NIMS-EMC MDE Report No.4
LCA-Based Investigation of Technological Scenarios of Expanding Use for Iron Scrap in Converter and Electric Furnace and the Consumption Trend of Iron Scrap

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Summary

If iron scrap, which is expected to increase in the future, is to be smelted in converters and electric furnaces, the prices of iron scrap and blast furnace pig iron will be very important considerations. However, putting aside the problem of prices, we will compare and investigate CO_2 loading for the following three technical scenarios using the life-cycle assessment, LCA.

Scenario 1: Iron Scrap content of electric furnaces is raised to 100%. .

Scenario 2: Share of electric furnace-based production is increased by 10% over its current level.

Scenario 3: Iron Scrap content of converter furnaces is increased by 10% over the current level.

Investigations revealed that in Scenario 1, little iron scrap would be loaded into the furnace, there would be little contribution to CO_2 reduction, and it would be technologically impractical. In Scenario 2, the amount of iron scrap put into the furnace would be the greatest, but there would be little reduction of CO_2 emissions. Moreover, even if the increase of the production capacity of the electric furnace would be technically feasible, there would be problems with reactivating the electric furnace industry. In Scenario 3, there would be much iron scrap loaded into the furnace, and the CO_2 reduction effect was twice as great as in Scenario 2. Given the outlook for advances in separation technology and quality improvements in iron scrap due to expectations for recycling, this is the most promising of the three scenarios for full-scale loading into converter furnaces, both from technical and LCA perspectives.

Next, production trends for iron scrap in various fields over the past 10 years were analyzed, and the quantity of surplus iron scrap around the year 2010 was considered. From 1990 until the present, supply has been exceeding consumption by about 5 million tons. What's more, it is predicted that raw iron scrap will have added about 3 million tons to this total sometime around 2010. Therefore, it appears that around 2010, there will be about 8 million tons of surplus iron scrap.

1. Introduction

The 21st century has heralded a new age for the world's steel industry. It has been growing at a rapid pace in Asia, particularly China. At the same time, the Japanese steel industry, which has state-of-the-art technology, a stable domestic production infrastructure, and a strong steel-exporting capacity, is also expected to grow in importance. The scrap collected by the steel industry has been resmelted in a built-in process, making it a valuable resource. Thus, when considering trends in the Japanese steel industry, it is important to consider trends in iron scrap over the past 10 years. Presently, a large amount of iron scrap is produced in Japan, roughly equivalent to 35% of raw steel production, and it appears that the increase in stockpiles will be accompanied by an increase in the generation of iron scrap.

Given the premise that there will be an increasing amount of iron scrap loaded into converter and electric furnaces as a technological choice, this report uses LCA to investigate consequent changes in CO_2 emissions in various production systems. However, the problems and issues associated with the loading of massive amounts of iron scrap, quality of scrap, etc., require a detailed analysis that is outside the realm of this report. It should also be noted that trends in the generation in iron scrap were analyzed for primarily the past 10 years in an effort to predict the amount that will be generated in the fiscal year 2010.

2. LCA-Based Investigation of Technological Application Scenarios of Surplus Iron Scrap

2.1 LCI on a process-by-process basis for steel production

The LCI (Life Cycle Inventory) for materials used in the steel-making process such as sintering, pellet-making and coke-burning, as well as for the various unit raw steel production processes from converter and electric furnaces and pig iron from blast furnaces, was derived sometime around 1995 by the Committee for Assessing Environmental Load of the Society of Non-Traditional Technology[1). The committee's data for raw material unit processes of the sintering, pellet-making, coke-burning, pig iron, and converter and electric furnaces, original fuel units, and the gases produced during the various processes are shown in Table 1.

Table 1 Original units in the unit processes of steel production

Item	Unit	Sintering	Pellet	Coke	Pig iron	Converter	Electric furnace
Produced COG	m^3			408.2			
Produced BFG	m^3				1,554.9		
Produced LDG	m^3					106.2	
Produced FEG	m^3						3.2
Pig iron	kg					1,031.6	62.9
Coke	kg	44.9	8.5	1.4	427.6	3.3	6.4
Sintering ore	kg				1,239.8	1.8	
Pellet	kg	2.8			121.2		
Iron scrap	kg				0.1	9.9	29.4
Steel scrap	kg				0.2	70.7	994.1
Iron ore	kg				264.2	14.6	
Limestone	kg	140.8	29.2		1.8	2.0	0.4
Dolomite	kg	4.9	52.4		0.2	6.6	0.3
Electrode	kg						2.7
Kerosene	l						2.8
Light oil	l						
Heavy oil A	l			0.1		0.1	1.4
Heavy oil B	l						0.1
Heavy oil C	l		0.5		0.2		0.1
Hydrocarbon oil	l			2.8			
LPG	kg				0.2	0.7	0.1
Petroleum coke	kg			8.7	1.9		0.5
Coal for coke	kg			1,451.0	21.4		
Coal without coke	kg	7.8	18.8		70.4	2.4	

Coke oven gas	m^3		13.6	59.9	19.7	4.5	1.0
Blast furnace gas	m^3	1.7		575.2	385.1	0.1	
Converter gas	m^3	0.6		9.3	16.1	0.1	0.1
Electric furnace gas	m^3	0.2					
LNG	m^3						0.2
City gas	m^3				0.2		0.5
Oxygen	m^3				19.7	59.5	31.9
Private power generation	kWh	11.1	19.7	11.1	23.3	28.7	156.9
Utility power	kWh	25.6	45.3	25.6	38.9	21.5	337.7

Table 2 shows the CO_2 emission coefficients per unit of fuel and unit of electrical power used in this report.

Table 2 CO_2 emission coefficients

Item	Unit	Kg-CO_2/unit
Limestone	kg	0.435
Dolomite	kg	0.471
Kerosene	l	2.492
Light oil	l	2.710
Heavy oil A	l	2.848
Heavy oil B	l	2.986
Heavy oil C	l	3.223
Hydrocarbon oil	l	3.002
LPG	kg	3.311
Petroleum coke	kg	2.464
Coal for coke	kg	2.506
Coal without coke	kg	3.251
Coke oven gas	m^3	0.850
Blast furnace gas	m^3	0.880
Converter gas	m^3	1.531

Electric furnace gas	m^3	1.571
LNG	m^3	2.692
City gas	m^3	2.108
Electrode	kg	3.667
Privately-generated power	kWh	0.602
Purchased electric power	kWh	0.378

Table 3 shows the kilograms of CO_2 emitted per ton of product produced in the steel unit processes described in Tables 1 and 2. It should be noted that the boundary conditions here for calculating CO_2 emissions are based on the estimates for Japanese domestic production. In other words, these figures do not include the environmental load resulting from the excavation and shipping of iron ore in other countries. The load created during steel production includes the load from raw materials such as coke, sintering ore, pellets, limestone, dolomite, electrical furnace electrode, etc., the load generated by the fuels used. The electric power load is estimated by dividing into power that is produced on site (privately produced), and power that is purchased. Gases produced in coke, blast, and converter furnaces are effectively used in other processes, so they were excluded from the load calculations. However, because the gases produced in electric furnaces are not used elsewhere, the amount of CO_2 emissions resulting from the consumption of electrodes, the main source of this gas, was calculated and included as load.

The amount of CO_2 emissions produced during the production of 1 ton of pig iron in a blast furnace was calculated to be 961 kg. Using 1,024 kg of pig iron and 80 kg of scrap to produce crude steel in a converter, the CO_2 load of the pig iron was assumed to be 961 kg, and the load from the scrap was zero, resulting in a reduction of CO_2 emissions from 961 kg to 884 kg. In contrast, 36 kg of pig iron and 1,000 kg of scrap would be used in an electric furnace, so the CO_2 emission would fall to 330 kg, a substantial decrease.

Table 3 Emissions kg-CO_2 per ton of steel produced in the unit process

Item	Unit	Sintering	Pellet	Coke	Pig iron	Converter	Electric furnace

Emitted gas, etc.							
Produced COG	m^3			-347			
Produced BFG	m^3				-1,404		
Produced LDG	m^3					-163	
Produced FEG	m^3						
Raw materials							
Pig iron	kg					991	60
Coke	kg	146	28	5	1,390	11	21
Sintering ore	kg				309	2	
Pellet	kg				19		
Iron scrap	kg						
Limestone	kg	61	13		1	1	
Dolomite	kg	2	25			3	
Electrode	kg						10
Fuels							
Kerosene	l						7
Light oil	l						
Heavy oil A	l						4
Heavy oil B	l						
Heavy oil C	l		2		1		
Hydrocarbon oil	l			9			
LPG	kg				1	2	
Petroleum coke	kg			29	6		2
Coal for coke	kg			3,575	53		
Coal without coke	kg	19	47		176	6	
Coke oven gas	m^3		12	51	17	4	1
Blast furnace gas	m^3	1		506	339		
Converter gas	m^3	1		14	25		

Electric furnace gas	m^3						
LNG	m^3						1
Propane gas	m^3						1
Electric power							
Private power generation	kWh	7	12	7	14	17	94
Utility power	kWh	10	17	10	15	8	128
Total		249	154	3,859	961	884	330

2.2 Comparison with the LCI reference values

Table 4 shows the emission kg- CO_2 per ton of produced steel in unit processes based on the initial units of the Committee for Assessing Environmental Load in comparison with the values of existing references.

The value for blast furnace pig iron destined for converter and electric furnaces is 916 kg in this report, but the data from the Japan LCA Forum[3)] shows 887 kg as the value of blast furnace pig iron for foundries.

The CO_2 emission for blast furnace-converter crude steel is 884 kg. This value is added to the CO_2 emissions for the cold rolling process when the yield is 87% for the process. Thus the total CO_2 emission is 1,231 kg for cold rolling steel sheets using the blast furnace-converter. There are 4 types of LCI data for this process: the CO_2 emissions from the database of the Japan LCA Forum are shown as 1,432 kg; Narita et al.[4)] show 2,410 kg; BUVAL's value[5)], based European data, for tinplate is 2,970 kg; and the CO_2 emission is 1,504 kg for blast furnace materials recommended by the Japan Society of Civil Engineering.[6)]

Table 4 Comparison with existing LCI reference values

Reference	Pig iron	Notes
NIMS	961	Pig iron for converter
LCA database	887	Pig iron for casting

Reference	Blast	Note	Electric	Note

	furnace-Converter		furnace	
NIMS	1.231	Cold rolling steel sheets	330	Raw steel for converter
LCA database	1,432	Cold rolling steel sheets	431	Bar steel
Narita & Inaba[11)]	2,410	Cold rolling steel sheets	530	Bar steel
BUVAL	2,970	Tinplate	1,260	Tinplate
Recommended value of the JSCE	1,504	Blast furnace materials	469	Pig iron for casting

The value of CO_2 emissions used in this report for blast furnace-electric furnace crude steel is 330 kg. For comparison, the steel bars data for electric furnaces from the LCA Forum shows 431 kg, while Narita et al. show 530 kg. The recommended value of the Japan Society of Civil Engineering for electric furnaces is 469 kg.

Perhaps the reason why the LCI values used in this report tend to be on the low side is because the boundary conditions were set for CO_2 emissions in Japan.

2.3 Status of materials loaded into converter and electric furnaces

The flow of pig iron and various scrap into converter and electric furnaces is shown in Figure 1 with the symbols used in this report.

Table 5 lists the production of pig iron, and crude steel from converter and electric furnaces for FY 2001. Pig iron production stood at 79 million tons. Crude steel included 94 million tons produced in converter furnaces, and 28 million tons in electric furnaces. Thus, converter furnaces accounted for 72.5% of crude steel production, or nearly 3 times as much as electric furnaces.

Figure 1　Flow of pig iron and scrap into converter and electric furnaces

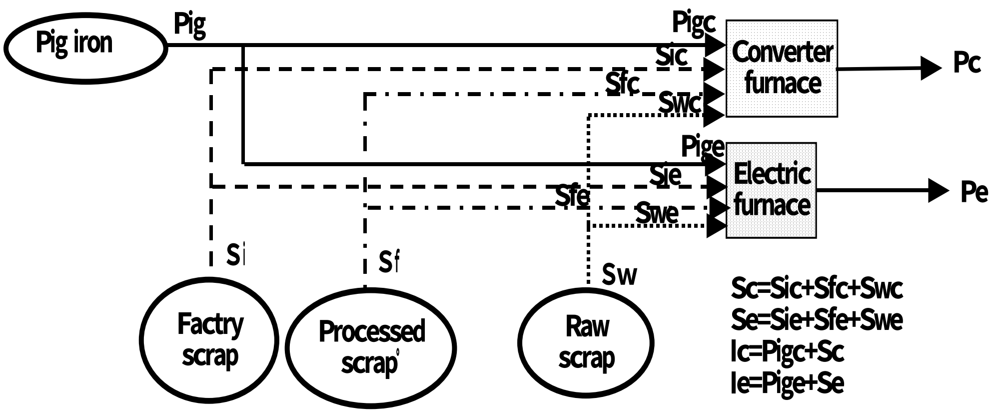


Table 5　Production results for pig iron and raw steel (FY 2001)

		Symbol	Unit/million ton	Market share
Pig iron	Pig iron for blast furnace	Pig	7.897	
Crude steel	Converter furnace	Pc	7.397	72.5%
	Electric furnace	Pe	2.809	27.5%
Casting		Scast	0.417	

As we can see in Table 6, about 79 million tons of pig iron is produced in Japan, and a mere 170,000 tons is imported. The vast majority of this pig iron, 76 million tons (93%) is consumed in converter furnaces, while only 1 million ton or so is consumed in electric furnaces. In addition, only 690,000 tons is destined for casting.

Table 6　Supply and demand of pig iron in Japan (FY 2001)

		Symbol	Unit/million ton	Composition(%)
Supply	Domestic Production		7,897	
	Imported		17	

Demand	Converter	Pigc	7,575	92.7
	Electric furnace	Pige	102	3.4
	Casting	Pigcast	69	

As we can see in Table 7, most of the supply of steel scrap is plant-generated (about 12 million tons), and the scrap purchased on the open market, (about 35 million tons). Only about 10,000 tons are imported. Six million tons of steel scrap is processed in converter furnaces, while the vast majority, 29 million tons or 96%, is processed in electric furnaces.

Table 7 Supply and demand of iron scrap (FY 2001)

		Symbol	Unit/million ton	Composition(%)
Supply	Factory scrap (plant-generated scrap)		1,228	
	Purchased domestic scrap		3,480	
	Imported scrap		1	
Demand	Scrap for converter	Sc	595	7.3
	Scrap for electric furnace	Se	2,895	96.6
	Scrap for casting	Scast	572	

The breakdown of factory scrap in Table 8 shows that blast furnace makers supply about 7.5 million tons, electric furnace makers provide about 2.5 million tons, and about 2.2 million tons come from foundry-based makers. About 3 million tons produced by blast furnace makers is processed in blast furnaces, while an estimated 4.5 million tons is processed in converter furnaces.

According to a questionnaire administered by the Japan Ferrous Raw Materials Association, scrap purchased on the open market is divided into processed and raw types, which account for 6.3 million tons and 280 million tons, respectively. Only about 10,000 tons of scrap is imported.

Table 8 shows the material flow for the pig iron and various types of scrap that were destined for converter and electric furnaces in FY 2001.

Table 8 Data on pig iron and steel scrap that were used in converter and electric furnaces in FY 2001

Ferrous raw materials	Supply	Demand	
Pig	7,746	Pigc	7.575
		Pige	102
I	11,081	Ic	8170
		Ie	2911
Si	685	Sic	440
		Sie	245
Sf	629	Sfc	155
		Sfe	474
Sw	2,851	Swc	0
		Swe	2090
S	4,165	Sc	595
		Se	2,090
Cs	10,206	Pc	7,397
		Pe	2,809

Unit: 10 thousand ton

About 75.75 million tons of pig iron are used in converter furnaces, and only 1.02 million tons in electric furnaces. Of the 7.55 million tons of iron scrap that is produced during the blast furnace-converter processing, 4.4 million tons are used in converter furnaces. The total for converter steel scrap is actually 5.95 million tons, but this includes 1.55 million tons of high quality processed scrap. Therefore, raw scrap is not used in converter furnaces. In electric furnaces, 28.95 million tons of scrap are processed, of which 2.45 million tons are made by the producer during the electric furnace processing. Assuming that of the 6.29 million tons of high quality scrap, 1.55 million tons are processed in converter furnaces and the remaining 4.74 million tons are consumed, then the consumption of raw scrap comes out to 20.9 million tons. Thus, of the 28.51

million tons of raw scrap that is available, about 7.6 million tons is surplus at the present time, and is destined for export. In FY 2001, the amount of exported scrap was 6.91 million tons.

Converter furnaces use 81.7 million tons of pig iron and scrap. Of this amount, 5.95 million tons are scrap, accounting for about 7.3% of the total. Electric furnaces use 29.11 million tons of pig iron and scrap, of which 28.09 million tons, or 96.5 %, is scrap.

2.4 LCA-based Analysis of technological application scenarios of surplus iron scrap

In this report, it is assumed that production of crude steel would not fluctuate much from the 2001 total of about 100 million tons. However, since Japanese steel production is being greatly affected by production in China and other Asian countries, there is a possibility that it will gradually decrease to about 95 million tons. If that is the case, then the amount of surplus iron scrap will gradually increase. Therefore, we should look at the amount of surplus iron scrap for technical applications in the steel industry as being roughly 8 million tons. In this report, LCA was used to consider production applications for about 8 million tons of iron scrap to investigate three technological scenarios for potentially reducing CO_2 emissions. These scenarios were all based on the following assumptions:

No. 1: Factory and processed scrap will continue to be generated in the current proportions in the production of crude steel.

No. 2: Production of crude steel for the next ten years will remain at the same level (100 million tons) as FY 2001.

No. 3: As long as they are not changed as factors being investigated, the scrap content and the production shares of converter and electric furnaces remain the same throughout.

No. 4: As society becomes more concerned with recycling, it will be incorporated into the design of steel products. At the same time, it appears that the project-to-project recycling process will be further developed and the quality of steel scrap will be improved.

Assume the following for the volume of CO_2 emissions, L_0, under the present production system, for pig iron consumed as an iron source in blast furnaces: 75.75 million tons for pig iron in converters (Pigc) and 1.02 million tons of pig iron in electric furnaces (Pige). The 102.06 million tons of crude steel (Cs) can be broken down into 73.97 million tons produced in converters (Pc) and 28.09 million tons in electric furnaces (Pe), giving a ratio of 72.5% for converters and 27.5% (Pe/(Pc+Pe)). Then including the CO_2 load of pig iron from blast furnaces (Lb), from converters (Lc), and from electric furnaces (Le), L_0 can be obtained from the following equation:

$$L_0 = Lb*(Pigc+Pige)+Lc*Pc+Le*Pe \qquad (1)$$

(1) Scenario 1: Scrap content of electric furnaces is increased to 100%

Assuming that the share of production in converters (Pc/(Pc+Pe)) is 72.5% and the ratio of scrap used in converters (Sc/(Pigc+Sc)) is 7.3%, if the ratio of scrap in electric furnaces (Se/(Pige+Se)) is increased from the current 96.5% to 100%, we can calculate how the CO_2 load will change from its present state.

Where,

Pc/(Pc+Pe) = 72.5% ＝ constant

Sc/(Pigc+Sc) = 7.3% = constant

Se/(Pige+Se) = 96.5-100% = variable (x).

The CO_2 emissions under Scenario 1 (L1), were calculated with Equation (2)

$$L1 = Lb*(Pigc + Pige(x)) + Lc*Pc + Le*Pe \qquad (2)$$

Table 9 shows the results of the calculations for variable pig iron content of blast furnaces when scrap content of electric furnaces (Pige(x)) was increased, and changes in the amount of surplus scrap that was loaded.

Table 9 Effects of scrap content of electric furnaces on CO_2 emissions (Scenario 1)

Assumption 1: The amount of factory scrap in converter and electric furnaces and processed scrap are proportional to the production amount of crude steel produced.

Assumption 2: Production of crude steel up to 2010 remains at the same level (102.06 million tons) as FY 2001.

<Assumptions of the calculations>

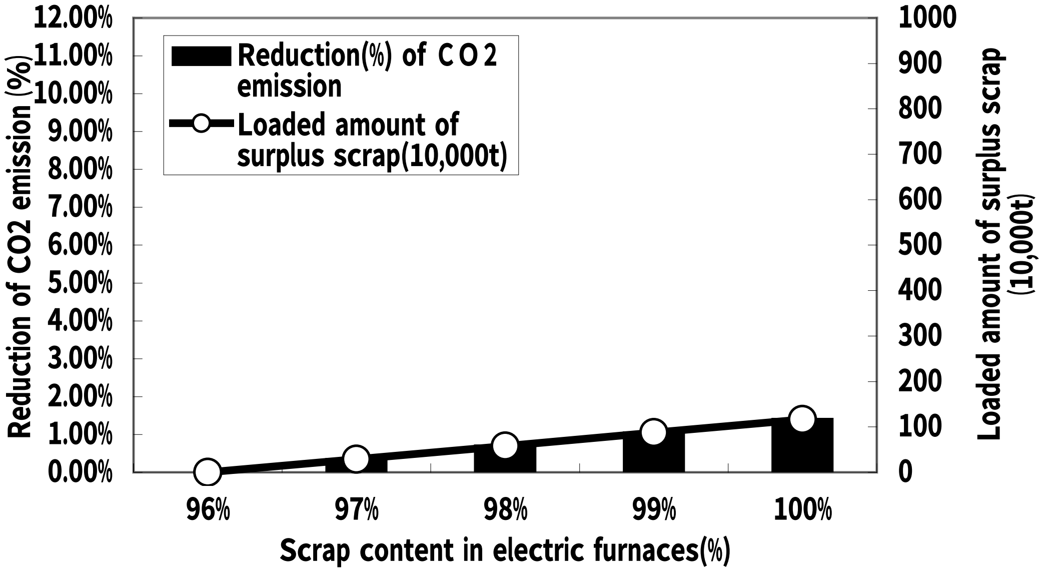
1. Pc/(Pe + Pc) = 72.53%
2. Sc/lc = 7.3%
3. Se/le = 95-100%

<Results>

Scrap content(%)	96	97	98	99	100
Amount used of pig iron (million tons)	7,691	7,662	7,633	7,604	7,575
Production for converter (million tons)	7,397	7,397	7,397	7,397	7,397
Production for electric furnace (million tons)	2,809	2,809	2,809	2,809	2,809
Surplus scrap loaded (million tons)	0	29	58	87	116
Reduction of CO_2 emission (kg)	0	27,451	54,901	82,352	109,803
Reduction ratio of CO_2 emission (%)	0.00	0.35	0.70	1.05	1.40

When the scrap content of electric furnaces is increased, only the corresponding amount is reduced for the blast furnaces. The percentage of CO_2 emission in scenario 1 (L1/L0) is greatly reduced as scrap content in the blast furnaces is increased (shown in Figure 2).

Figure 2 Effect of scrap content in electric furnaces on CO_2 load



The results indicate that in Scenario 1, an increase of about 1.2 million tons of iron scrap would reduce CO_2 emission by about 1.5%. Increasing the iron scrap content by 1%, or about 290,000 tons, would reduce CO_2 emission by roughly 0.38%.

(2) Scenario 2: Increase current production in electric furnaces by 10%

Assuming a proportion of 7.3% scrap for converters and 96.5% for electric furnaces, calculations were made in which the share of electric furnace-based production was increased by 9% from 27.5% to 36.5%.

In other words, the equation was modified to be

$$Pe/(Pc+Pe) = 27.5\% - 36.5\% = y$$

The amount of CO_2 emissions (L_2) from Scenario 2 was derived in the following equation:

$$L_2 = Lb*(Pigc(y)+Pige(y)) + Lc*Pc(y) + Le*Pe(y) \quad (3)$$

Table 10 shows the results of calculations made for changes in the amounts of blast furnace pig iron (Pigc(y) + Pige(y)) and iron scrap that occurred when the production share of electric furnaces was increased.

Table 10 Effects of the share of electric furnace-based production on CO_2

emission (Scenario 2)

<Assumptions of the calculations>

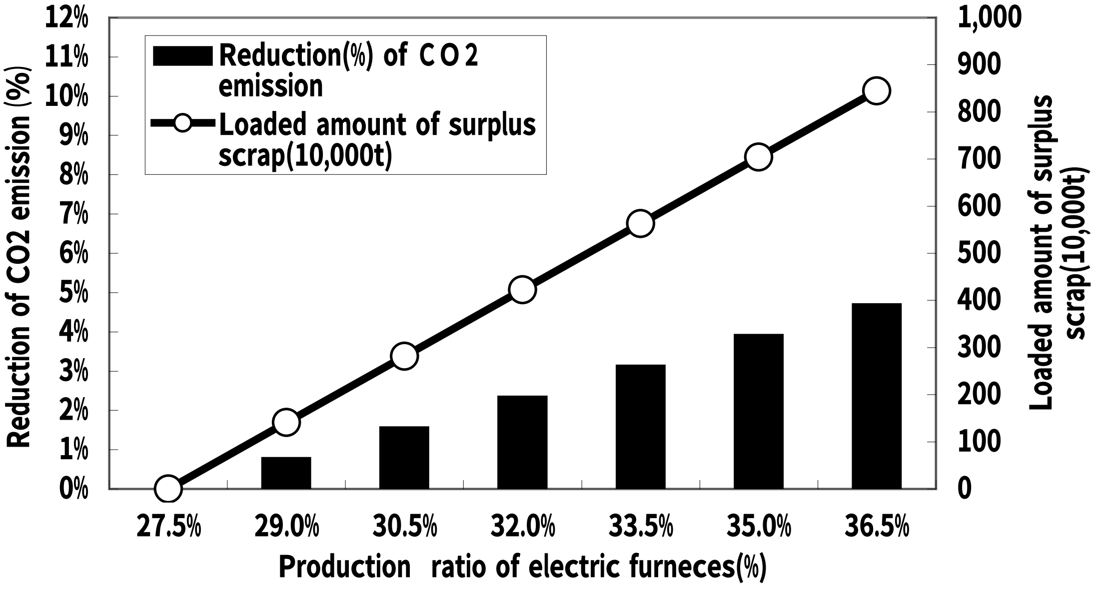
1. Pc/(Pe + Pc) = 72.53%
2. Sc/lc = 7.3%
3. Se/le = 95-100%
4. Pe + Pc = 10.20

<Results>

Production ratio of electric furnace (%)	27.5	29.0	30.5	32.0	33.5	35.0	36.5
Amount of pig iron used (million tons)	7.679	7.528	7,377	7,226	7,074	6,923	6,772
Amount of converter furnace-based production (million tons)	7,399	7,246	7,093	6,940	6,787	6,634	6,481
Amount of electric furnace-based production (million tons)	2,807	2,960	3,113	3,266	3,419	3,572	3,725
Amount of surplus scrap iron loaded (million tons)	0	141	282	422	563	704	845
Reduction of CO_2 (kg)	0	61,305	122,610	183,915	245,220	306,525	367,829
Reduction ratio of CO_2 (%)	0.00	0.78	1.57	2.33	3.13	3.91	4.70

Raising the share of electric furnace-based production increases the amount of iron scrap used, and reduces the production of converter furnaces that consume a lot of blast furnace pig iron. Thus, this amount alone is deducted from the blast furnace pig iron total. Figure 3 shows increases in both iron scrap loading and the reduction ratio (L_2/ L_0) of CO_2 emissions in Scenario 2 that occur as electric furnace-based production increases.

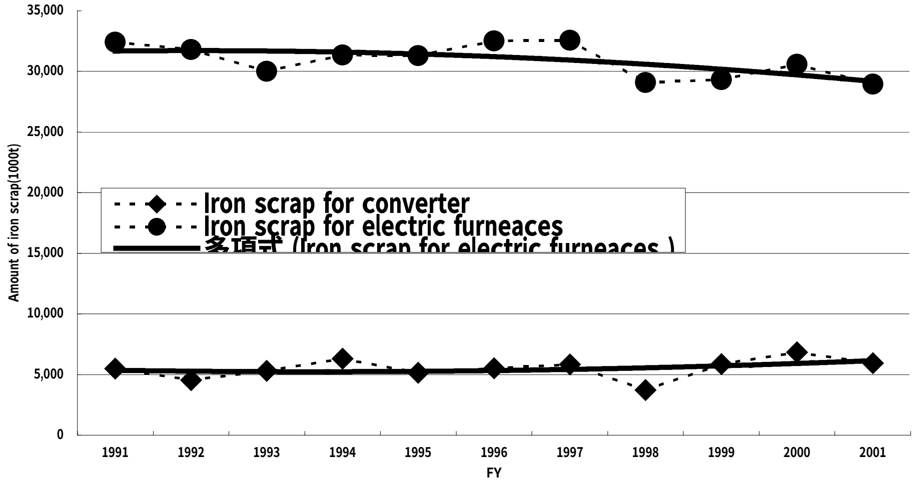
Figure 3 Effect of proportion of electric furnace-based production on CO_2 emissions



In Scenario 2, CO_2 load decreases by about 7.2% when the amount of iron scrap is increased by roughly 8.5 million tons. An increase of 1% in the share of electric furnace-based production would increase the amount of iron scrap use by 940,000 tons and reduce CO_2 emissions by approximately 0.80%.

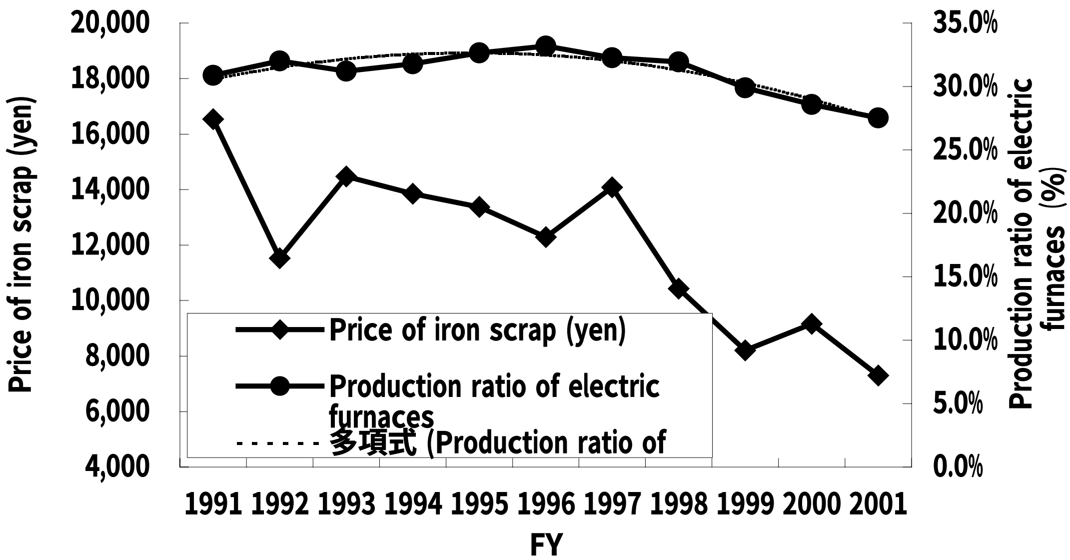
Looking at trends over the past ten years in the use of iron scrap in converter and electric furnaces shown in Figure 4, we can see that there has been a nominal increase in iron scrap used in converters, while iron scrap use in electric furnaces has shown a noticeable decline.

Figure 4 Trends in the use of scrap iron in converter and electric furnaces for the past 10 years



Furthermore, Figure 5 a comparison over the same period of electric furnace share and average prices of iron scrap for calendar years.

Figure 5 Comparison of scrap prices and electric furnace-based production for the past 10 years



There was some fluctuation in the price of iron scrap from 1991 to 2001, but overall it was declining. Up to 1996, the share of production of electric furnaces was increasing as the price was declining, but since then production has been declining despite the lower prices. This probably reflects a decline in the market for products made in electric furnaces, dwindling export competitiveness, and other structural problems that have occurred during this time.

Therefore, Scenario 2 involves issues related to the vitality of the Japanese electric furnace steel industry, so these must be investigated in more detail.

(3) Scenario 3: Increasing the content of scrap iron in converter furnaces by 10% over the current level

Assuming a share of converter-based production (vis-a-vis electric furnaces) of 72.5% and a scrap iron content of 96.5% in electric furnaces, the following results were obtained by raising the scrap iron content of converters from the current 8% to 18%.

In other words, the change can be expressed as follows:

$$Sc/(Pigc+Sc) = 7.3\% = 8\%\text{-}18\% \ = z$$

L_3, the amount of CO_2 emissions in Scenario 3, was derived with the following equation:

$$L_3 = Lb*(Pigc(z)+Pige) + Lc*Pc + Le*Pe + Lb*Pe \quad (4)$$

Table 11 shows the results of calculations made for changes in the amount of blast furnace pig iron consumption (Pigc (z)) and excess scrap loading that occurred when the proportion of scrap iron loaded into converters was increased.

Table 11 Effects of the share of converter-based production on CO_2 emission (Scenario 3)

<Assumptions of the calculations>

1. Pc/(Pe + Pc) = 72.53%
2. Se/le = 96.5%
3. Sc/lc = 8-18%

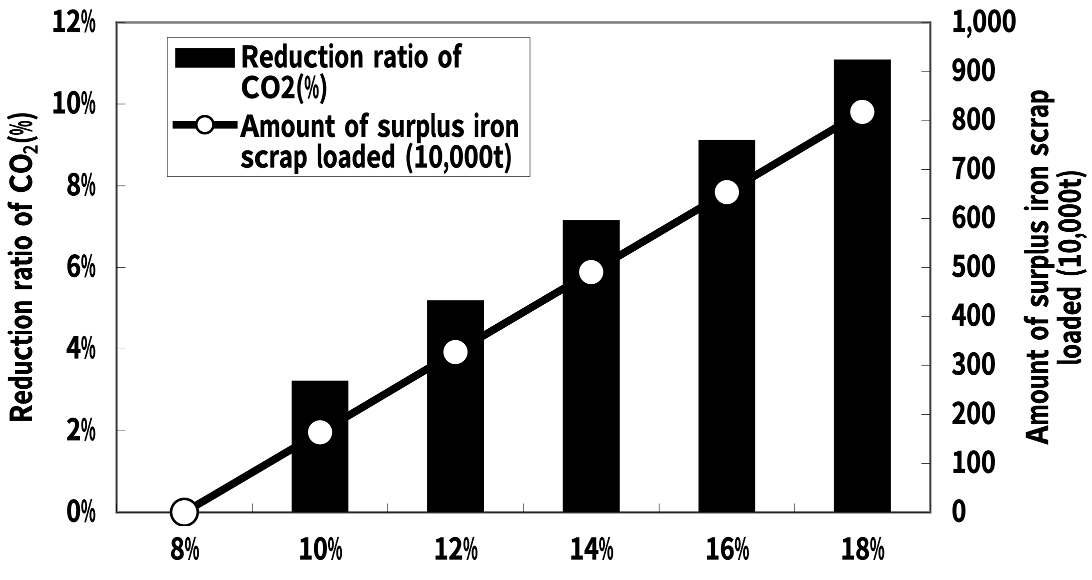
<Results>

Scrap content (%)	8	10	12	14	16	18

Amount used of pig iron (million tons)	7,677	7,412	7,248	7,085	6,921	6,758
Production for converters (million tons)	7,397	7,397	7,397	7,397	7,397	7,397
Production for electric furnaces (million tons)	2,809	2,809	2,809	2,809	2,809	2,809
Surplus scrap loaded (million tons)	0	163	327	490	654	817
Reduction of CO_2 emission (kg)	0	250,272	404,358	558,445	712,531	866,617
Reduction of CO_2 emission (%)	0.00	3.20	5.16	7.13	9.10	11.06

The amount of increased scrap was subtracted from the amount of blast furnace pig iron used in converters. In Scenario 3, there was a greater reduction in CO_2 emissions （L_3/L_0）. Figure 6 shows these data, along with increases in the amount of loaded scrap.

Figure 6 Effect of converter scrap content on CO_2 emissions



These results indicate that in Scenario 3, CO_2 emissions could be reduced by 12% when

the amount of iron scrap were increased by roughly 8 million tons. An increase of 1% in the
share of electric furnace-based production would increase the amount of iron scrap use by
820,000 tons and reduce CO_2 emissions by approximately 1.2%.

It is also apparent that increasing the amount of iron scrap by 10,000 tons could reduce CO_2 emissions by approximately 0.014%, from both converter and electric furnaces However, when the production share was increased for electric furnaces, an increase of 10,000 tons of iron scrap resulted in a mere 0.009% reduction in CO_2 emissions. In this case, it is effective to use a large amount of iron scrap, but it has little effect on CO_2 emissions. The reason for this is that the reduction of CO_2 emissions resulting from reduced converter production is cancelled out by the increase in electric furnace-based production. In contrast, when there was an increase in iron scrap content in converter and electric furnaces, the increased amount was deducted from the pig iron volume, which had a direct effect on reducing CO_2 emissions.

One of the problems here is how much cold iron scrap can be used in converters. There are two reports that have investigated this. Kitagawa's reports that under normal operating conditions, converters can handle up to a 20% increase in the content of iron scrap.[7] Takeuchi's investigation of impurities in current iron scrap suggest that if only heat restraints are taken into consideration, the limit for cold iron scrap is about 30%.[8] In the case of Japan's converter furnaces, which produce a high-grade steel, Takeuchi concluded that impurities in iron scrap must be rigorously controlled. We believe that this problem will be resolved once the physical selection technology has been improved and recycling is incorporated into the design of steel products. It is possible that production issues, such as temperature control during the use of cold iron scrap, should also be resolved. Here, we investigated CO_2 emissions assuming that it was possible to use about 20% in the converter-based production process.

Recently, a melting-smelting technology has been developed as an intermediate process. While its application could possibly enable the use of 100% iron scrap, it is not discussed in this report.

2.5 Chapter wrap-up

As will be discussed in the next chapter, about 3 million tons of raw iron scrap will be produced in 2010, if the current trends continue. Therefore, assuming that there are currently about 5 million tons of surplus iron scrap, we could expect there to be a total of about 8 million tons of surplus iron scrap in 2010.

As ways of dealing with this excess scrap, we considered the following three scenarios:

Scenario 1: Scrap content of electric furnaces is raised to 100%

Scenario 2: Share of electric furnace-based production is increased by 10% over its current level

Scenario 3: Scrap content of converter furnaces is increased by 10% over the current level.

Scenario 1: Since the content of electric furnaces is already 96%, consumption will still be about 1 million tons even if the figure is increased to 100%. In addition, if we consider that CO_2 emissions would only be reduced by about 1.5%, and there will likely be demand for electric furnaces to produce high quality steel, we would have to conclude that, given all the technical problems, this would not be a very attractive scenario.

Scenario 2: Increasing the share of electric furnace-based production by 9 % from 27.5% to 36.5% would enable the use of about 8 million tons of iron scrap and result in a 7% reduction in CO_2 emissions. While the remaining issues are all related to existing technology, they are relatively minor and could be overcome. Nevertheless, despite the low price of iron scrap, the production share of electric furnaces has been decreasing since 1996. This decline has likely been due to changes in the market for products produced in electric furnaces and structural issues with the electric furnace industry, such as international competitiveness. Therefore, from a practical standpoint, it would probably be difficult to take this route.

Scenario 3: Increasing the content of iron scrap by 10 % from the current 8% to 18% could enable the use of about 8 million tons of iron scrap and reduce CO_2 emissions by about 12%, making it an attractive option. From a technical standpoint as well, if the quality of iron scrap is improved, it could be applied in conjunction with advancements in converter operating techniques.

The main problem with all these scenarios is that the increased use of iron scrap is its price vis-a-vis the price of blast furnace pig iron. If the price of iron scrap were to fall far below its current level of 10,000 yen/ton, this would greatly enhance its attractiveness. It appears that the supply and demand of iron scrap in the Asian markets will be tight, resulting in upward pressure on its price. Therefore, it might actually be practical to export the projected 10 million tons of iron scrap if the price increases dramatically. However, with the rapid growth of the Chinese steel industry and increases in the prices of raw materials such as ores for blast furnaces, the value of pig iron would become a rising trend. Given these considerations, it would be very important to formulate a variety of technological strategies.

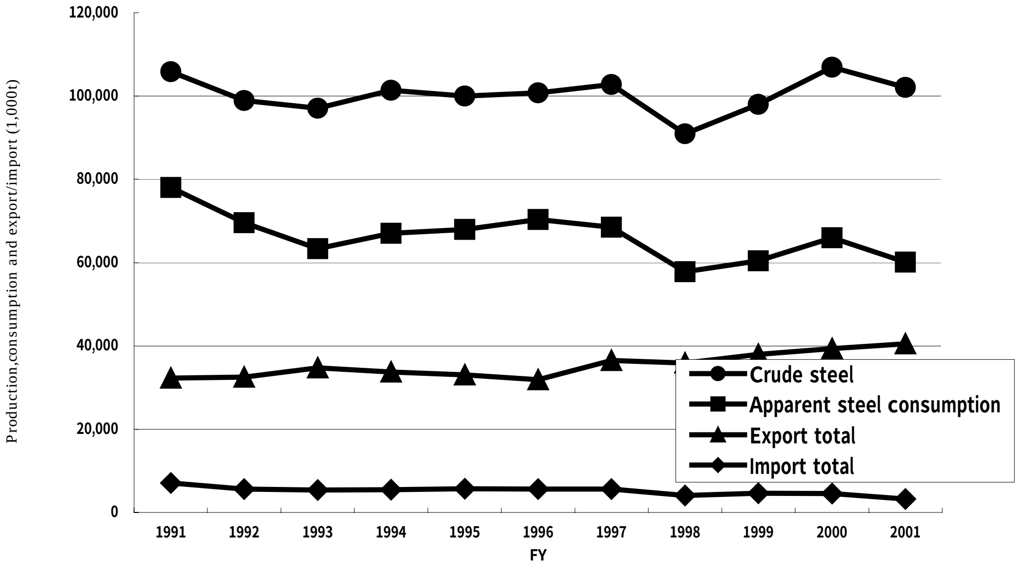
Certainly, the price of iron scrap is an important factor. However, the development of technologies to enable the use of massive amounts of iron scrap, and the possession of technical know-how which can respond to major fluctuations in the price, supply and demand of iron scrap will be very important in order to strengthen the international competitiveness of Japan's steel industry.

3. Outlook for Iron Scrap Volume for 2010

3.1 Current state of the Japanese steel industry

As Figure 7 shows, over the past 10 years the Japanese steel industry has been producing around 100 million tons of crude steel.[9)] During this time, apparent domestic steel consumption has declined by about 10 million tons, from 70 million tons to 60 million tons, while exports have increased by about the same amount, from 30 million to 40 million tons. Imports declined from 7 million to 3 million tons.

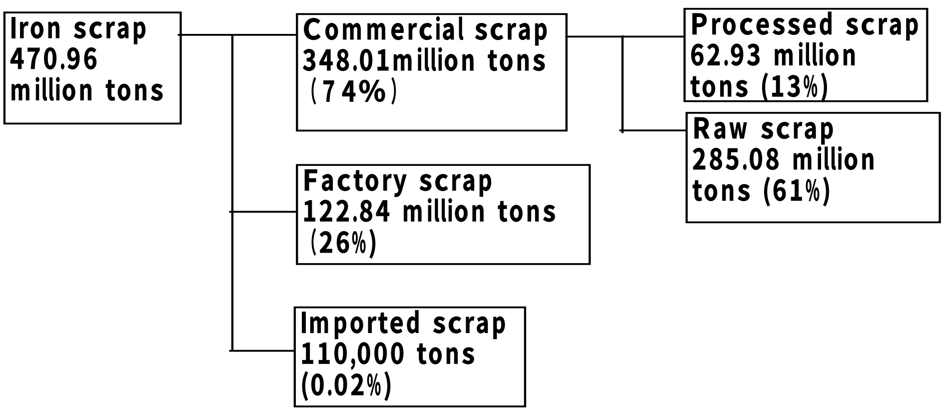
Figure 7　Trends in crude steel production, apparent steel consumption and exports/imports in the past 10 years



Let us now examine the production levels of some major countries in 2001.[9)] Production of crude steel in China increased dramatically to 140 million tons, propelling the country to number one in the world. Production in the United States was a little less than 100 million tons, which was not enough to meet domestic demand, so nearly 40 million tons were imported. Total production of crude steel in the EU was 160 million tons, with exports at the 20 million ton level.

3.2 Current supply and demand of iron scrap

Iron scrap is generally divided into the following categories:



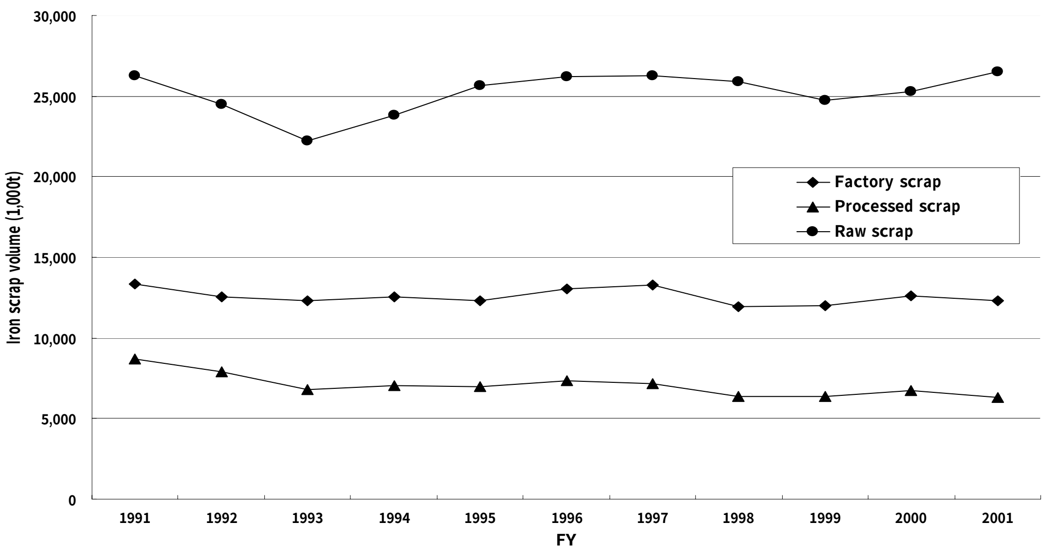
breakdown of this figure shows that about 6.3 million tons, or 13%, was processed scrap, while 28.5 million tons, or 61%, was raw scrap. Factory scrap stood at about 12.3 million tons, or 26%. Volume of imported scrap was an insignificant 10,000 tons, or 0.02%. Domestic consumption was 59.5 million tons in converters, 28.95 million tons in electric furnaces, and 5.72 million tons for foundries, for a total of 40.6 million tons. The respective shares were 15% of converter production, 71% of electric furnace production, and 14% of foundry production.

The 40.6 million tons of iron scrap consumed in Japan in FY 2001, when added to the 78.1 million tons of pig iron, represent 34% of the total steel resource consumption of 119 million tons. The total of commercial scrap and imported scrap, 34.81 million tons, is divided by total iron consumption, 119 million tons, to get the recycling rate, which stands at about 29%.

3.3 Ten-year trend in iron scrap

As we can see in Figure 8, the volume of raw scrap declined temporarily from the 26.5 million tons in 1990, but had returned to the same level by 2001. The next largest source was factory scrap, which kept pace with crude steel production at 12 million tons. Processed scrap production during this ten-year period fell by about 2.8 million tons, from 9.1 million to 6.3 million tons.

Figure 8　Ten-year trend in iron scrap volume

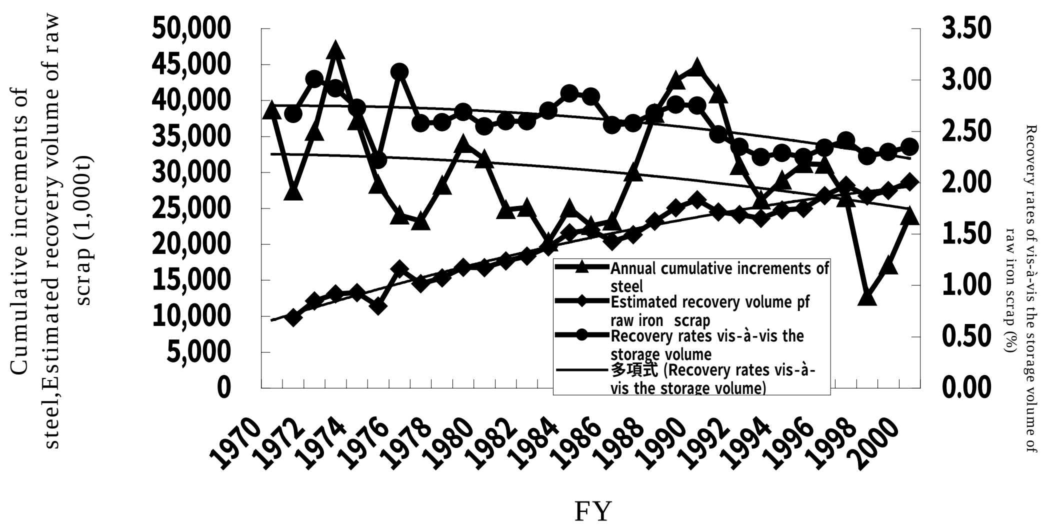


3.4 2010 outlook for raw iron scrap

The volume of raw iron scrap in FY 2001 had returned to the same level it was at in 1990. Although the volume had been declining, it was rebounding in the last three years. It is expected that much of the steel that was produced during the bubble economy and period of high growth will deteriorate in the near future, so this is being taken into consideration.

Figure 9 shows the 30-year cumulative increments of steel production and trends in the recovery rates vis-a-vis the cumulative storage volume of steel and the volume of recovered raw iron scrap.

Figure 9 Annual cumulative increments, recovery rates vis-a-vis the cumulative volume and storage volume of raw scrap for 30-years, 1970-2000



Here, the annual cumulative increments were derived from the following formula:

Cumulative increment for year X = Production total + Import total

– Export Total – Iron consumption – Amount of purchased iron scrap

We can also calculate the cumulative storage volume of steel. Dividing the recovered iron scrap volume for year X by the storage volume of steel gives us the recovery rates vis-a-vis the cumulative storage volume.

The annual cumulative increment is highly dependent on the economy. The largest peak occurred in 1973, with the 2nd largest peak occurring in 1990, during the bubble economy. In the ten years after this second peak, there was a marked decline. Although it's not shown in the figure, the cumulative storage volume of steel has been increasing every year. In contrast, the recovery rate during that time fell from about 3% to roughly 2.3%.

Next is an estimate of future trends in raw iron scrap. Assuming the same rate of increase in the cumulative storage volume of steel as during the previous 30 years, it appears that the total volume in 2010 will be about 1.4 billion tons, up from the 2001 level of 1.2 billion tons (see Figure 10). In contrast, if we assume a continuing decline in the recovery rate, then we can expect that the amount of raw iron scrap in 2010 will be around 30 million tons. However, given the recent trends in recycling, if a rate of 2.25% can be maintained, then the amount of raw iron scrap in 2010 will be around 32.5 million tons.

Figure 10 Outlook for raw iron scarp in 2010- Model 1

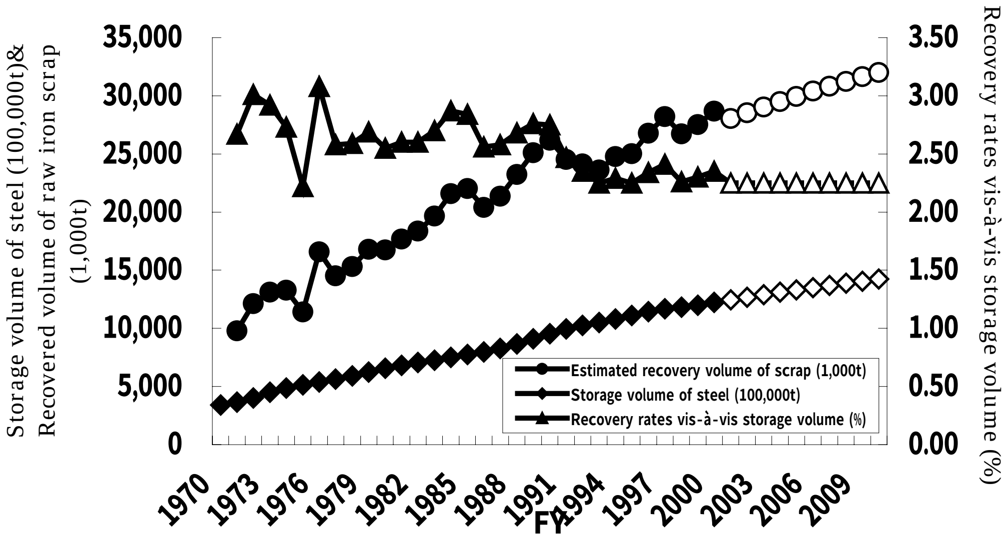
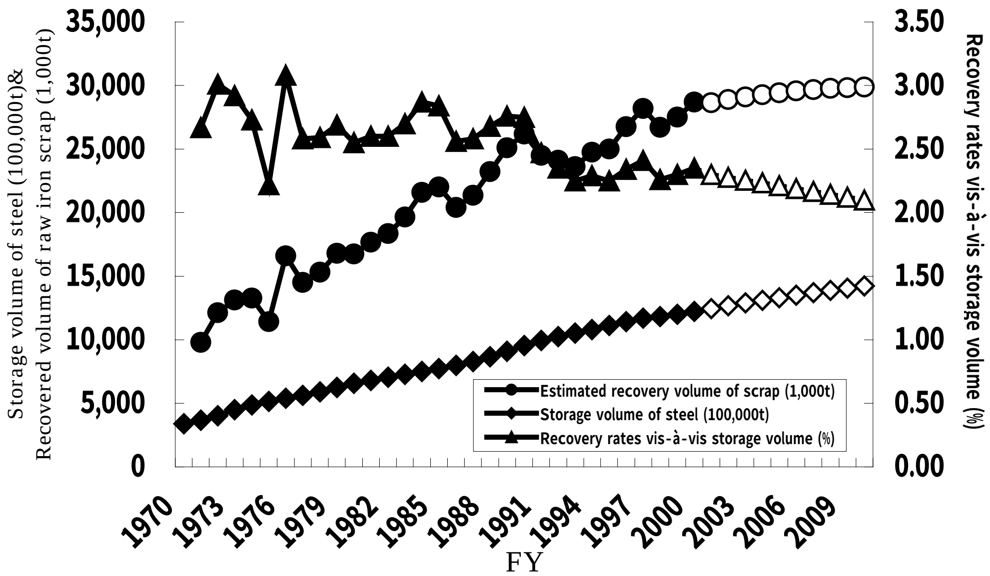


Figure 11 Outlook for deteriorated scarp in 2010- Model 2



Therefore, as we can see in Table 12, if there is an increase up to 2010, it will be within a range of 1.5 million and 40 million tons over the 2001 level (28.5 million tons).

Based on Hayashi's[11] estimate of 31.5 million tons of raw iron scrap for 2010, the figure presented here would represent a reasonable increase of about 3 million tons.

Table 12 Estimated recovery rate for raw scrap in 2010

	Actual value	Estimated value	
FY	2000	2010-1	2010-2
Estimated volume of recovered raw iron scrap (1,000t)	28,690	30,013	32,690
Cumulative increments of raw iron scrap since 2000(1,000t)		1,323	4,000

3.5 Expected demand for raw iron scrap by sector

As we can see in Figure 12,[10] the largest producer of raw iron scrap is the construction industry a 20%, followed by the automobile industry at 19%, production machinery at 15% and electrical machinery at 10%. If the two machinery sectors were combined, they would rank first. Next in order are the public works at 12%, secondary production at 10%, home appliance industry at 8% and container industry at 6%. This report will examine the top four producers.

Figure 12　Share of raw scrap production by sector (FY2001)

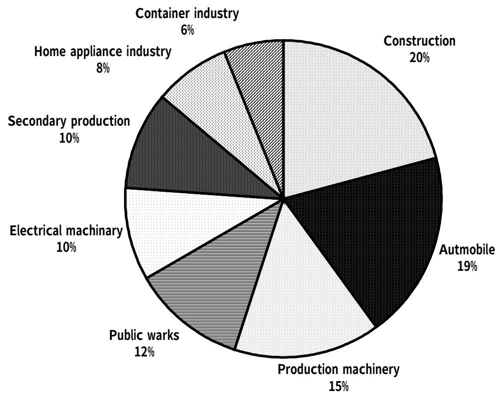
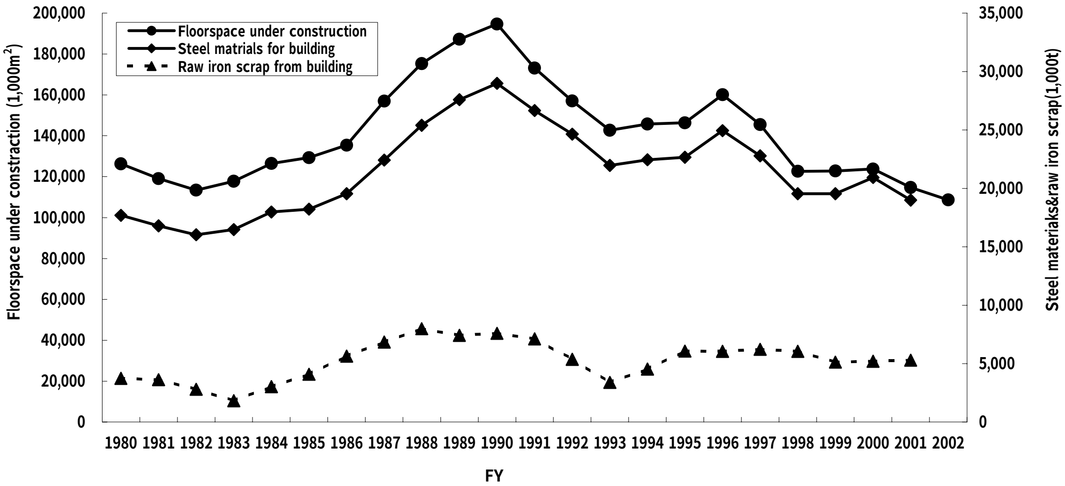


Figure 13 is a comparison between the amount of new floorspace in steel for constraction begun in previous 20 years and the amount of steel materials consumed in the construction industry. As we can see, there is a very good correlation. Looking at this information in conjunction with the raw iron scrap generated in the construction sector, we can see that up until the 1993 bubble, there was an excellent correlation. Considering that the average life span of a steel structure is about 35 years, this is a rather odd phenomenon.

Figure 13 Comparison between the amount of floorspace in new steel building begun in the previous 20 years and the amounts of steel materials consumed and raw iron scrap



Building lots in Japan are usually relatively small. During the period of high economic growth, wooden structures were replaced with steel ones; after the bubble economy, some of these floorspace and steel consumption have declined, but raw iron scrap apparently has not.

The authors would like to use current statistical data to estimate the amount of raw iron scrap that will be produced in the construction sector in 2010. Therefore, estimates were made from the past trends in the cumulative storage amounts and the recovery rate vis-a-vis the cumulative amounts, then the amount of raw iron scrap was estimated as described shortly. There are no good statistical data on the cumulative storage amounts for the construction industry alone. Thus, the amount of steel materials input into the statistical sectors for the previous 30 years was taken from the steel statistics, so the following formula for estimating annual storage increment was used to derive the cumulative amounts:

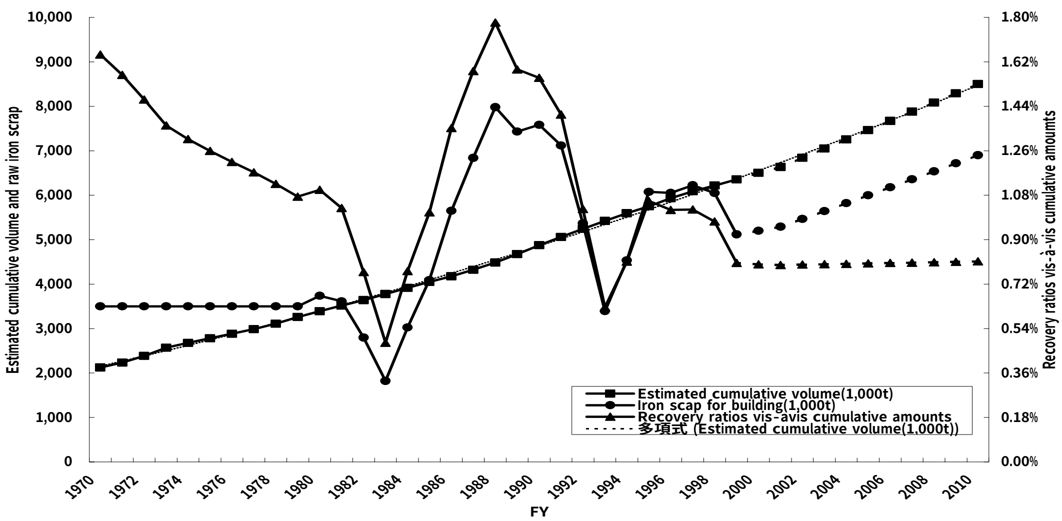
Annual storage increment in the construction industry = Normal steel consumption in the construction industry – Raw iron scrap – Processed iron scrap

Since amount of steel that is either directly imported/exported or indirectly imported/exported as processed goods is not known, the value obtained with this formula is only a very rough estimate.

Figure 14 shows values for the storage increment, the cumulative storage amount, and the recovery rate vis-a-vis the cumulative amounts that were derived here. For the time being, the cumulative storage amount is increasing. However, as Figure 14 indicates, the recovery rate vis-a-vis the cumulative amounts is abnormally large due to the large amount of iron scrap that was generated and collected as a result of the replacement during the bubble economy of steel structures that were still in usable condition.

Assuming a cumulative storage amount for 2010 that will continue past trends, and a recovery rate vis-a-vis the cumulative amounts that will rebound somewhat due to the implementation of recycling laws, it appears that there will be an increase of about 700,000 tons of raw iron scrap.

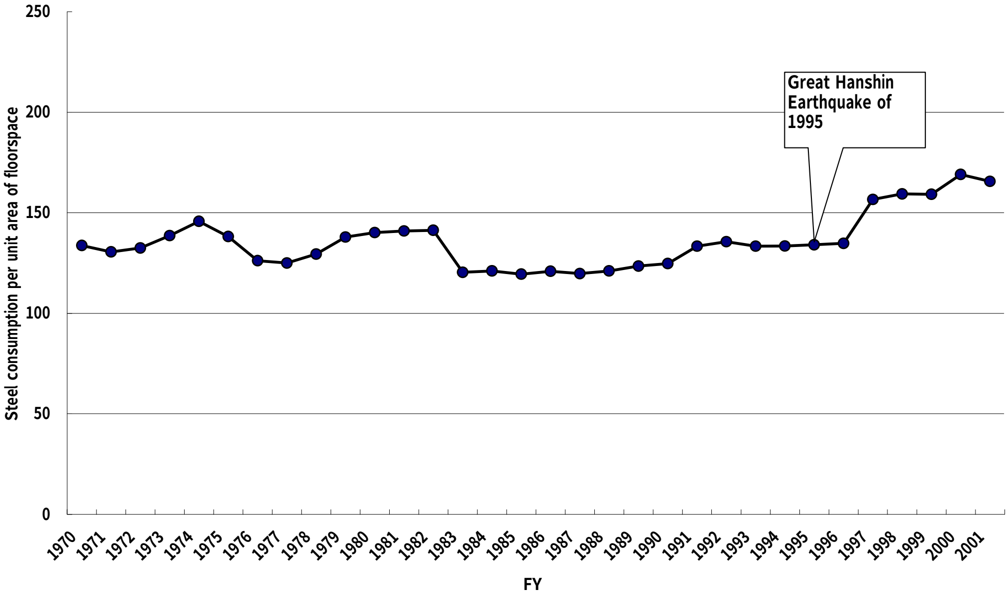
Figure 14 Outlook for raw iron scrap in various construction fields for 2010



Although the economy will become more stable and steel structures will be replaced once they reach the end of their conventional life cycle, it will take a little time for there to be a decline due to the large accumulations that have already been amassed in the construction fields.

Figure 15 shows trends in steel consumption per unit area of floorspace over the previous 30 years. What is particularly interesting here is that after the Great Hanshin Earthquake of 1995, the consumption of steel per unit area of floorspace increased by about 20%, from 130 kg to 160 kg.

Figure 15 Trends in steel consumption per unit area of floorspace over the previous 30 years.



Given this background, even if the consumption of construction-related steel materials does not dramatically increase in the future, we can expect for there to be an increasing trend in the amount of raw iron scrap in the construction sector over the next 10 years, because of significant increases in cumulative storage, the recovery rate vis-a-vis cumulative storage, are improved, and average durability increases.

Figure 16 shows a comparison between the number of registered vehicles and the number of cars junked over the past 18 years, and the amount of scrap from junked automobiles.[9)] Domestic production began to decrease around 1990, but the number of registered vehicles has been increasing. As a result, the number of junked cars has been increasing, as has the amount of raw iron scrap.

Figure 16　Trends in number of registered vehicles, number of junked vehicles and amount of raw iron scrap for 1983 to 2001

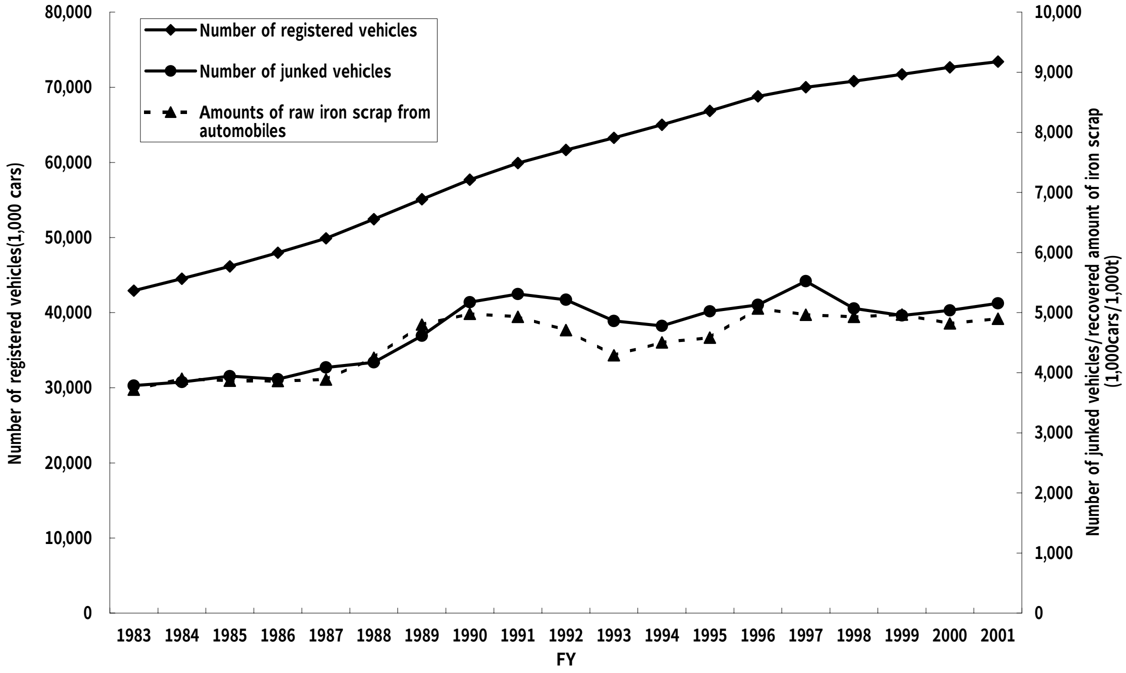
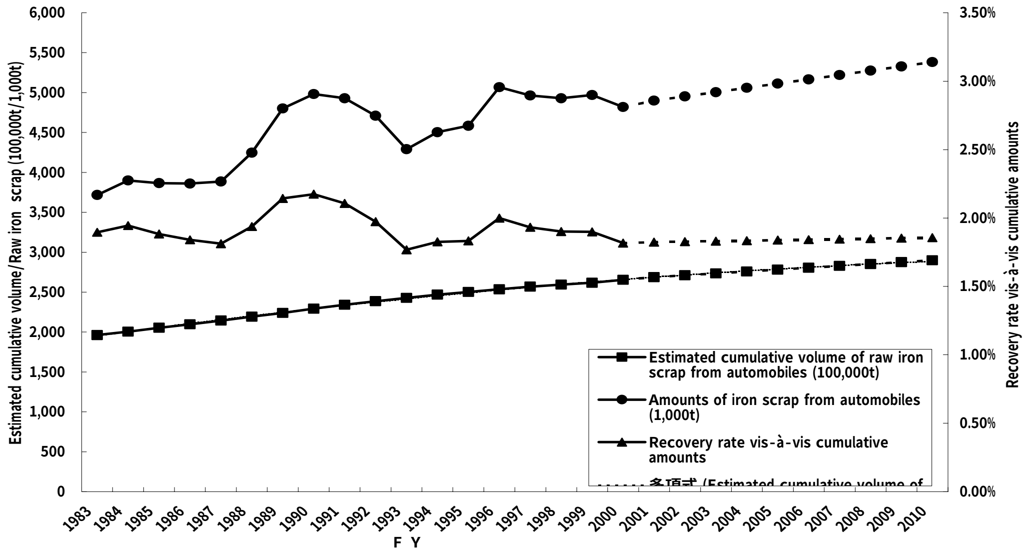


Figure 17 shows quantitative data from the automobile sector that were derived using the same formula used to derive construction sector data.

Figure 17　Projected volume of raw iron scrap from the automobile sector for 2010



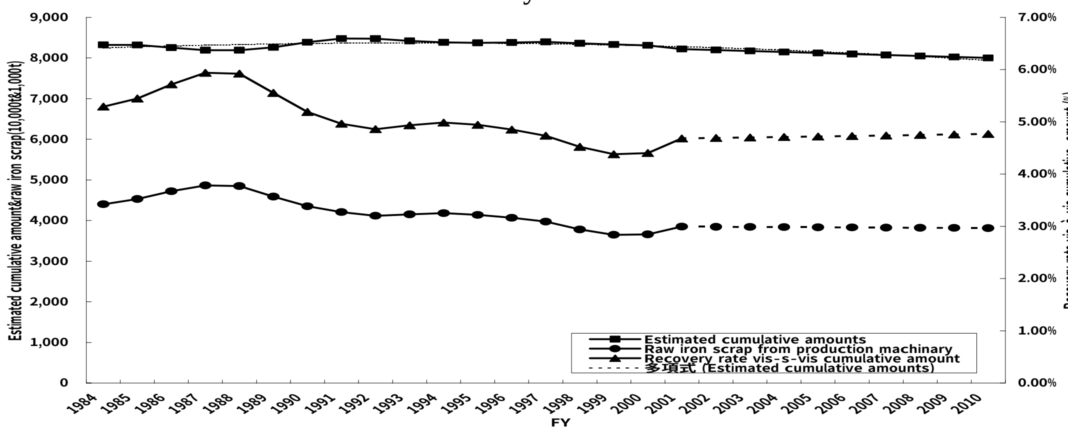
Assuming the same rate of increase in cumulative storage amounts as in the past, we can expect an increase of about 400,000 tons if the recovery rate to storage amounts is even slightly improved..

Over the next 10 years, we can expect that recovery rates for scrap will increase as society becomes more environmentally conscious, so there will probably be a slight increase in raw iron scrap from automobiles.

However, used car exports increased from 400,000 vehicles in 1996 to 730,000 in 2001.[13)] What's more, the export of parts transported to Russia as baggage is the equivalent of 200,000 vehicles,[14)] meaning that in 2001 the total export was actually the equivalent of 900,000 used vehicles. Assuming that each vehicle contains about 0.8 tons of steel materials, that would mean that about 700,000 tons of steel was exported in the form of used vehicles. It is said that the increase in exports of iron scrap from junked cars and A press waste is about 300,000 tons. If this is true, then the amount of raw iron scrap from cars in Japan is about 1 million tons, less than previously reported. While detailed studies are needed to confirm this, it is possible that that actual amount of iron scrap would start to decrease in some case where there are statistical errors.

Figure 18 shows an attempt to estimate raw scrap from industrial machinery[9)] using the same method as previously described. As we can see, the cumulative storage amount has been decreasing. The recovery rate vis-a-vis storage amount was quite high during the bubble economy, but since this it has been stable. Even assuming that the recovery rate will increase in the future, we can expect the amount of raw scrap from industrial machinery will start decreasing somewhat.

Figure 18　Projected amount of raw iron scrap from industrial machinery for 2010

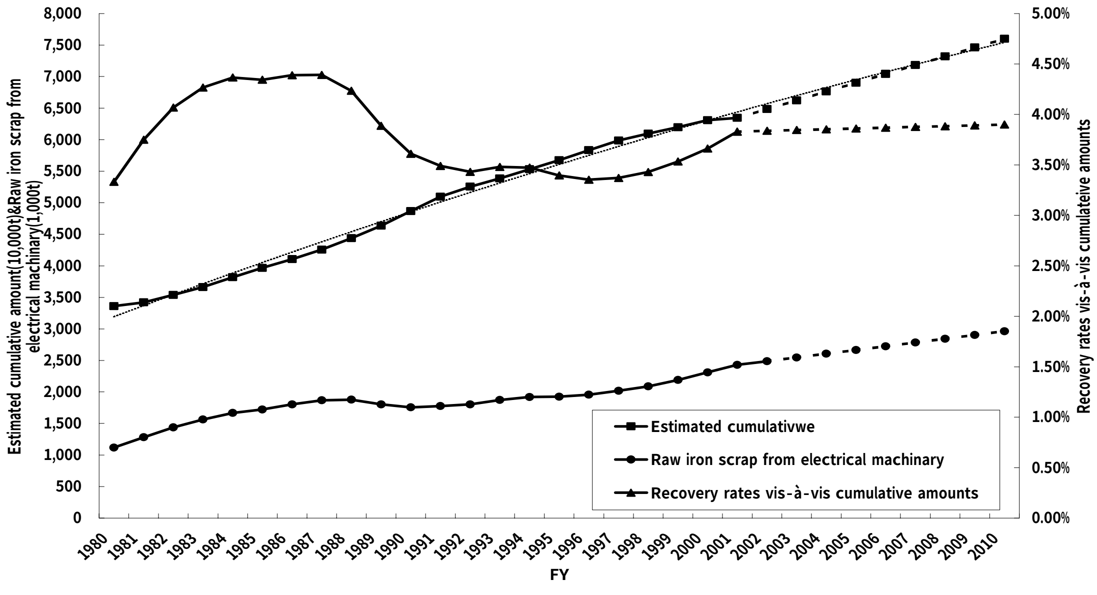


Assuming the average useful life of industrial machinery to be 14 years, and that steel consumed for industrial machinery will be scrapped within those 14 years, it appears that a large amount of scrap will be produced in the near future (about 5 years from this writing) as machinery that was produced in the peak years of the 1990s will start to be taken out of commission. Even if a higher proportion of this scrap is recovered, however, it would be difficult to predict how much increase there will be based solely on the data that are presently available.

Furthermore, the amount of used machinery coming on the market rose from about 70,000 units in 1991 to 100,000 units in 1999. About 50% of this was exported. As with the automobile sector discussed in the previous section, more detailed research will have to be conducted.

Now let us examine the case of iron scrap from electrical machinery.[9] As Figure 19 suggests, we might expect that the cumulative storage amount, given past trends, will increase linearly to about 500,000 tons if the recovery rate vis-a-vis the cumulative storage amount increases. However, assuming a usable life of 10 years and that steel consumed for electrical machinery will be scrapped within 10 years, there will be little change in the amount of iron scrap produced over the next 10 years. Therefore, while there might be some sort of increase in the electrical machinery sector, it probably will not be a very big increase.

Figure 19 Projected amount of raw scrap from the electrical machinery sector for 2010



The container sector and the home appliance sector have been fairly constant for the past 10 years, and the volume produced has been relatively small. Figure 20 indicates that we can expect this trend to continue into the future.

One sector to take note of is public works. The amount of raw scrap was based on a normal distribution pattern in which there is an average usable life of public works structures of 35 years, and replacement (scrapping) begins at 25 years, peaks at 35 years, and ends at 45 years. As the results in Figure 20 show, over the past 10 years, steel structures built 35 years earlier have been scrapped, with a very conspicuous linear increase. In FY 2001, raw scrap generated in the public works sector increased to a little less than 3 million tons per year, surpassing the amount in the electrical machinery sector. Steel for public works is currently consumed at an annual rate of 9 million tons, and can be expected to increase in the future.

Recently, the Japan Technical Information Service has released a detailed estimate of the amount of scrap iron produced in the public works sector.[15)] In FY 2000, 9.7 million tons of steel were used there, of which about 60% was recoverable. Under several hypothetical scrapping patterns, we can derive a theoretical value of 3.2 million tons of recovered steel. In contrast, the statistics for FY 2000 show that about 2.7 million tons of scrap were recovered. Thus, overestimates in this model would make it difficult to use to predict the amount recovered in 2010. A cursory examination of the results (the details are given in a previous report) suggests that the difference in the amount recovered in 2010 estimated from the FY 2000 rate would be about 1.3 million tons; thus, it appears that in 2010 there will be an increase of about 1.3 million tons in raw scrap from the public works sector.

Figure 20　Trends in raw scrap by sector for the past 10 years

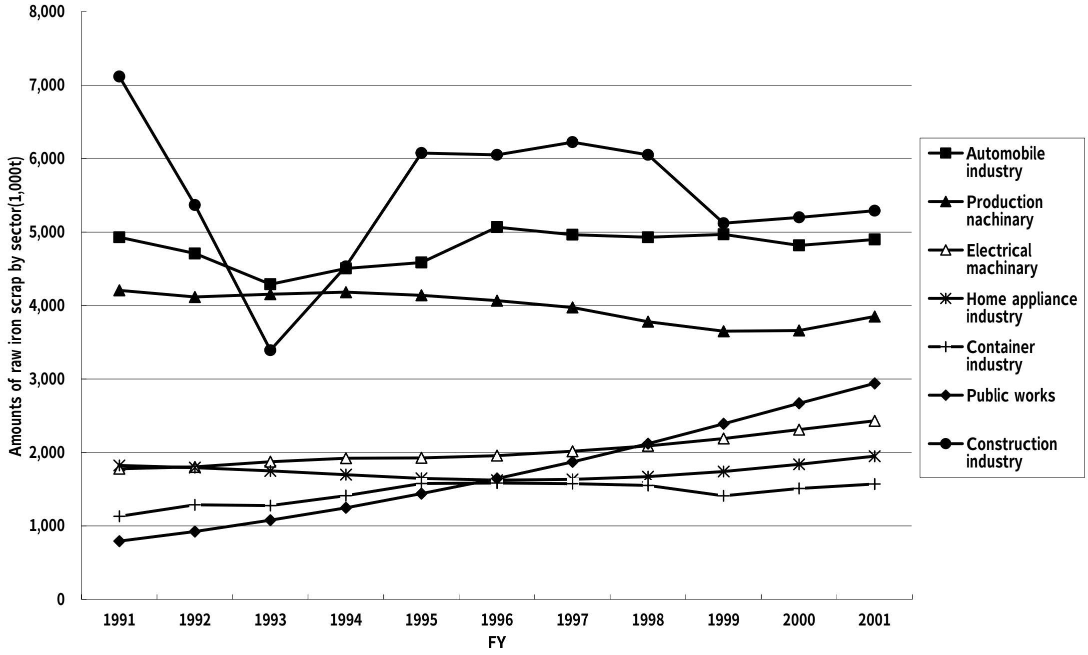
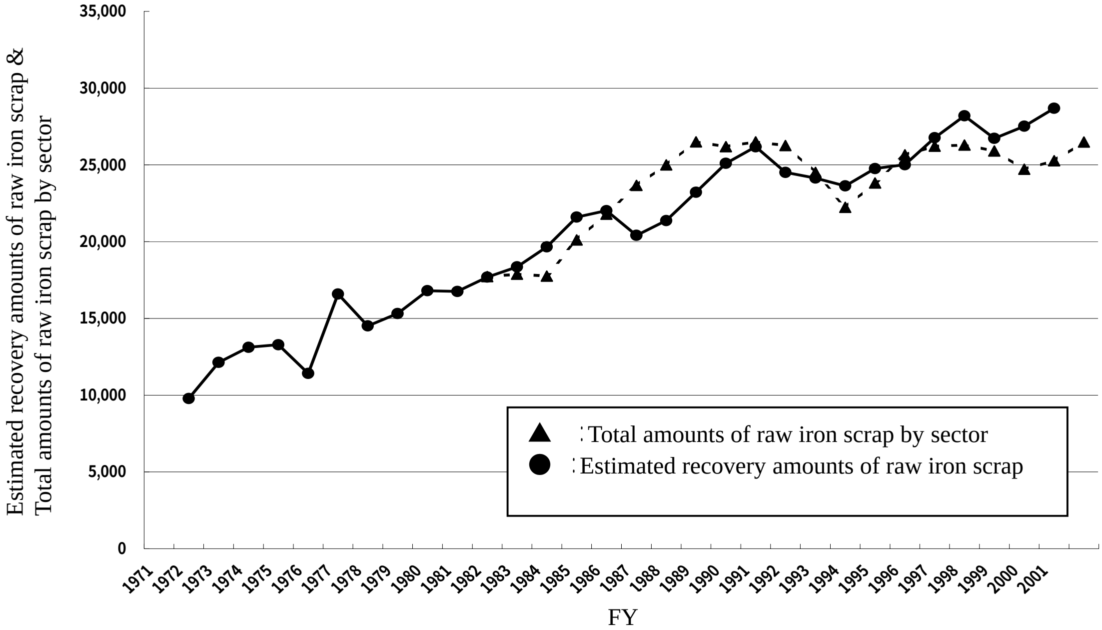


Figure 21[10)] shows trends for the past 30 years in the estimated amount of raw scrap that was recovered. These values do not include the amount of processed scrap iron that was estimated in an industry survey from the amount of purchased scrap. At any rate, the amount of scrap exported since 1991 has exceeded 1 million tons, so the amount of exported raw scrap was estimated and added to get the figure for estimated amount of recovered raw scrap.

Figure 21 shows the sum total of the raw scrap produced by different sectors from 1981 to 2001.[10)] As we can see, there is an excellent correlation with the estimated value. In the previously discussed estimates of raw scrap from figures 10 and 11 the estimated scrap iron recovery rate was used, while in the predictions of supply and demand by sector the estimated cumulative value of scrap iron was used. In both cases, it appears that the error is within the allowable range.

From the above results, it appears that about 1.3 million tons of the 3 million ton increase in raw scrap iron that is projected for 2010 will come from the public works sector, 700,000 tons from the construction sector, 400,000 tons from the automobile sector, and 500,000 tons from the electrical machinery sector. It appears that there will be little or no increase from the industrial machinery sector.

Figure 21　Trends in total raw scrap iron recovered from the various sectors from 1981 to 2001



3.6 Trends in factory scrap in the previous 10 years

The amount of iron scrap produced by blast furnace-based makers[10)] reached a trough due to the introduction of the continuous foundry technique in the 1980s and improvements in rolling yield. In the last 10 years, it has been relatively steady. The amount of iron scrap produced within a plant fluctuates widely with the production of crude steel, which in the case of blast furnace- and electric furnace-based makers, is about 7-8%.[16)]

Making a projection for the next 10 years depends on the way that crude steel production is predicted, and amounts of factory scrap are also changing. As will be discussed later, crude steel production will be greatly affected by activity in China, but it would be best to maintain it at the 100 million-ton level, or at the very least at 95 million tons. Therefore, there probably will not be any major changes in the amount of iron scrap produced in the private sector.

3.7 Trends in processed iron scrap over the past 10 years

According to a survey conducted by the steel industry,[9)] iron scrap purchased on the market is divided into processed and raw iron. In FY 2001, the amount of processed iron scrap was about 6.3 million tons. Looking at the trends for past 10 years, we can see that the amount fell by 2.8 million tons over the span of a decade, from 9.1 million tons in 1990 to 6.3 million tons in 2001. This was largely due to the shifting of Japanese companies' production to overseas facilities.

As Figure 22 indicates, the automobile sector is the largest producer of processed scrap, accounting for 49% of production. It is followed by the production machinery sector at 15% and the electrical machinery sector at 13%.

Figure 22 Production of processed iron scrap by sector

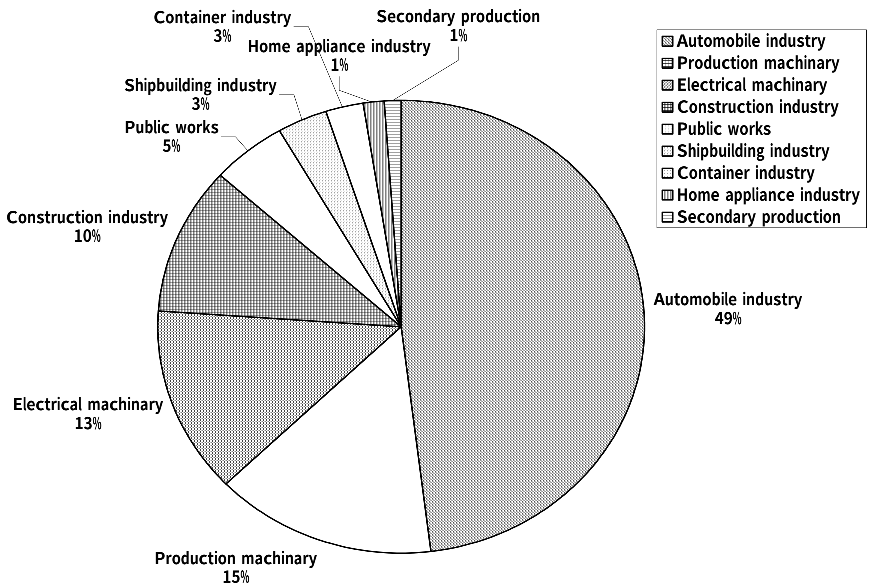


Figure 23 shows trends in processed scrap in the automobile sector. Here we can see that there is a good correlation between the number of automobiles produced and the amount of steel that is consumed for their production. With the decline in domestic automobile production that picked up steam around 1990 as manufacturing was moved overseas, the amount of processed scrap produced by the sector declined by about 800,000 tons, falling from 3.8 million tons in 1990 to about 3.0 million tons in 2001.

Figure 23　Trends in passenger car production, steel consumption, and scrap iron processing in the automobile sector from 1983 to 2001

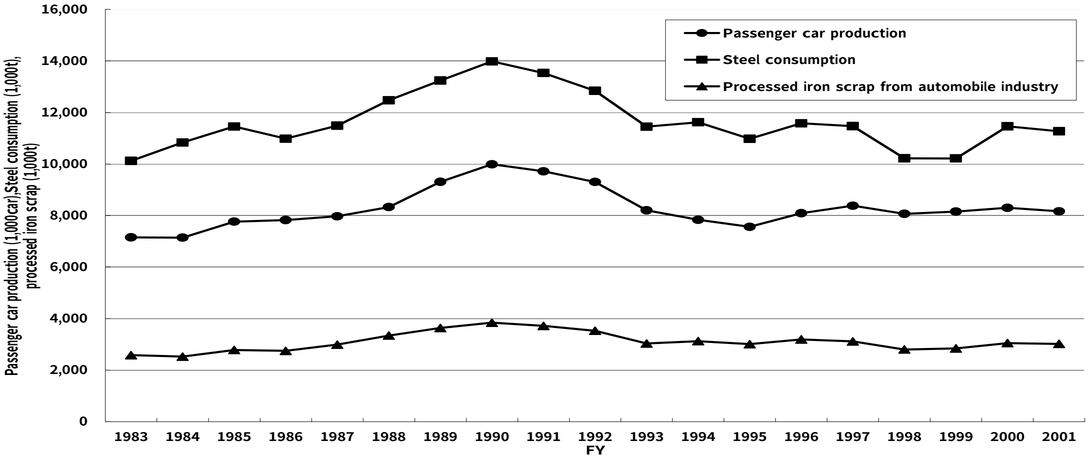
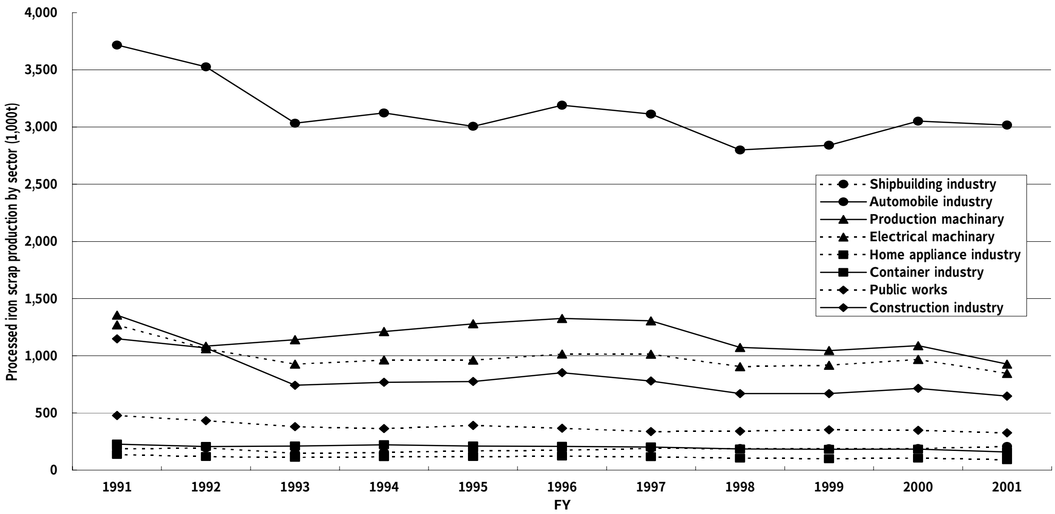


Figure 24 shows trends in processed iron scrap production by sector for the past 10 years. There are clear declines in the automobile and electrical machinery sectors, which have both been moving production overseas. The figures may also be reflecting the state of the economy during that time, and/or declines in the industrial machinery and construction sectors. Specifically, there was a decrease of 430,000 tons in the electrical machinery sector, 570,000 tons in the industrial machinery sector, and 500,000 tons in the construction sector. With the addition of the automobile sector, the total decline in processed scrap production in these four sectors for the past 10 years comes to 2.8 million tons.

Figure 24　Trends in processed iron scrap production by sector for the past 10 years



The biggest factor in predicting trends for the coming 10 year is the Japanese economy. However, if we assume that Japanese companies will not continue to conspicuously shift production overseas, there may be a little decline over the next 10 years.

3.8 Chapter wrap-up

This chapter has been an attempt to predict overall trends in iron scrap. While figures for processed scrap are dependent on the degree to which Japanese sectors move production overseas, it appears that there will not be a repeat of the rapid relocation that occurred in the early 1990s, so any decline will likely be minimal. Iron scrap produced within plants reached its peak in the 1980s with the expansion of continuous foundry production and improvements in rolling yield, while in the 1990s there were relatively minor technological advances, which resulted in a relatively minor decline. It appears that there will be no significant technological breakthroughs in the near future either, so we can expect the figures for factory scrap to remain more or less where they are.

Trends in iron scrap are essentially depending on trends in raw scrap, which had been declining up to about 10 years ago but have been increasing for the past 3 years. It appears that they will continue to increase with the increase in the cumulative storage amount of steel in Japan. In the year 2010, it appears that the 3 million tons mentioned previously, which is intermediate between 1.5 million and 4 million tons, will increase even further. Therefore, we can expect an overall increase of about 3 million tons of iron scrap.

However, in actuality there were about 7.5 million tons of excess iron scrap in FY 2001, of which about 7 million tons were exported. Thus, given that there is currently about 5 million tons of excess iron scrap, it is possible that about 8 million tons of excess iron scrap will come into existence by 2010.

Given that the steel industry will continue to grow in China and other countries in the Asian region, it appears that in the next 10 years, there will be a good chance that there will be an annual consumption of about 8 million tons of iron scrap there. The Japanese steel industry will be involved not only with steel exports but also with developing highly efficient cargo loading and unloading systems for ports, which may even be applicable to meeting export needs for iron scrap.[17)] However, there is great fluctuation in the supply and demand, as well as the price, of iron scrap, so naturally it will be necessary to investigate ways of dealing with about 8 million tons of excess iron scrap. In the following sections, this report will examine this issue using life cycle assessment, or LCA.

4. Concluding Remarks

The steel industry features a built-in recycling process of iron scrap. In FY 2001, about 35% of the iron used in the industry came from scrap. In the same year, a little less than 7 million tons of iron scrap was exported, which is very important to keep in mind when taking a supply-side approach to iron and steel resources.

The following three technological scenarios were considered for promoting the full-scale loading of iron scrap into electric furnaces and converters. At the same time, the CO_2 reduction effect for each of these scenarios was investigated using LCA.

Scenario 1: Scrap content of electric furnaces is raised to 100%.
Scenario 2: Share of electric furnace-based production are increased by 10% points over current levels over current levels
Scenario 3: Scrap content of converters is increased by 10% over current levels.

As a result, the following findings were made.

Scenario 1: Raising the scrap content of electric furnaces from the current 96.5% to 100% would increase scrap use by about 1.2 million tons, and reduce CO_2 emissions by about 1.5%. Raising the content by 1% would increase the use of iron scrap in electric furnaces by 290,000 tons and reduce CO_2 emissions by 0.38%, while raising it by 10,000 tons would result in a 0.013% reduction in CO_2 emissions.

Scenario 2: Increasing the production share of electric furnaces (vis-a-vis converters) by 9% over current levels (from 27.5% to 36.5%) would increase the use of iron scrap by 8 million tons, and reduce CO_2 emissions by 7.2%. An increase of 1% would increase the use of iron scrap by 940,000 tons, and reduce CO_2 emissions by 0.80%. However, in this case an increase of 10,000 tons of iron scrap use would reduce CO_2 emissions by a mere 0.009%.

Scenario 3: Raising the iron scrap content of converters from the current 7.3% to 18% would increase iron scrap use by 8 million tons and reduce CO_2 emissions by 12%. In addition, increasing the iron scrap content by 1% would increase iron scrap use by 820,000 tons and reduce CO_2 emissions by 1.2%, which an increase of 10,000 tons of iron scrap would reduce CO_2 emissions by about 0.013%, the same level as electric furnaces.

To promote the full-scale use of iron scrap, its quality would have to be improved. However, because future products will be designed with recycling in mind, advancements will be made in physical sorting methods, there will be a transition to product-to-product recycling, etc., we can assume that the quality of iron scrap will get better.

There is also the issue with the prices of iron scrap and pig iron. Because the steel industry in Asia, especially in China, is growing at a rapid pace, the supply and demand of iron scrap will likely be tight, which will generally work to keep upward pressure on the price. At that time, 8 million tons of iron scrap could not simply be exported—its bargaining power as a resource could be used to make strategic exports.

However, given that the iron scrap market is prone to severe fluctuations in supply and demand and thus severe fluctuations in price, the possession of technology for handling 8 million tons of iron scrap could also be necessary for the Japanese steel industry to enhance its international competitiveness.

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