		BU	BAU			Zhou, 2003
U.S.	Cement	9	11%		BU*	BAU	~14%	Enhanced market	IWG, 2000
China	Bldg materials	45	10%		BU	BAU			Zhou, 2003
EU	Ammonia	0.3	1%		BU	BAU			Rafiqul *et al.*, 2005
U.S.	Ammonia	1.2	4%		BU	BAU			Rafiqul *et al.*, 2005
India	Ammonia	2.5	7%		BU	BAU			Rafiqul *et al.*, 2005
U.S.	Non-energy-int	199	19%		BU*	BAU	~14%	Enhanced market	IWG, 2000

Notes: * = U.S. EIA's National Energy Modeling System, ** = Markal model

Table 7.10.1. *Greenhouse Gas Mitigation or Energy-Efficiency Programs of Selected Countries*

Category of Ancillary Benefit	Examples
Health	Reduced medical/hospital visits, reduced lost work days, reduced acute and chronic respiratory symptoms, reduced asthma attacks, increased life expectancy
Emissions	Reduction of dust, CO, CO_2, NO_x, SO_x; reduced environmental compliance costs
Waste	Reduced use of primary materials; reduction of waste water, hazardous waste, waste materials; reduced waste disposal costs; use of waste fuels, heat, and gas
Production	Increased product output or yield; improved product quality or purity; improved equipment performance and capacity utilization; reduced process cycle times; increased production reliability; increased customer satisfaction
Operation and maintenance	Reduced wear on equipment; increased facility reliability; reduced need for engineering controls; lower cooling requirements; lower labor requirements
Working environment	Improved lighting, temperature control and air quality; reduced noise levels; reduced need for personal protective equipment; increased worker safety
Other	Decreased liability; improved public image; delayed or reduced capital expenditures; creation of additional space; improved worker morale.

Source: Aunan *et al.*., 2004; Pye and McKane, 2000; Worrell *et al.*., 2003

Figures

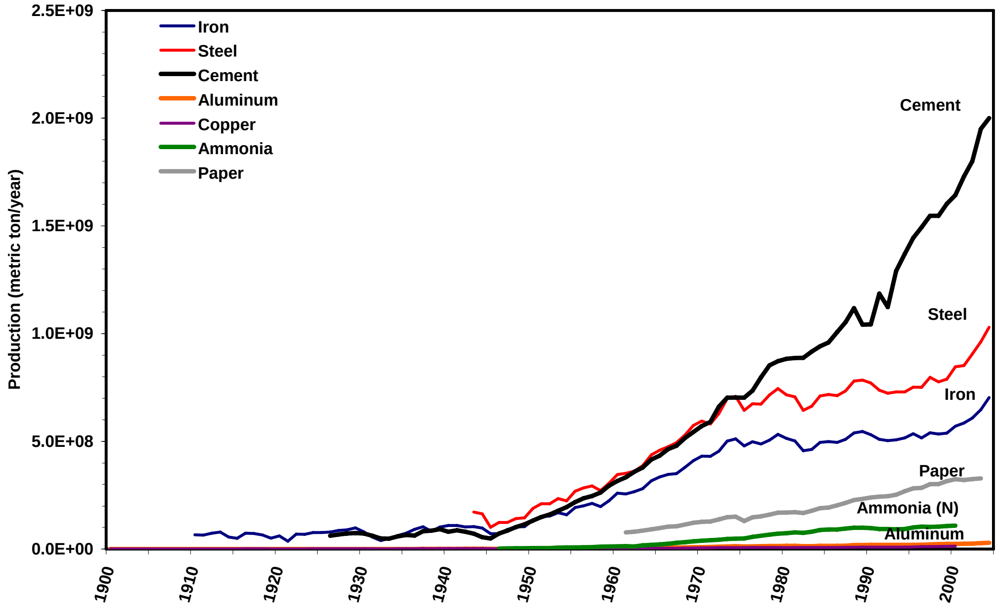

Figure 7.1.1. *Annual production of major GHG-intensive industrial products (in tonnes/year). Statistics on the aluminum, cement iron, and steel are provided by the USGS2004, Ammonia by the IFA, 2005 and FAO, 2005.*

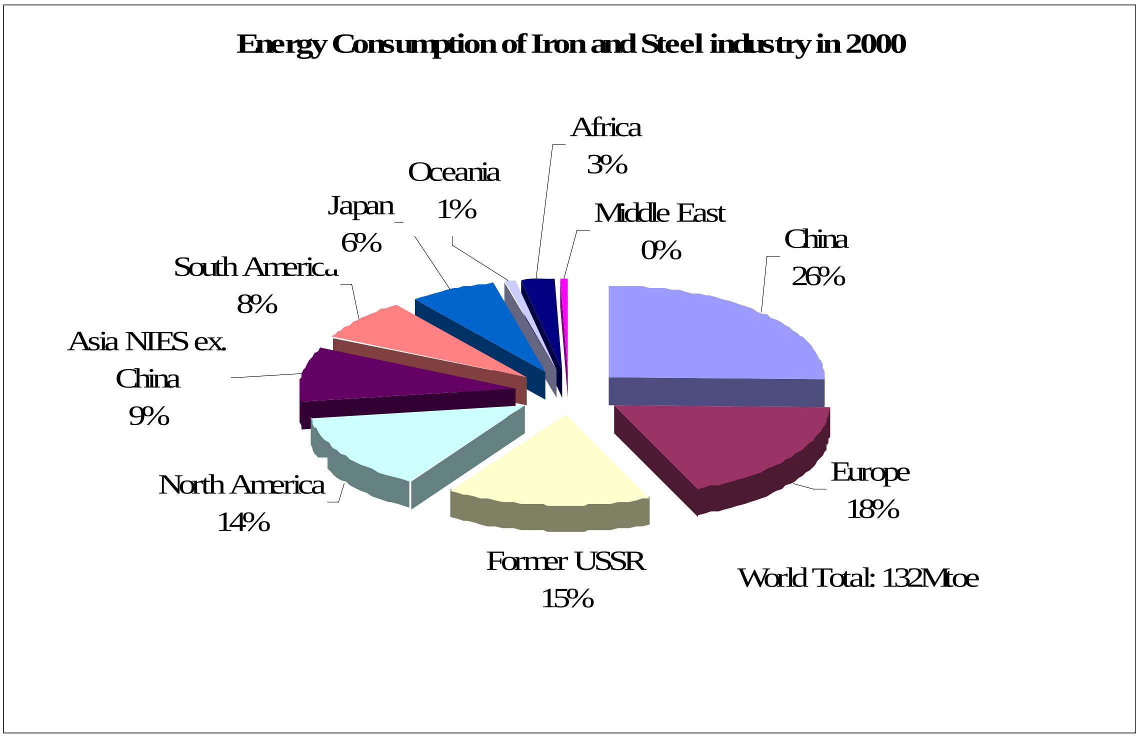

Figure 7.4.1. *Energy Consumption by the Steel Industries of the World (IEA, 2002)*

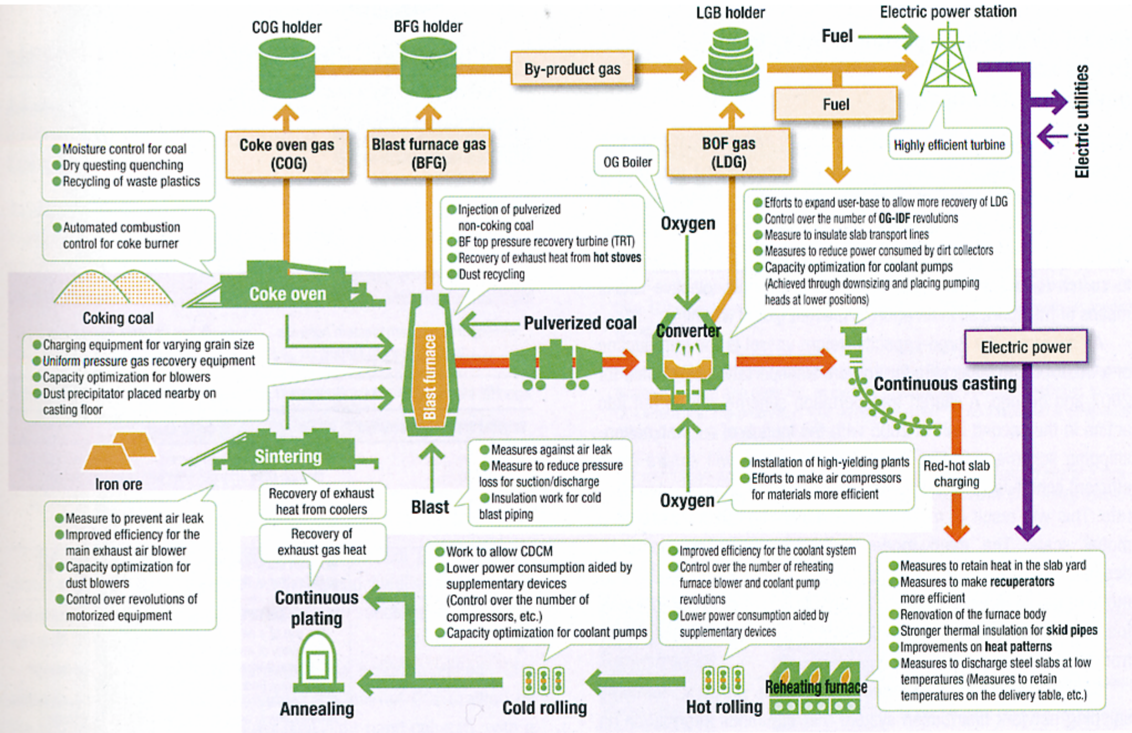

Figure 7.4.2. *Options for efficiency improvement in the iron and steel industry.*
(Nippon Steel Corporation, 2004)

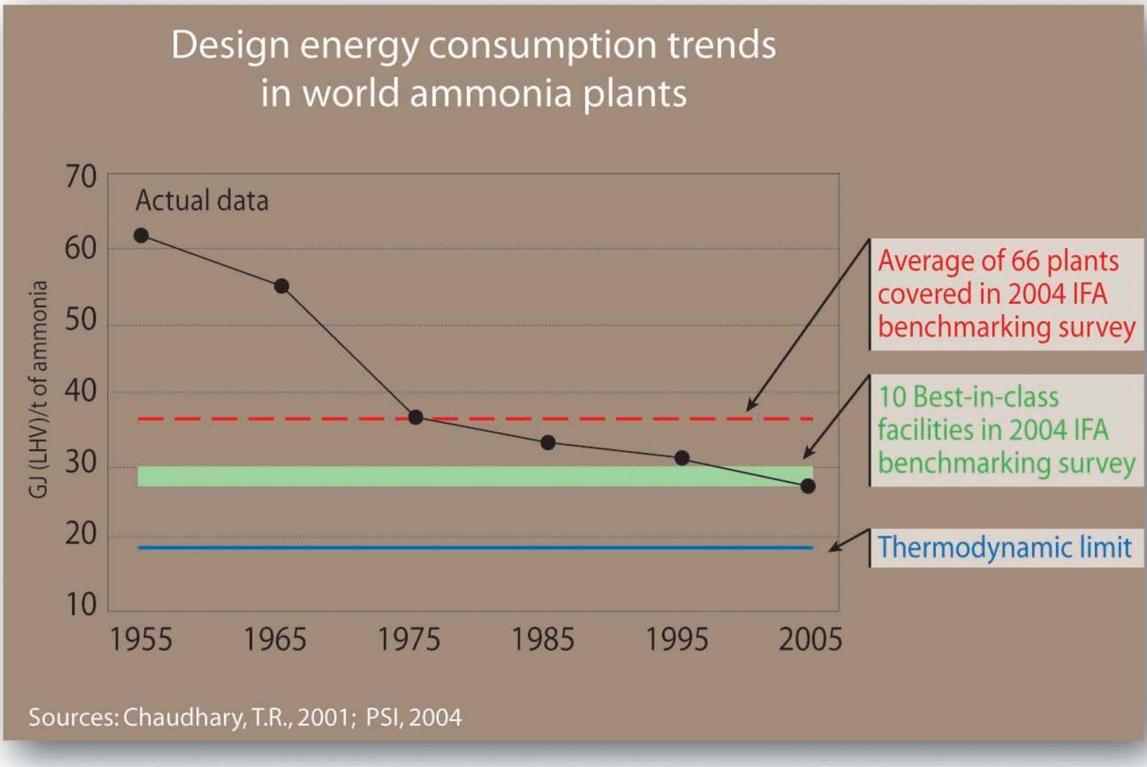

Figure 7.4.3. ***Energy efficiency improvement in ammonia plants***