Research on Contribution of Steel Products to Society-wide Energy Conservation from LCA Perspectives (2)[1]

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Introduction

Since the oil crisis, Japan has achieved the world's highest level of energy conservation as a result of concerted efforts from the public and private sectors. Nevertheless, Japan continues to depend so heavily on Mideast crude oil that the country's energy supply mix may be regarded as vulnerable. On top of this, in June 2002 Japan ratified the Kyoto Protocol, an international framework to arrest global warming, and is now obliged to meet the Kyoto target by taking effective actions. Under these circumstances, Japan's energy consumption in recent years has been on the increase, particularly in the residential, commercial and transportation sectors, which means that determined efforts for energy conservation must be continued from now on.

High functionality given to steel products results in incremental energy intensity at the steelmaking stage. At the stage of their utilization, however, high-functional steel products prove more energy-efficient than their conventional counterparts in many cases. Therefore, when we consider what impacts the wider use of high-functional steel products can have on energy consumption, such characteristics must be taken into account.

This paper discusses each of the steel products dealt with in our preceding paper, "Research on Contribution of Steel Products to Society-wide Energy Conservation from LCA Perspectives (1)," in three points. Specifically, we shall explain the characteristics of each of the products, the methods with which we assessed energy conservation, and the impacts[2] that each high-functional steel product can have on energy consumption during its life cycle.

In this paper, our analysis focuses on 1990, 1995 and 2000 (evaluation of actual records) and on 2005 and 2010 (projections). We also simulated a potential case that assumed the potentials of wider application of technology, including ever-more-functional products.

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[1] This paper was prepared based on the specifics of our research (Energy Assessment of Steel Product Use from LCA Perspectives) assigned in FY2001 by the Japan Steel Federation, a corporate juridical person. The JSF has kindly allowed us to publish them. Acknowledgements are due to the JSF for its understanding and cooperation.

[2] These include changing energy needs for using high-functional steel-made products and for manufacturing such products, the latter as a result of lesser steel needs thanks to higher functionality.

1. H Beam for Building Steel Frames (High Strength Steel)[3]

1-1 **Trends toward use of high strength steel in H beam**

Among those available, SN standard section steel[4], which have good weldability and stricter control of impurities, are coming into popular use for building structures. In the case of conventional ordinary steel, increasing their thickness requires quality governing in order to secure strength, which leads to higher carbon equivalence and thus inevitably to deterioration in weldability. This has led to the development of TMCP[5] (thermo mechanical control process) steel, which features higher strength than ordinary steel despite having low carbon equivalence. Compared with conventional high strength steel, TMCP steel has higher strength, lighter weight and better workability.

From H-section steel output destined for the domestic market for building steel frames, changing shares held by high strength steel in H beam production and economic outlooks, among other data, we estimated the H beam output for 2005 and 2010, the results of which are shown in Fig. 1-1. Since 1990, Japan's H beam output has generally stayed at around 6.00 million tons. High strength H beams as referred to here represent two types, H beams made of 490N-class steel products (incl. SN standard ones) and those of 590N-class TMCP steel, which have been coming into wider use in recent years. In comparison, conventional steel represents 400N-class steel products. As H beam output in the last ten years has been interrelated to total private equipment investment, we took private equipment investment as an indicator, then estimated H beam output in 2005 and 2010 by extrapolating the expected investment growth for 2005 and 2010 over 2000 records. Our estimated results show no drastic changes in quantitative terms.

Between 1990 and 2000 High strength steel accounted for around 27% of overall H beams. Given the expected demand growth for IT (information technology)-based ultrahigh-rise office buildings (200m-high class), we assumed that demand for high strength H beams would be slightly on the increase. Breaking down high strength steel by grade, 490N occupied 98% of the whole as of 2000. On the assumption that the trends in 1990 – 2000 would continue thereafter, we assumed that production of 590N will be slightly on the increase in the future (Table 1-1).

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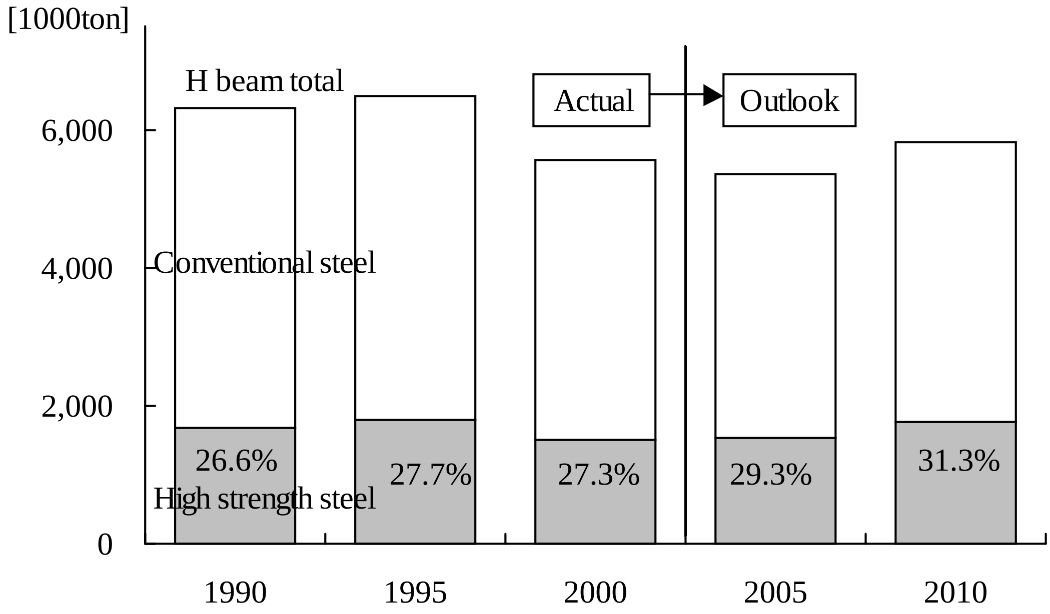
[3] http://eneken.ieej.or.jp/data/pdf/463.pdf

[4] That is, the newly set standards from July 1994 onward for rolled steel products for structures. SN stands for steel new structure.

[5] TMCP is a general term for the manufacturing process, which, based on control rolling, involves subsequent air-cooling or forced control cooling (accelerated cooling). Thanks to finer grain size and structure control, TMCP steel has such special features as lower carbon equivalence and better toughness than conventional steel.

Fig. 1-1 H beam Production for Domestic Use: Past and Future



(Note 1) Output shown here is in terms of total output of rolled and buildup-type H beams.
(Note 2) Actual records for 1990, 1995 and 2000 available from the Japan Steel Federation The figures for 2005 and 2010 estimated by IEEJ.

Table 1-1 Shares of High strength H beams Assumed by Grade of Strength

		1990	1995	2000	2005	2010	Potential case
Share by grade of strength (%)	490N	100%	99%	98%	97%	95%	90%
	590N	0%	1%	2%	3%	5%	10%

1-2 Energy conservation assessment method

H beams made of high strength steel involve fewer steel products than ordinary steel-made ones. As a result, energy needs for manufacturing steel products are also lower (a manufacturing energy-saving effect of lower steel needs). On the other hand, high strength H beam manufacturing involves strict quality governing at the steelmaking stage to better meet required specifications. At the rolling stage also, temperatures, draught, cooling and others in each of the heating, rolling and cooling processes are computer-controlled by a thermal processing control process designed to optimize grain size, structure and deposited matters of grains. As a result, manufacturing of high strength steel has shown itself to be more energy-intensive than conventional ordinary steel by the same margin as the incremental energy needs for additional thermal processing control processes (higher functionality-based incremental energy). We assessed these points.

(Manufacturing energy-saving effect of lower steel needs)

The expressions used in our calculation are described below.

Saved amount of manufacturing energy

= [Domestic output of high strength H beams (490N)

× Rate of reduced steel needs resulting from the shift from conventional (400N) to high strength H beams (490N)

(Rate of reduced steel needs[6]: 325/235 – 1 = 0.383)

+ Domestic output of high strength H beams (590N)

× Rate of reduced steel needs resulting from the shift from conventional (400N) to high strength H beams (590N)(TMCP steel)

× Energy intensity in manufacturing conventional H beams (400N)

(High functionality-based incremental manufacturing energy)

The expressions used in our calculation are described below.

Incremental energy at manufacturing stage

= [Domestic output of high strength H beams (490N)

× Incremental energy intensity resulting from the shift from conventional (400N) to high strength H beams (490N)

+ Domestic output of high strength H beams (590N)

× Incremental energy intensity resulting from the shift from conventional (400N) to high strength H beams (590N)(TMCP steel)

1-3 Summary of energy ups/downs resulting from greater use of high strength H beams

Table 1-2 contains the results of our estimation of ups/downs in energy consumption expected from the greater use of high strength H beams. Unlike the other steel products discussed later, H beams for building steel frames are characterized by the fact that they show no cumulative energy-saving effects in their service life[7]. In the potential case, we assumed that H beam output would be the same as that projected for 2010, but that the share of high strength steel in total H beam production would be 2% higher than the share assumed for 2010.

Between 1990 and 2000, because high strength steel output showed little change, the

[6] The relation between stress of H beam and steel product needs for H beam manufacturing can be expressed as follows: S = F/A (S : stress, F: external force, A: section area). Therefore, the rate of increase in strength = the rate of decrease in steel product needs (the difference in steel product needs for H beam manufacturing of equivalent strength between the cases using 400N and high-strength steel. Because design standards for structures are regulated with the yield point, we made the calculations by taking the lower yield points of individual grades (400N: 235N/mm^2, 490N: 325N/mm^2, 590N: 440N/mm^2, all representing JIS or Steel Product Manufacturers Club Standards).

[7] When in use, High strength steel improves the strength and corrosion resistance of steel frames and thus leads to a longer service life of buildings, resulting in reduced amounts of steel products used in building construction as well as energy needs for manufacturing steel products in the future. However, our analysis did not cover these potentials.

overall energy-saving effect likewise remained unchanged. As a result of growing high strength steel output plus a rising share of 590N, a roughly 17% greater amount of energy could be saved in 2010 than in 1990. In the potential case, where ever-more-functional H beams were assumed, we found that the energy-saving effect would be about 32% greater than in 1990.

Table 1-2 Energy-saving Effect of High strength H beams for Building Steel frames (Summary)

<table>
<tr><th colspan="2"></th><th>1990</th><th>1995</th><th>2000</th><th>2005</th><th>2010</th><th>Potential case</th></tr>
<tr><td colspan="2">Hi-tensile steel total [1,000 tons/year]</td><td>1,676</td><td>1,801</td><td>1,529</td><td>1,582</td><td>1,847</td><td>1,965</td></tr>
<tr><td rowspan="2">Output by grade of strength [1,000 tons/year]</td><td>490N</td><td>1,676</td><td>1,782</td><td>1,498</td><td>1,535</td><td>1,754</td><td>1,768</td></tr>
<tr><td>590N</td><td>0</td><td>18</td><td>31</td><td>47</td><td>92</td><td>196</td></tr>
<tr><td>Saved energy [10,000 kl crude oil equivalent]</td><td>Fuel-saving effect</td><td>41.21</td><td>44.84</td><td>38.56</td><td>40.40</td><td>48.31</td><td>54.49</td></tr>
<tr><td>Incremental energy [10,000 kl crude oil equivalent]</td><td>High functionality-based effect</td><td>0.50</td><td>0.55</td><td>0.48</td><td>0.51</td><td>0.61</td><td>0.72</td></tr>
<tr><td colspan="2">Saved energy total [10,000 kl crude oil equivalent]</td><td>40.71</td><td>44.29</td><td>38.08</td><td>39.89</td><td>47.70</td><td>53.77</td></tr>
</table>

2 Generating Boilers (Heat-resistant Tubes)[8]

2-1 Trends toward use of high-performance heat-resistant tubes in generating boilers[9]

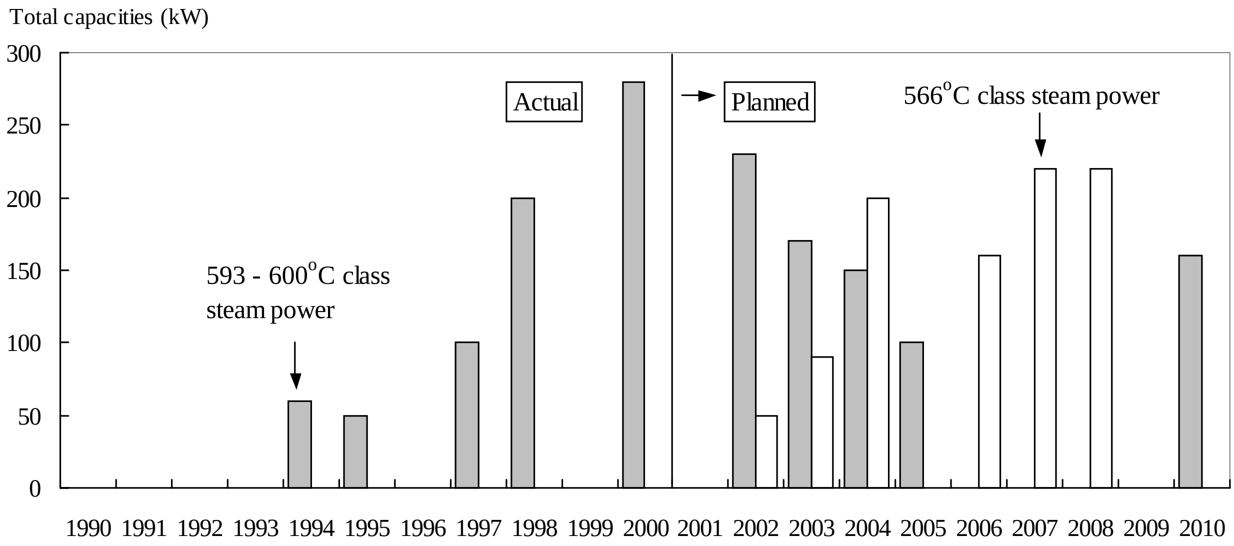
In recent years, along with an increasing per-unit capacity of fossil-fired generating facilities installed in Japan, efforts have been made to increase their efficiency in response to conditions of higher temperatures and steam pressures. As a result, demand has been growing for boilers made of high-performance heat-resistant tubes that can withstand high-temperature, high-pressure steam. The production of high-performance heat-resistant tubes for generating boilers will depend on the plans for installing supercritical pressure power plants in which the tubes are to be used. Fig. 2-1 illustrates actual records in 1990 – 2000 and plans for 2001 – 2010 of total capacities commissioned each fiscal year of the 593-600^{o}C class steam power plants[10] and those of the 566^{o}C class steam power plants. It should be noted that, in case of the 593-600^{o}C class coal-fired steam power plants subject to our analysis, the total capacities commissioned each year, 60 MW in 1994, continued to rise from then to 2000 (Fig. 2-1). Over the coming period from 2001 to 2010, it is planned to commission a total of 8.10 GW[11].

8 http://eneken.ieej.or.jp/data/pdf/464.pdf
9 These represent heat-resistant tubes made of high alloy steel, notably improved 9Cr and stainless steel seamless tubes. In particular, our analysis covered high alloy steel used in steam power plants of 593^{o}C – 600^{o}C steam temperature.
10 All steam power plants subject to our analysis are coal-fired.
11 Power development currently planned contains no plans for installing any steam power plants with steam temperatures of over 600^{o}C (according to our interview surveys conducted at the ten electric utilities and Electric Power Development Co.).

Because the total capacities commissioned each fiscal year have varied (Fig. 2-1), we took a five-year average of total capacities of the 593-600°C class steam power plants commissioned in five years preceding to each target year as the total capacities put on stream in a given target year (Table 2-1).

The generated output of steam power plants varies depending on operating conditions at individual plants. In our analysis, we calculated the generated output for the target fiscal years by taking an average utilization factor (about 80%) recorded in FY1999 by 11 units of the 593-600°C class steam power plants (Table 2-1).

Fig. 2-1 Total Capacities of 566°C-class and 593 – 600°C-class Steam Power Plants Commissioned Each Fiscal Year (Actual Records and Planned)



(Source) Prepared from METI, "General Descriptions of FY2000/2001 Power Source Development – Plans and Outlines," and our interview survey results made with the ten electric utilities and Electric Power Development Co. on their power development plans.

Table 2-1 Capacities Commissioned and Generated Output Planned in Target Years

	1990	1995	2000	2005 (expected)	2010 (expected)
Annual capacities commissioned (10 MW)	0	22	116	130	32
Annual generated output [GWh]	0	1,542	8,129	9,110	2,243

We investigated how much low- and high-alloy steel was used in the 593°C-class and the 600°C-class steam power plants (both coal-fired) per 10 MW of generated output. We found that, in the case of the 600°C-class steam power plants, high-alloy steel use was up by 11.83 tons per 10 MW of generated output, while low-alloy steel use was down by 11.55

tons per 10 MW[12]. Table 2-2 shows the changing amounts of steel products used in the 600°C-class steam power plants commissioned each target year compared with those used in the 566°C-class ones.

Table 2-2 Steel Product Consumption in Target Years

	1990	1995	2000	2005	2010
Low-alloy steel consumption down (tons/year)	0	-254.18	-1,340.22	-1,501.97	-369.72
High-alloy steel consumption up (tons/year)	0	260.35	1372.75	1538.43	378.69
Steel product use up (tons/year)	0	6.17	32.54	36.46	8.98

2-2 Method of assessment of energy conservation

When employed in a steam power plant, high-performance heat-resistant tubes can improve steam conditions and thus increase its generating efficiency. As a result, the power plant consumes a smaller amount of fuel than any steam power plants in which conventional heat-resistant tubes are employed (fuel-saving effect of introducing high-performance heat-resistant tubes). A shift from the 566°C-class steam power plants to the 593-600°C class ones sends the ratio of high-alloy steel use up and that of low-alloy steel down (incremental manufacturing energy resulting from introduction of high-performance heat-resistant tubes). We assessed these points.

(Fuel-saving effect of introduction of high-performance heat-resistant tubes)

The expressions used in our calculation are described below.

Saved amount of fuels
= Saved amount of fuels resulting from the shift from conventional power plants to those employing high-performance heat-resistant tubes
× Rate of contribution of high-performance heat-resistant tubes, or 25%
× Number of years power plants are in service[13]

As generating efficiency, a variable essential in investigating the saved amount of fuel, we took the average of gross generating efficiencies at power plants actually in operation (three plants for each class), which we ascertained during our interview surveys. In specific terms, we put generating efficiencies at 41.5% for the 566°C-class, and 43.1% for the 593°C – 600°C-class[14].

We also assumed that one-fourth of the saved amount of fuel resulting from improved generating efficiency could be attributed to high-performance heat-resistant tubes employed

[12] Surveyed by the Japan Steel Federation.
[13] We assumed that power plants were in operation for 40 years as calculated by the Nuclear Power Subcommittee, a unit of the Advisory Committee for Energy, in its calculations (as of December 1999).
[14] Averages of gross generating efficiencies (with three samples) ascertained from our interview surveys with electric utilities.

in the boilers[15].

(High functionality-based incremental manufacturing energy)

The expressions used in our calculation are described below.

Incremental manufacturing energy

= The gap in manufacturing energy needs reflecting the different steel needs between the 593^{o}C – 600^{o}C-class steam power plants commissioned in a given fiscal year and the 566^{o}C-class ones, if commissioned instead of the 593^{o}C – 600^{o}C-class ones

= (High functionality-based incremental energy)

+ (Incremental energy resulting from greater steel needs for product manufacturing)

Here,

(High functionality-based incremental energy) = Larger high-alloy steel consumption × Difference in manufacturing energy between high- and low-alloy steels

(incremental energy resulting from greater steel product consumption)

= Larger steel product consumption × Energy intensity in manufacturing low-alloy steel

2-3 Energy saved by introduction of high-performance heat-resistant tubes

Table 2-3 presents a summary of ups/downs in energy consumption that high-performance heat-resistant tubes could bring about, if employed in steam power plants of the 593^{o}C – 600^{o}C-class.

The combined commissioned capacity in the potential case was gained not only from the combined capacities of the 593^{o}C – 600^{o}C-class steam power plants expected to start operation in FY2001 – 2010 but also from the case where the 593^{o}C – 600^{o}C -class steam power plants were commissioned instead of the 566^{o}C-class ones in the programme.

The actual records in 1990 – 2000 as well as the outlooks for the years up to 2005 reveal that the energy-saving effect has been growing in proportion to the size of commissioned capacities under power development plans. In 2010, the energy-saving effect decreases as a result of the shrinking size of commissioned capacities. However, the potential case, which covers the 566^{o}C-class steam power plants as well, shows that the energy-saving effect in 2010 will be about 1.5 times larger than in 2000.

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[15] Based on our interview surveys made with the Japan Electrical Machinery and Appliances Manufacturers Association, the Japan Industrial Machinery Manufacturers Association and others, we judged that it would be reasonable to follow what was described in Literature (1). Accordingly, we assumed that, of the total contribution made by improved steam conditions (temperature rises) to fuel conservation, 50% each could be attributed to turbine and boiler sides. We also assumed that, of the 50% contribution attributable to the boiler side, half (50%) resulted from higher functionality given to boiler materials.

Table 2-3 Energy-saving Effects Expected from Greater Use of Heat-resistant Tubes

		1990	1995	2000	2005	2010	Potential case
Capacities commissioned each year [10 MW]		0	22	116	130	32	175
Changes in steel product use (when shifted from 566oC to 600oC-class)	Low-alloy steel [tons/year]	0	-254.18	-1,340.22	-1,501.97	-369.72	-2,021.88
	High-alloy steel [tons/year]	0	260.35	1,372.75	1,538.43	378.69	2,070.96
	Incremental steel product use [tons/year]	0	6.17	32.54	36.46	8.98	49.08
Generated output each year [GWh]		0	1,542	8,129	9,110	2,243	12,264
Saved energy	Fuel-saving effect (year of use) [10,000kl crude oil equivalent]	0	13.50	71.17	79.76	19.63	107.37
Incremental energy	High functionality-based effect (year of manufacturing) [1,000kl crude oil equivalent]	0	0.02	0.11	0.12	0.03	0.16
	Incremental steel product use (year of manufacturing) [kl crude oil equivalent]	0	4.87	25.67	28.76	7.08	38.72
Total energy saved [10,000kl crude oil equivalent]		0	13.49	71.15	79.74	19.63	107.35

3 Automobiles (High Strength Sheets)[16]

3-1 Trend toward use of high strength sheets in automobiles

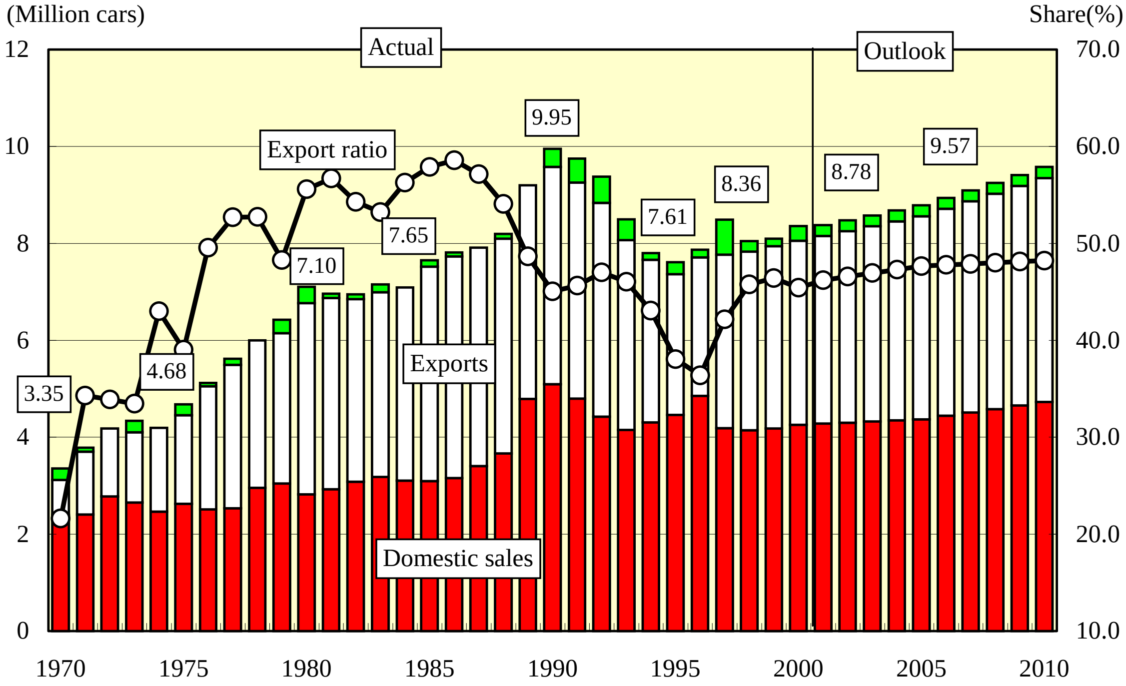
One of the principal requirements for a car body is that it should provide drivers with a safe and comfortable space, guarantee necessary strength and toughness for driving, and offer attractive styling. In recent years, Europe's tougher safety standards have required carmakers to make safety and weight reduction compatible. As a result, partly thanks to the development of a wide variety of high strength sheets, application of high strength sheets is expanding.

Fig. 3-1 shows production, exports and domestic sales of passenger cars in the past and the future. Exports and domestic sales of passenger cars, constantly on the increase by around 1990, dropped sharply in the years up to 1995, indicating a drastic change. Therefore, without resting on any long-term trends, we calculated the future development by extrapolating the growth rates in the immediately preceding three years into the years up to 2010 in an appropriate manner.

As a result of the greater use of high strength sheets in automobiles, the sheets used in car manufacturing are becoming thinner, which in turn helps reduce the white body weight per automobile projection area (area weight). Fig. 3-2 summarizes the data that show changing ratios of high strength sheets used in automobiles and resultant area weight.

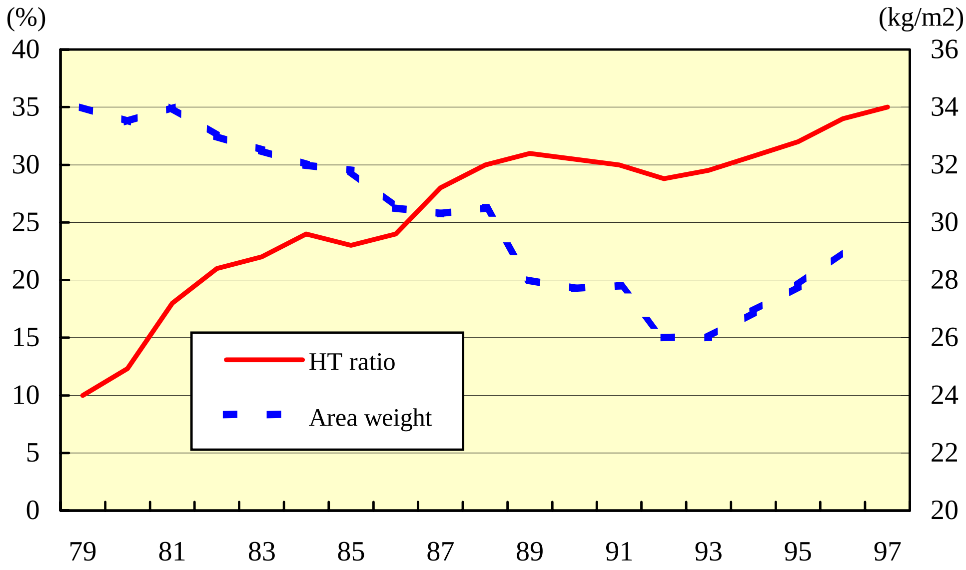
16 http://eneken.ieej.or.jp/data/pdf/465.pdf

Fig. 3-1 Automobile Production Records and Outlook



(Source) Outlook was prepared from the growth rates of exports and domestic sales in the last three years.

Fig. 3-2 High strength Ratios and Area Weight of Automobiles



(Source) FUERAM, Vol. 11, No. 2, 1996

3-2 Method of assessment of energy conservation

The thinness realized by high strength sheets helps to reduce the weight of automobiles, and this is expected to have an energy-saving effect as a result of better fuel efficiency while driving (motor fuel-saving effect of weight reduction). Furthermore, weight reduction resulting from application of high strength sheets is helpful in lowering steel product requirements for manufacturing automobiles, so that an energy-saving effect can be expected in the form of lower energy needs for manufacturing (manufacturing energy-saving effect of lower steel needs for car manufacturing). On the other hand, at the manufacturing stage, high strength sheets are more energy-intensive than ordinary steel sheets, resulting in greater energy consumption in their manufacturing processes (high functionality-based incremental manufacturing energy).

The energy-saving effects expected from the use of high strength sheets are manifold. They include lower energy needs for product processing, longer service life of cars thanks to improved corrosion resistance of surface-treated sheets, and lower energy consumption in transporting steel products for car manufacturing, in terms of both lower steel needs and lighter steel products. However, as few data were available, these effects were not covered this time.

(Fuel-saving effect of weight reduction while driving)

The expressions used in our calculation are described below.

Saved amount of fuel while driving
= Number of new car production (passenger cars) (cars/year)
× Average mileage (passenger cars) (km/car)
× Rate of fuel-efficiency improvement (passenger cars) (%)/average fuel efficiency of new cars (passenger cars) (km/l)
× Number of years in service (years)
× Calorific value of fuels (gasoline 33.405 (MJ/l) (7,980 kcal/l)

With this analysis, we estimated the effect of weight reduction on decreases in fuel consumption by employing the number of new passenger cars produced, including exported cars, in order to ascertain the effects of passenger car production activities overall. Here, we assumed the driving conditions of exported cars to be the same as those in Japan.

The rate of improvement of the fuel-efficiency of passenger cars[17] as a result of lighter car bodies made of high strength sheets was obtained from two factors. One is the

[17] Passenger cars can be broadly divided into three groups, namely ordinary cars, small four-wheeled cars and light four-wheeled cars. Each group contains a wide variety of passenger cars differing in displacement, etc. We decided nevertheless to take average and typical models as representative ones. Based on the results of our interview survey made with the Japan Automobile Manufacturers Association, we assumed that representative models of average size have a vehicle weight of 1,100 kg. Also, as we were informed that a projection area of white body was 7.3 – 7.4m^2, we set this at 7.5m^2 in our analysis.

relation between the high strength ratio and the vehicle weight reduction rate. The other is the proportional relation between the vehicle weight reduction rate and the fuel-efficiency improvement rate. We determined how the high strength ratio was related to the vehicle weight reduction rate by examining which parts could be made lighter by use of high strength sheets and what their resultant weight would be. In doing so, we referred to the changes in the ratio of high strength sheets used in passenger car bodies and in area weight (Fig. 3-2) as well as the interrelation between the high strength ratio and area weight as clarified by research of the ULSAB Project[18]. As the rate of fuel-efficiency improvement corresponding to the vehicle weight reduction rate, we used the median between maximum and minimum values. Namely, we assumed that fuel efficiency improves by 4.5% when the vehicle weight is reduced by 10%[19].

We summarized the changes in characteristic indicators required for assessment, the results of which were shown in Fig. 3-3. In regard to the average mileage and the average number of years cars were in service, we calculated their average growth rates during the decade of the 1990s, and then extrapolated the growth rates for the years up to 2010. As for the average fuel efficiency of new cars, the target rate of improvement from 1990 records is specified in Japan's voluntary action plan for global warming abatement. On the assumption that the target rate would be achieved in 2010, we calculated what the rate would be between 2000 and 2010.

(Manufacturing energy-saving effect of lower steel product needs)

The expressions used in our calculation are described below.

Saved amount of manufacturing energy
= Number of new cars produced (passenger cars) (cars/year)
× Weight reduction per projection area (passenger cars) (kg/m^2)
× Projection area (passenger cars) (m^2/car)
× Energy intensity in steel sheet manufacturing (ordinary steel) (MJ/kg)

(High functionality-based incremental manufacturing energy)

The expressions used in our calculation are described below.

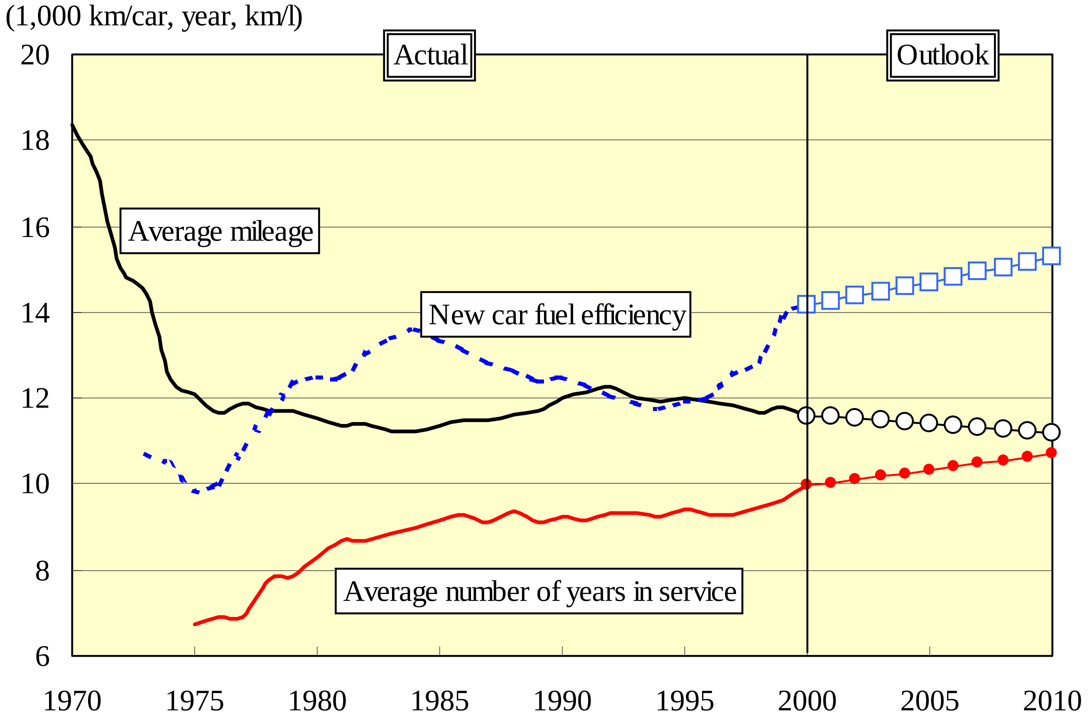
Incremental manufacturing energy
= Number of cars produced (passenger cars) (cars/year)
× [Car body weight per projection area (kg/m^2)

[18] This is a R&D project on ultra-light steel automobile bodies (ULSAB) by the major steel makers of 15 member countries of the International Iron and Steel Institute (IISI). It targets weight reduction of white body by around 30% while securing toughness and collision safety of automobiles. ULSAB results gained through May 1998 showed that the high strength ratio could be increased to 64%. This means that the vehicle weight of the target vehicles having a white body projection area of $8.64m^2$ could be reduced to 203 kg, namely to 23.5 kg/m^2 in terms of white body weight per projection area (area weight).

[19] Based on literature data (IPCC: Intergovernmental Panel on Climate Change, ULSAB Project) as well as our interview survey results to the Japan Automobile Manufacturers Association.

× Projection area (m^2/car))
+ Weight of other high strength-made parts] (passenger cars)
× high strength ratio (passenger cars)
× [Energy intensity in sheet manufacturing (high strength sheets) (MJ/kg)
– Energy intensity in sheet manufacturing (ordinary steel) (MJ/kg)]

Fig. 3-3 Average Mileage, Average Number of Years in Service and New Car Fuel Efficiency



(Note) Outlook was prepared based on the average growth rate in the last ten years as well as 2010 targets.
(Sources) Japan Automobile Manufacturers Association's homepage, IEEJ "Energy and Economy Statistical Handbook 2002"

3-3 Summary of energy ups/downs resulting from application of high strength sheets to automobiles

Table 3-1 summarizes the ups/downs in energy consumption that can result from application of high strength sheets to car manufacturing.

Actual records in 1990 – 2000 and outlooks for 2005 and 2010 reveal that passenger car production were decreasing in number from 1990, while the rising high strength ratio enables energy-saving gains to remain above certain levels. The potential case was found to have an energy-saving effect more than double the 1990 records. This is because the high strength ratio was assumed to be 50%, in addition to the secondary effects of lighter white body in a single unit and the additional weight reduction effect of high strength-made chassis parts.

Table 3-1 Energy-saving Effect of High tensile Sheets Used in Automobiles (Summary)

	1990	1995	2000	2005	2010	Potential case
Automobile output (10,000 cars)	995	761	836	878	957	957
High tensile consumption (1,000 tons)	651	517	631	713	830	858
High tensile ratio (%)	30.5	32	37	41	45	50
Vehicle weight reduction rate (%)	6.1	6.4	7.1	7.6	8.1	16.3
Average number of years in service	9.26	9.43	9.96	10.33	10.71	10.71
Average mileage (1,000 km/car)	12.02	12.01	11.59	11.39	11.18	11.18
New car fuel efficiency (km/l)	12.5	11.9	14.15	14.7	15.28	15.28
Saved energy (10,001 kl crude oil equivalent)	225.27	190.73	198.25	217	245.48	497.78
Fuel-saving effect (year of use)	47.44	37.51	46.07	52.14	60.38	121.06
Steel-saving effect (year of manufacturing)	-1.15	-0.91	-1.11	-1.26	-1.47	-2.46
Incremental energy (10,000 kl crude oil equivalent)	271.56	227.33	243.21	267.88	304.39	616.38

4 Vessels (High Tensile Plates)[20]

4-1 Trends toward use of high tensile plates in shipbuilding

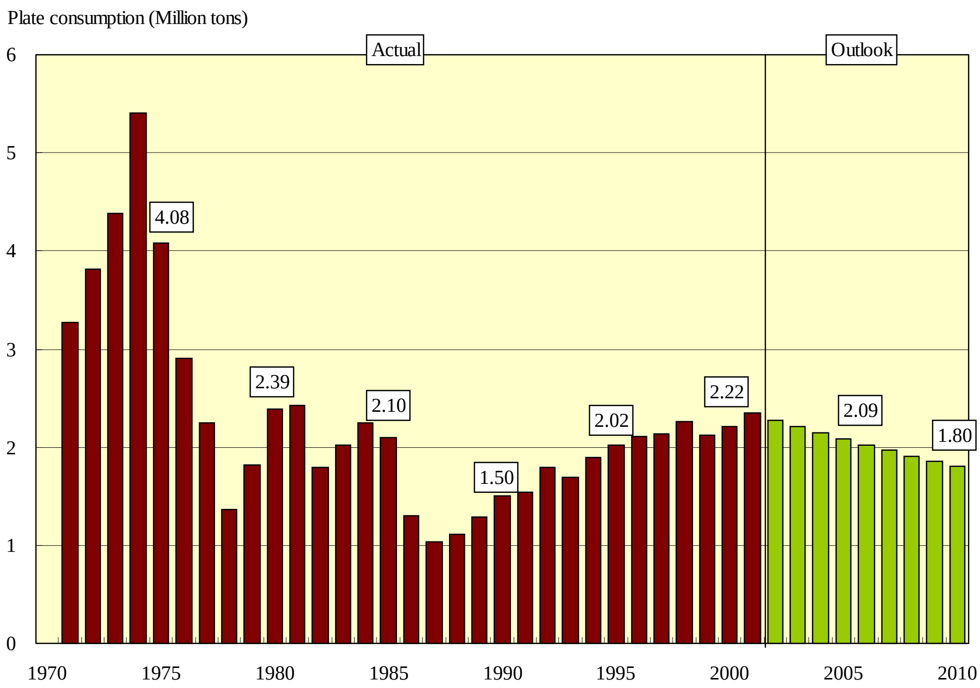
Fig. 4-1 shows changing plate consumption in shipbuilding in the past, and the outlook. Given the pause in replacement demand in the 1970s, among other things, we assumed that plate needs for shipbuilding would be declining moderately by the same margin as the falling rate of total tonnage of vessel construction projected by shipbuilders.

With the oil crises of the 1970s as the turning point, improvement of fuel-efficiency in navigation has become the top priority from the standpoint of energy conservation and, in this connection, efforts have been made to increase propulsion efficiency and reduce hull resistance, among others. As a result, shipbuilders have been required to make lighter hulls than ever. Today, almost all side structural members and those inside the hull are made of high strength plates. Fig. 4-2 shows the changing ratios of high strength plates to total plate use in shipbuilding. The high strength ratio remained as low as less than 30% until the first half of the 1970s. However, from the beginning of the 1980s, the high strength ratio started to rise sharply thanks to TMCP capable of manufacturing high-strength steel of outstanding low-temperature toughness at low carbon equivalence, and had reached about 70% by 1985. In regard to recent high strength ratios, we calculated the weighted average

[20] http://eneken.ieej.or.jp/data/pdf/465.pdf

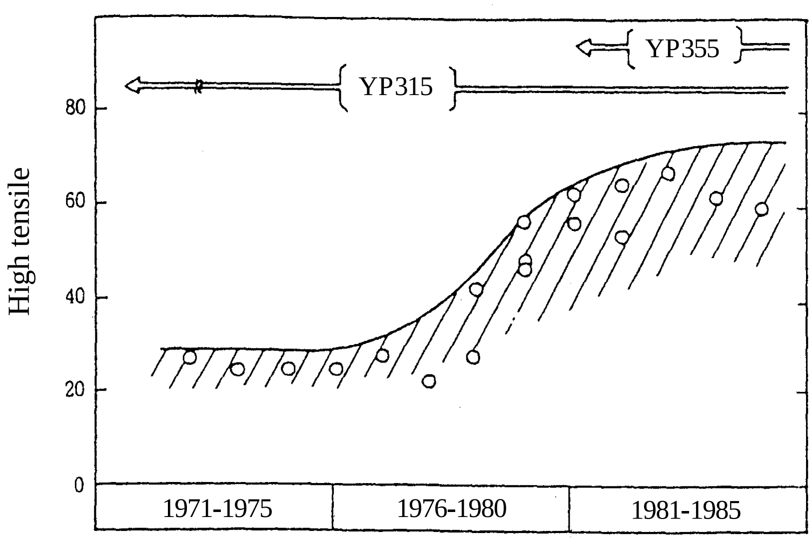
of high strength ratios of ocean-going vessels, of which the high strength plate needs were found to be particularly large when examined by using the bottoms ratio available from the Japan Shipbuilders Association. Our calculation result was 70%. In other words , after reaching 70% around 1985, the high strength ratio has remained virtually unchanged at 70% to date.

Fig. 4-1 Changing Plate Use in Shipbuilding and Outlook



(Source) Japan Shipbuilding Industry Association

Fig. 4-2 Shares of High tensile Plates in Shipbuilding



(Source) Japan Steel Society

4-2 Method of assessment of energy conservation

Replacement of ordinary steel plates used as structural members in shipbuilding with high strength plates allows energy conservation in two points. One is that a lighter hull makes possible less bunker fuel consumption than ever (bunker fuel-saving effect of weight reduction). The other is a lighter hull requires fewer steel products for shipbuilding than ever (manufacturing energy-saving effect of lower steel product needs). However, compared with ordinary steel plates, high strength plates involve additional processes such as degassing to finish cleanness of steel at the steelmaking stage, controlled rolling to adequately regulate heating temperatures, rolling temperatures and draught amounts of slabs, and controlled cooling to quench plates immediately after rolling. The energy used in these additional processes is added to manufacturing energy (high functionality-based incremental manufacturing energy). We assessed these points.

(Bunker fuel-saving effect of weight reduction)

The expressions used in our calculation are described below.

Saved amount of bunker fuels
= Bunker fuel consumption (kl/year)/(1 – Weight reduction rate of vessels in service (%) × Rate of contribution to reducing fuels (%))
× (Weight reduction rate of vessels in service × Rate of contribution to reducing fuels)
× Calorific values of fuels[21] × number of years vessels are in service

In view of the fact that since 1983 bunker fuel oil consumption has been on the increase in the long run, we estimated bunker fuel consumption from now up to 2010 by calculating the respective average growth rates of diesel and heavy fuel oil in the decade of the 1990s. From bunker fuel consumption recorded in the past and projected for the future, we estimated the bunker fuel consumption of newly constructed vessels in Japan, the results of which were shown in Table 4-1. Here, we calculated bunker fuel consumption of the newly in-service vessels in Japan for each target year from the ratio of total tonnage of newly constructed vessels in Japan for each target year to the cumulative total tonnage of the vessels constructed in the preceding 25 years for each target year.

We took the weight reduction rate of the vessels in service to be 0.135 by calculating the weighted average set by type of high strength steels (YP315 and YP355) based on the proportional relation between ordinary and high strength steels' ratios in weight to the high strength ratio[22].

[21] Lower calorific values of bunker fuels (MJ/kl), crude oil 36,795 MJ/kl (8,790 Mcal/kl), diesel 36,586 MJ/kl (8,740 Mcal/kl), heavy fuel oil 38,972 MJ/kl (9,310 Mcal/kl).

[22] High strength steels used in crude oil tankers, bulk carriers, container vessels and the like are generally either YP315 (HT32) or YP355 (HT36). Because YP355 (HT36) has been on the market since the early 1980s, we assumed in this analysis, which is designed to cover the post-1990 period, that YP315 (HT32) and YP355 (HT36) each accounted for 50%.

Table 4-1 Estimated Fuel Consumption of Newly Constructed Vessels in Japan

	1990	1995	2000	2005	2010
Fuel consumption (10,000 TJ)					
World total	473	508	587	654	730
Japan's cumulative vessels	253	258	260	274	295
Japan's newly constructed vessels	7.19	9.7	12.64	12.2	10.77

The rate of contribution to reducing fuels was assumed to be about 5.6% (= 1/12 × 2/3) of the hull weight reduction. This is based on the calculation results that about 1/12 of the hull weight reduction leads to a decreased displacement of vessels, and that fuels can be saved at an equivalent ratio to about two-thirds of the decreased displacement. Hence, we assumed that a hull that is lighter by 13.5% could save fuels by 0.75%. The service life of vessel was taken to be 25 years.

(Manufacturing energy-saving effect of lower steel product needs)

The expressions used in our calculation are described below.

Saved amount of manufacturing energy
= Vessel plate output (tons/year)/(1 – Weight reduction rate of constructed vessels[23] (%)
× Weight reduction rate of constructed vessels (%)
× Energy intensity in plate manufacturing (ordinary steel) (MJ/kg)

(High functionality-based incremental manufacturing energy)

The expressions used in our calculation are described below.

Incremental manufacturing energy
= Vessel plate output (tons/year) × Ratio of high strength plates in use (%)
× [Energy intensity in plate manufacturing (high strength plates)
– Energy intensity in plate manufacturing (ordinary steel)] (MJ/kg)

4-3 Summary of energy ups/downs resulting from use of high strength plates in shipbuilding

Table 4-2 presents a summary of the ups/downs in energy consumption that can be expected when high strength plates are used in shipbuilding.

The share of high strength plates used in shipbuilding reaches its ceiling at the present 70%. Also, there are only low incentives for a switchover to high strength plates of higher quality from the standpoints of longer service life and better corrosion resistance. On these accounts, we assumed in our estimation of the years up to 2010 that the present conditions of high strength plates will remain unchanged. From both actual records and future outlooks, it is clearly noted that an energy-saving effect can be gained in proportion to plate demand

[23] The rate of weight reduction in the vessels constructed in a given year from the case where ordinary steel is in use.

for shipbuilding. In the potential case, in which a shift[24] to even stronger high strength plates was assumed to enhance weight reduction (by 15%), the energy-saving effect was found to be larger by about 12% than that projected for 2010.

Table 4-2 Energy-saving Effect of Use of High strength Plates in Shipbuilding (Summary)

	1990	1995	2000	2005	2010	Potential case
Plate consumption (1,000 tons)	1,482	1,995	2,187	2,060	1,781	1,750
High strength plate consumption (1,000 tons)	1,037	1,396	1,531	1,442	1,246	1,225
Constructed hull weight reduction rate (%)	13.5	13.5	13.5	13.5	13.5	15
Number of years in service	25	25	25	25	25	25
Fuel consumption (1,000 TJ/year)	71.86	96.99	126.4	122	107.7	107.58
Fuel-saving rate (%)	0.75	0.75	0.75	0.75	0.75	0.83
Saved energy (10,000 kl crude oil equivalent)						
Fuel-saving effect (year of use)	36.35	49.06	63.95	61.73	54.46	60.41
Steel-saving effect (year of manufacturing)	16.12	21.7	23.8	22.41	19.37	21.52
Incremental energy (10,000 kl crude oil equivalent)						
High functionality-based effect	-2.90	-3.90	-4.28	-4.03	-3.49	-3.42
Total energy saved (10,000 kl crude oil equivalent)	49.57	66.86	83.47	80.11	70.34	78.51

(Note) It was assumed that 98.7% of plate consumption in shipbuilding shown in Fig. 4-1 would be used in ocean-going vessels.

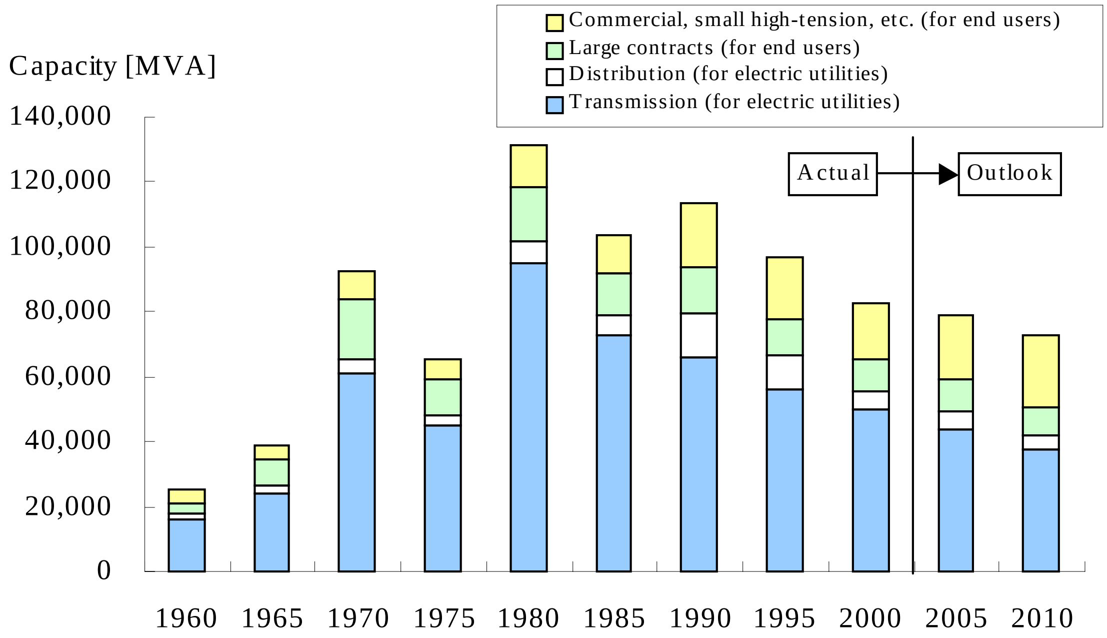
5 Transformers (Grain-oriented Silicon Steel Sheets[25])[26]

5-1 Trends toward use of directional silicon steel sheets in transformers

Fig. 5-1 shows actual records and outlooks of transformer production by type. Meanwhile, Fig. 5-2 presents the historical changes in production of grain-oriented silicon steel [27] used in iron cores of transformers. It is noted that production of transformers has been on the decline since 1990, while output of silicon steel sheets has been generally on the rise from 1970 to recent years.

[24] The share of YP355 (HT36) in high strength plates is assumed to reach 100%.
[25] Silicon steel, if used in the iron core of transformers, can improve the magnetic characteristics (greater permeability of silicon steel can increase magnetic flux density inside steel products). Because of this characteristic, silicon steel is called electromagnetic steel.
[26] http://eneken.ieej.or.jp/data/pdf/467.pdf
[27] The steel products used in transformers are divided into ordinary steel products used in containers and supporting structural parts, and the silicon steel sheets used in iron cores.

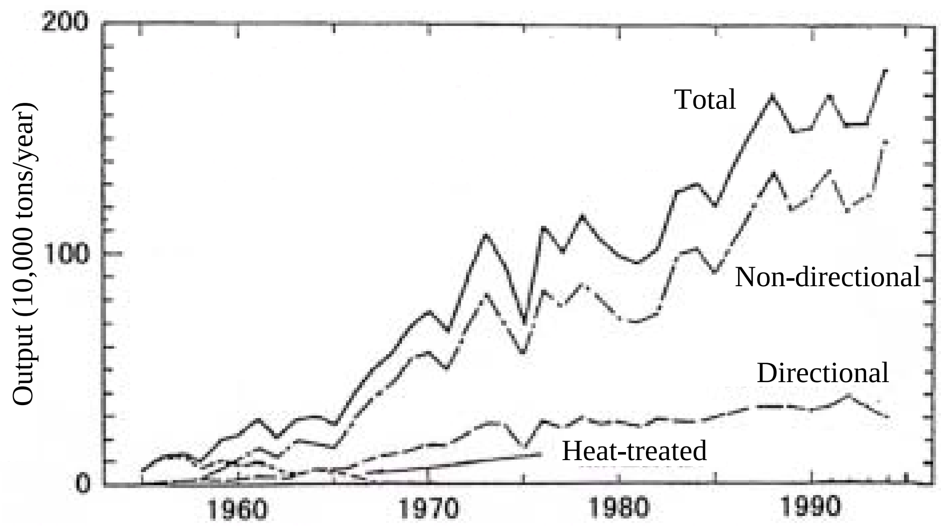
Fig. 5-1 Transformer Output Records and Outlook (by Type)



(Note) As the categorization in 1960 was different from that employed at present, transformers were this time re-categorized into those designed for electric utilities and others for end users, as well as into standard and non-standard transformers. In particular, those produced in the 1960 – 1980 period were estimated from cumulative production records in 1987 – 2000 with proportional allotment. Outlooks for 2005 and 2010 were calculated by extrapolating output records.

(Source) METI, "Machinery Statistical Yearbooks"

Fig. 5-2 Silicon steel Sheet Production



(Source) Japan Steel Federation, "Energy Assessment of Steel Product Use from LCA Perspectives," March 1997

5-2 Method of assessment of energy conservation

Transformer demand generally includes new and replacement demand, the former in response to new electricity demand largely from newly constructed buildings, etc. In the case of new demand for transformers, it appears reasonable to compare the energy efficiency of brand-new transformers with that of newer ones among those already installed. This approach, however, ends in a very limited energy-saving effect. Therefore, our analysis focused on what energy-saving effects could be expected when the existing old-fashioned silicon steel-made iron-core transformers were replaced with the most advanced highly directional ones. This kind of replacement has two favorable effects. First, no-load losses of the iron core are lessened, which is effective in decreasing losses while a transformer is in service (electricity-saving effect of reduced losses of transformer). Second, thanks to the better silicon steel characteristics of iron cores, conversion of a given amount of electricity involves a smaller iron core than is conventionally required, which means lower needs for silicon steel sheets than ever (manufacturing energy-saving effect of lower steel needs).

(Electricity-saving effect of decreasing losses of transformer)

The expressions used in our calculation are described below.

Saved amount of energy by decreasing losses of transformer
= Capacity of transformers replaced in a given year (minimum value in the bracket on right (capacity of transformers produced in an assessment year, capacity of those produced 30 years ago)
× (Transformer no-load losses per unit MVA in an assessment year
- Transformer no-load losses per MVA 30 years ago)
× Annual operating hours × Number of years transformers are in service

We decided to assess how much energy had been saved by the replacement of transformers as of 1990 by calculating the energy-saving effect that could be gained if all the transformers produced in 1960 were replaced with new ones. In this connection, we assumed that all were replaced if a comparison showed that the transformers produced in 1990 outnumbered those produced in 1960. Conversely, if the transformers produced in 1960 outnumbered those produced in 1990, this would mean that not all the 1960-made transformers had been replaced with 1990-made ones. In other words, we assumed that replacement took place for an identical number of 1960-made transformers and of 1990-made ones.

Regarding transformer no-load losses per MVA, we estimated the historical changes from the relation between voltage of higher voltage side and per-MVA no-load losses as well as yearly trends of no-load losses by type of transformer (Table 5-1).

Table 5-1 Decreasing No-load Losses per Unit Capacity (kW/MVA)

Year		1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Voltage (kV)	Rated capacity (MVA)	No-load losses per unit capacity (kW/MVA)										
500	1,000	-	-	0.45	0.35	0.30	0.26	0.22	0.20	0.18	0.17	0.16
275	300	1.09	0.92	0.82	0.69	0.60	0.55	0.49	0.44	0.41	0.38	0.36
154	200	1.38	1.22	1.09	0.97	0.90	0.80	0.73	0.68	0.62	0.57	0.53
66	20	2.12	1.69	1.42	1.23	1.10	0.95	0.89	0.80	0.74	0.70	0.63
6.6	0.02	2.62	2.20	1.93	1.70	1.50	1.33	1.22	1.13	1.03	0.92	0.88

(Source) Expert Committee on Energy Conservation of Substation Appliances, "Energy Conservation Measures of Substation Appliances and Efficient Operation," Electricity Joint Research, Vol. 40 (1984), No. 4 , Electricity Joint Research Group

Regarding annual running hours of transformers, we assumed this to be 8,760 hours for those used by electric utilities in transmission and distribution 24 hours a day. Running hours of the transformers for any other uses were estimated from supply & demand statistics in the Electric Utilities Handbook. The service life of transformers was put at 30 years based on actual records.

(Manufacturing energy-saving effect of lower steel needs)

The expressions used in our calculation are described below.

Saved amount of silicon steel sheets in transformer manufacturing
= Iron loss per MVA of new silicon steel sheets
Iron loss per MVA of silicon steel sheets of 30 years ago
× Weight of silicon steel sheets used in an assessment year

Here, the weight of silicon steel sheets used in a given assessment year can be obtained with the following expressions.

Weight of silicon steel sheets used in a given year
= Capacity of the transformers replaced in a given year
× Per MVA weight of transformer (high-voltage-side)
× Share of silicon steel sheets in use (high- voltage -side)

Table 5-2 shows the weight of transformer and shares of silicon steel sheets in use.

Table 5-2 Ratios in Weight of Silicon steel Sheets Used in Transformers

	Voltage at high-voltage-side	Capacity (MVA)	Weight (t)	Weight per capacity (t/MVA)	Steel product consumption (percentage in weight) (%)	Silicon steel consumption (iron core) (%)	Ordinary steel consumption (container, etc.) (%)
Transformers provided on poles	6.6kV	0.02	0.143	7.15	57	35	22
Transformers for distribution	66.0kV	5	20	4.00	56	28	28
Transformers for transmission	500kV~154.0kV	100~300			62	31*	31*
e.g. Transformers for electric utilities	500kV (to boost pressure)	784	550	0.70			

(Source) Japan Electrical Machinery and Appliances Manufacturers Association, "A Report on Status Quo, Trends and Future Subjects of Recycling of Transmission & Distribution Equipment"
Electricity Joint Research Group et al., "Transforming Technologies in the 21st Century – From Substation to Multi-station"

5-3 Assessment of energy saved by high-functional silicon steel sheets

Table 5-3 contains a summary of the estimated energy-saving effects produced by high-functional silicon steel sheets.

It is noted that from 1990 through 2000, the gaps between 30-year-old and new transformers in no-load losses have narrowed year by year, and that energy-saving effects have grown in proportion to the growing amount for silicon steel sheets along with that for transformer replacement. We also found that, despite an expected saturation of the ratio of decreasing iron losses, energy-saving gains in 2005 and 2010 could be almost as large as in 1990. Meanwhile, the amount of silicon steel sheets in use and the rate of decreasing no-load losses assumed in the potential case were taken from the projected values for 2010, which at present is the furthest foreseeable point in future time.

In addition to the above, the use of silicon steel sheets having superior magnetic characteristics allows the size of transformers to be reduced. As a result of replacement with smaller transformers, the amount of silicon steel sheets used in transformers is at present declining further. Our calculation results show growing amounts of silicon steel sheets being saved: 7,400 tons in 1990; 15,100 tons in 2000, and 14,000 tons in 2010. This trend is likely to last long into the future.

Table 5-3 Energy-saving Effects of Replaced Transformers (Summary)

		1990	1995	2000	2005	2010	Potential case
Silicon steel sheet consumption	(t)	22,803	30,227	54,829	43,289	59,816	59,816
Saved amount of silicon steel sheets	(t)	7,399	8,950	15,121	11,177	14,022	14,022
Reduced amount of no-load losses while in service (30 years)	(MkWh)	4,168	4,822	7,806	5,219	4,320	4,320
Crude oil equivalent							
Saved energy while appliances are in use	(10,000 kl)	107.1	123.9	200.5	134.1	111.0	111.0
Saved energy resulting from lower steel needs for manufacturing appliances	(10,000 kl)	0.8	1.0	1.6	1.2	1.5	1.5
Total energy saved	(10,000 kl)	107.9	124.9	202.1	135.3	112.5	112.5

6 Railway Cars (Stainless Steel Sheets)[28]

6-1 Trends toward use of stainless steel sheets in railway vehicles

In reflection of intensifying energy conservation needs since the first oil crisis, weight reduction of railway vehicles has been promoted, largely through development of lighter stainless steel-made vehicles. Today, stainless steel-made vehicles that are about 40% lighter than those made of steel are being commercialized. Currently, railway vehicles are being produced from steel, stainless steel and aluminum alloy. Special features of stainless steel-made vehicles include the fact that they permit weight reduction and eliminate painting needs thanks to the outstanding strength and corrosion resistance of stainless steel. Finally, stainless steel-made vehicles contribute greatly to energy conservation while in service since they are maintenance-free.

Table 6-1 shows actual records and outlooks for 2005 and 2010 of railway cars (by material) produced by the member companies of the Japan Railway Vehicle Manufacturers Association (JRVMA) and JR Niizu Vehicle Mfg. Table 6-2 contains actual records and outlooks for 2005 and 2010 of vehicle mix by material. Regarding railway vehicle production from now on, JRVMA believes that production is likely to stay 10% above the 2000 records in the five years from 2001 through 2005. JRVMA also considers that the vehicle production mix by material will remain unchanged in the years ahead. This is because the railway companies are too rigid to change their choice of vehicle materials.

[28] http://eneken.ieej.or.jp/data/pdf/468.pdf

Table 6-1 Railway Cars Manufactured by JRVMA Members and JR Niizu Vehicle Mfg. (by Material)

Vehicle material	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total	2005	2010
Bullet trains (steel-made)(vehicles)	27	24	12	48	0	0	0	0	0	111	0	0
Bullet trains (aluminum-made)(vehicles)	278	358	136	149	267	400	294	266	307	2,455	300	300
Ordinary trains (steel-made)(vehicles)	316	353	383	337	252	188	183	140	144	2,296	200	220
Ordinary trains (aluminum-made)(vehicles)	484	128	487	302	338	280	308	549	381	3,257	440	500
Ordinary trains (stainless steel-made)(vehicles)	874	852	850	952	918	558	535	1,027	899	7,465	1,060	1,180
Ordinary trains (stainless steel-made)(Note)(vehicles)				120	180	172	186	203	220	1,081		
Total (vehicles)	1,979	1,715	1,868	1,908	1,955	1,598	1,506	2,185	1,951	16,665	2,000	2,200

(Note) This column shows the number of vehicles (largely stainless steel-made ones) manufactured by JRNiizu Vehicle Mfg., a non-member of the Japan Railway Vehicle Manufacturers Association (JRVMA).

Table 6-2 Shares of Materials Used in Railway Cars Manufactured by JRVMA Members and JR Niizu Vehicle Mfg.

(Unit: %)

Vehicle material	1992	1993	1994	1995	1996	1997	1998	1999	2000	96-00 average	2005	2010
Steel-made	17.3	22	21.1	20.2	12.9	11.8	12.1	6.4	7.4	10.1	10	10
Stainless steel-made	44.2	49.7	45.5	56.2	56.2	45.7	47.9	56.3	57.4	52.7	53	53
Aluminum-made	38.5	28.3	33.4	23.6	30.9	42.5	40	37.3	35.2	37.2	37	37
Total	100	100	100	100	100	100	100	100	100	100	100	100

(Note 1) The material mix is assumed to remain unchanged in 2005 and 2010.
(Note 2) Vehicle production in 2005 is assumed to remain the same as in 2000, and that in 2010 up 10% over 2000 records.

6-2 Method of assessment of energy conservation

Because stainless steel-made vehicles weigh less than conventional steel-made vehicles, they consume less energy while in service (traveling energy-saving effect of lighter weight). Also, weight reduction resulting from use of stainless steel sheets contributes to reducing steel needs for vehicle manufacturing, thus producing an energy-saving effect in the form of lower steel needs for manufacturing (steel product-saving effect). On the other hand, because stainless steel sheets are more energy-intensive than ordinary steel when manufactured, they involve incremental energy in the manufacturing processes (high functionality-based incremental manufacturing energy). We assessed these points. Meanwhile, in addition to vehicle weight reduction, the use of such systems as electricity regeneration brakes[29] and VVVF inverter control[30] can also be cited as contributors to reducing energy consumption by railway cars while in service.

In this analysis, we calculated how much traveling energy could be saved by weight reduction, how much manufacturing energy could be saved by reduced needs for steel product, and how much incremental energy would be required for manufacturing in the manner described below.

Total amount of energy saved in a given target year (Z)
= (P × YA – ED) × NS (y)

Here,

P (annually saved amount of energy per vehicle)
= e (saved amount of traveling energy per km of traveling per ton of vehicle weight reduction) (MJ/km/vehicle ton)
× X (amount of weight reduction per vehicle)
× L (annual traveling distance per vehicle (km/year/vehicle)
YA: Actual number of years stainless steel-made vehicles are in service (years)
ED (Incremental input energy when producing stainless steel per vehicle)
= ES (Input energy when producing stainless steel required for manufacturing a stainless steel-made vehicle) (GJ/t))
– E (Input energy when producing ordinary steel required for manufacturing a steel-made vehicle)
NS (y): Number of stainless steel-made vehicles produced each year

No data have been published on JR vehicles' travelling energy. Therefore, we calculated how much energy was saved by weight reduction when an electric vehicle travels 1km by using Tokyu Dentetsu's data on its stainless steel-made vehicles (0.055 kWh/km/vehicle ton). On the basis of this data, we identified the ratios of traveling energy consumption between steel-made and stainless steel-made vehicles (energy consumed by steel-made vehicle: energy consumed by stainless steel-made vehicle = 100: 66)[31].

Taking the vehicles in service on the Yamanote Line as an example, a shift from steel-made to stainless steel-made vehicles means that a stainless steel-made vehicle uses 12.9 tons less ordinary steel but 6.6 tons more stainless steel than its steel-made counterpart. These factors result in a 6.4 tons[32] weight reduction of a vehicle, and this was employed in

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29 With this system, when the brakes are applied, the motor is designed to generate electricity, which is recycled into running the railway cars.

30 VVVF stands for variable voltage variable frequency. This is a system to control the speed of vehicles by varying the number of rotations of the motor by virtue of VVVF.

31 0.055/0.66 – 0.055 = 0.028 (kWh/km/vehicle ton) = 0.1 (MJ/km/vehicle ton)

32 Japan Railway Vehicle Manufacturers Association, a foundation

our analysis.

We assumed an annual travelling distance per vehicle of 160,000 km/year/vehicle, which was estimated from various data available from JR Higashi Nippon and JRVMA.

The actual number of years stainless steel-made vehicles were in service was put at 30 years based on our interview surveys made with JRVMA, the Japan Private Railway Operators Association and the Japan Aluminum Association's Light Metal Vehicle Committee.

6-3 Assessment of saved energy resulting from greater use of stainless steel-made vehicles

We estimated the energy-saving effects gained from the greater use of stainless steel-made vehicles, the results of which were shown in Table 6-3.

In the table, both the actual records and the outlooks show that energy-saving effects of at least a certain amount can be gained in proportion to the number of stainless steel-made vehicles produced in a given target year. In the potential case, which assumed replacement of all the steel-made vehicles with stainless steel-made ones, the resultant energy-saving effects were found to be some 1.6 times larger than in the 1992 records.

Table 6-3 Energy Ups/Downs Resulting from Wider Use of Stainless Steel Sheets in Electric Cars (Summary)

	1992	1995	2000	2005	2010	Potential case
Saved energy when manufacturing vehicles (GJ/vehicle)	94	94	94	94	94	94
Saved energy while vehicles are in service (GJ/year/vehicle)	102	102	102	102	102	102
Number of stainless steel-made vehicles each year (vehicles/year)	874	1,072	1,119	1,060	1,180	1,400
Saved energy (10,000 kl crude oil equivalent)						
Energy-saving effect when manufacturing vehicles	0.22	0.27	0.27	0.27	0.30	0.35
Energy-saving effect while vehicles are in service	7.24	8.89	9.27	8.78	9.78	11.60
Total energy saved (10,000 kl crude oil equivalent)	7.46	9.16	9.54	9.05	10.08	11.95

Conclusions

With this analysis, which covered H beam for building steel frames, generating boilers, automobiles, vessels, transformers and railway cars, we estimated the energy-saving gains from application of high-functional steel products not only at the steelmaking stage but also throughout the service life of high-functional steel-made products. For each of the steel products we analyzed, we found that high-functional steel products involved incremental energy at the steelmaking stage in response to specific demands, but that this was more than offset by energy-saving effects in the subsequent processes. These take such forms as reduced fuel consumption by weight reduction of steel-made products when in use, and reduced energy needs for product manufacturing resulting from lower steel needs for manufacturing such products. Regarding the future outlook, all the products we analyzed seem to have energy-saving potentials, depending on the demand for the respective product. However, unilateral commitments to energy conservation, if made by individual industries, may increase each industry's energy intensity considerably, depending on market trends.

Our analysis results suggest that taking right measures at the right time for increasing energy efficiency in the total chain of a product's life cycle, from industrial material production to product use, can lead to energy conservation society-wide. Hence, from now on, it will be essential in any energy conservation measures to make an energy assessment for each product at all the stages of its life cycle. This is because, if fully informed of LCA (life cycle assessment) results, consumers can be encouraged to choose more energy-efficient products and thus contribute to increasing efficiency society-wide.

[Literature]

1) Agency of Natural Resources and Energy (ANRE), MITI and the Japan Steel Federation, a FY1996 Basic Research Project to Prompt Introduction of New Energies and Others, "Energy Assessment of Steel Product Use from LCA Perspectives," March 1997
2) Japanese Economy Research Center, the 28th Medium-term Japanese Economic Outlook (forecast period FY2001 – 2010), "A Path to Economic Renaissance – Toward A Private-led Sustainable Growth," FY2001
3) Steel Materials Manufacturers Club's Committee for the Promotion of Steel Products, 2nd edition, Knowledge of Steel Products for Construction – Basic Knowledge and Product Introduction," October 1994
4) Expert Committee on Iron & Steel Statistics, "Iron & Steel Statistics Handbook 2001 (1990), 2001 (1989)
5) Fujita et al, "Fossil-fired & Nuclear Power Generation," Vol. 45, No. 10, 1994
6) Ministry of Economy, Trade and Industry (METI), edited by the Electric Power and Gas Industry Division, ANRE, "General Descriptions of FY2000 Electric Power Supply and Demand," March 2001
7) METI, edited by the Electric Power and Gas Industry Division, ANRE, "General Descriptions of FY2000/2001 Power Source Development – Plans and Outlines," July 2001
8) Japan Automobile Manufacturers Association, "The Japanese Automobile Industry 2000"
9) FUERAM, Vol. 11, No. 2, 1996
10) Yukihisa Kuriyama et al, "Subsequent Progress in ULSAB Related Projects," the Automobile Technology Working Group, Materials Forum, 2000
11) Japan Shipbuilders Association, "Shipbuilding Related Materials (2001)"

12) Katsuyuki Yoshi et al, "Recent Trends of the Use of High Tensile Steel in Hulls," Japan Shipbuilding Society's Journal No. 652, October 1983
13) Hideo Manabe, "Basic Knowledge of Shipbuilding Steel Products," Iron & Steel News, October 2001
14) METI, "Machinery Statistical Yearbooks"
15) Toshio Yamazaki, Tadaaki Kimoto, "New Edition, History of Technology of Electricity," Ohm Co., Ltd.
16) Kazuya Naokawa, "History of Science and Technology – Development of Electric & Electronic Technologies," Publications Dept., Tokyo College of Electrical Machinery and Appliances, Expert Committee on Energy Conservation of Substation Appliances, "Energy Conservation Measures of Substation Appliances and Efficient Operation," Electricity Joint Research, Vol. 40 (1984), No. 4, Electricity Joint Research Group
17) Expert Committee on Rationalization of Substation Equipment Inspections, "Rationalization of Inspections of Substation Equipment," Electricity Joint Research, Vol. 56 (2000), No. 2 , Electricity Joint Research Group
18) Light Metal Vehicle Committee, the Light Metal Society, "The Light Metal Vehicle Committee Report," No. 6 (1990 – 1997), March 1999
19) Light Metal Vehicle Committee, the Light Metal Society, "Aluminum Alloy-made Vehicle – Status Quo and Future of Recycling," March 2001
20) Clean Japan Center, "A Report on How to Prepare Instruction Manuals of Product Assessment," (Aluminum Alloy-made Railway Vehicles), March 1998
21) Yasuo Koseki, Railway Research Institute Report No. 213, "Life Cycle Energy of Railway Vehicles," March 1997
22) Toru Miyauchi et al, Railway Research Institute Report Vol. 12, No. 10, "Basic Research for the Application of Life Cycle Assessment to Railway," 1998

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