

# Environmental Conservation and Energy Saving Activities in JFE Steel†

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## Abstract:

*JFE Steel has been actively tackling on prevention of global warming, reduction of the environmental load in steelmaking processes and recycling of resources to achieve the environmental philosophy of the corporation, “aiming to build a prosperous society by promoting business activities, which are in harmony with the environment.” This paper outlines achievements and future efforts in these activities in JFE Steel.*

## 1. Introduction

Global environmental issues such as global warming and biodiversity have been a focus of rising concern in recent years. On the other hand, the more familiar problems of air pollution, water pollution, etc. also continue to receive attention, lending increasing importance to environmental conservation.

Efforts to reduce environmental loads in steel manufacturing processes are particularly critical, as those processes require large quantities of resources such as iron ore, coal and water, energy in the forms of electric power, fuels, etc., and various chemicals.

As its environmental policy, JFE Steel has made a commitment “To reduce the environmental impact of all business operations,” and established the JFE Steel Environmental Committee chaired by the President to implement this policy. A diverse range of environmental initiatives such as technology development, capital investment, and others are planned and implemented by top management.

The following describes measures to prevent global warming in the Japanese steel industry, and initiatives by JFE Steel to date in connection with energy saving in the steel manufacturing process, reduction of environmental loads, and construction of a recycling society, together with future efforts.

## 2. Efforts to Prevent Global Warming by the Japanese Steel Industry

### 2.1 Three “Eco” Contributions

In November 2009, the Japan Iron and Steel Federation (JISF) announced a concept of efforts to address global warming. Its basic thinking aims at contributing to reducing emissions of greenhouse effect gases (GHG) at the global scale by activities that go beyond the scope of each company’s own steel manufacturing process and extend to other industries and overseas manufacturers. The core elements of this philosophy are the three “Eco” contributions: “Eco Processes,” “Eco Products,” and “Eco Solutions.”

### 2.2 “Eco Processes”

“Eco Processes” are processes for reducing CO<sub>2</sub> in the production process by optimization of the production system, improvement of operating equipment and technologies, and use of state-of-the-art energy saving technologies and equipment. As shown in **Fig. 1**, through the period of the two Oil Crises in the 1970s, the Japanese steel industry made capital investments totaling ¥3 tril-

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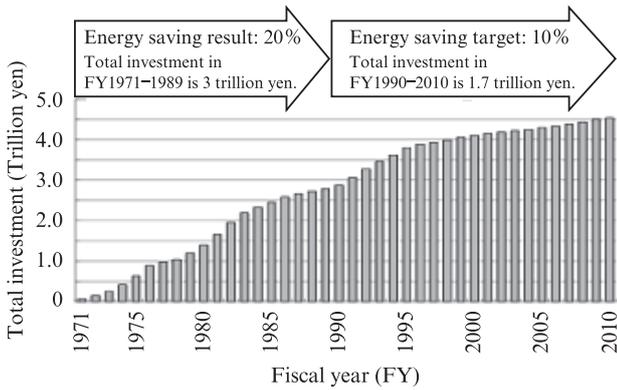
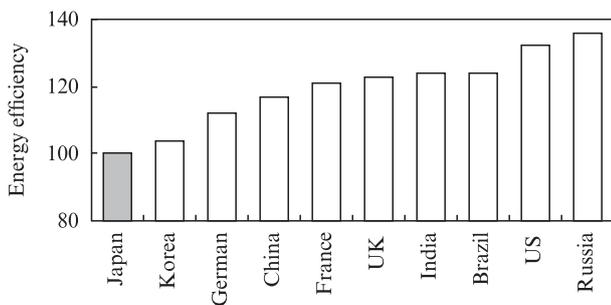


Fig. 1 Trend in the total amount of environmental/energy saving investment of Steel Works in Japan<sup>1)</sup>

lion in environmental conservation and energy saving from the 1970s through the 1980s, by introducing large-scale energy saving equipment such as continuous casting machines, coke dry quenching (CDQ), and others, thereby achieving energy savings of 20%. The Japanese steel industry invested approximately ¥1.7 trillion between fiscal year (FY) 1990 and FY 2010, and under the JISF’s Voluntary Action Plan for the First Commitment Period of the Kyoto Protocol (FY 2008–2012), the industry implemented measures to reduce energy consumption by 10% from FY 1990. When converted to CO<sub>2</sub> reduction, these efforts resulted in a 9% reduction from FY 1990, which is equivalent to 17.87 million tons-CO<sub>2</sub>/year. Based on this performance, the JISF foresees achievement of the industry target.

As a result of these untiring energy saving efforts, dissemination of energy saving technologies and equipment has made great progress in the Japanese steel industry, and substantially 100% introduction of items now on the practical level has been achieved. As a result, the Japanese industry has realized the world’s highest level of energy efficiency. As shown in Fig. 2, the energy efficiency of the Japanese steel industry is at maximum approximately 30% superior to that of other countries.



JISF indexed original figures (GJ/t-s) which are reported in RITE “Estimation of Energy Unit in 2010” when taking it of Japan as 100.

Fig. 2 Comparison of steel industry energy efficiency (2010)<sup>1)</sup>

Dissemination of these outstanding equipment and technologies to other countries, namely, the “Eco Solutions” described in Section 2.4, is expected to be an effective approach to energy saving/global warming prevention measures on a global scale.

### 2.3 “Eco Products”

In the area of “Eco Products,” energy saving in the product use stage is promoted by supplying high performance functional steel materials. For example, developing and supplying products which simultaneously reduce auto body weight while maintaining/improving the strength of automobiles, such as high-strength steel sheets for automotive applications, contributes to society by realizing energy saving and CO<sub>2</sub> emission reduction through improved fuel economy.

Since it is only possible to develop this kind of high performance functional steel products, and thereby realize energy saving/CO<sub>2</sub> emission reduction effects by collaboration and joint development with the customers who use those products, it is not necessarily easy to quantify the precise contribution of steel products to the effects materialized in final products.

The Institute of Energy Economics, Japan, made a trial calculation of the CO<sub>2</sub> reduction effect in the use stage of final products as of 2010 for representative high performance functional steel products whose effects can be quantified. The object product categories were automotive steel sheets, grain-oriented electrical steel sheets, plates for shipbuilding, steel boiler tubes, and stainless steel sheets. As shown in Fig. 3, the CO<sub>2</sub> reduction effects of the products in these 5 categories was evaluated at 9.26 million t-CO<sub>2</sub> for steel products used in Japan and at 12.82 million t-CO<sub>2</sub> for those used overseas, resulting in a total reduction of 22.08 million t-CO<sub>2</sub>.

Japanese industries, beginning with the steel industry, have implemented energy saving and CO<sub>2</sub> reduction measures in their manufacturing processes, and now have little room for further improvement in comparison with other countries. In order to continue to promote effective measures utilizing technology, it appears to be necessary to motivate industry by introducing this kind

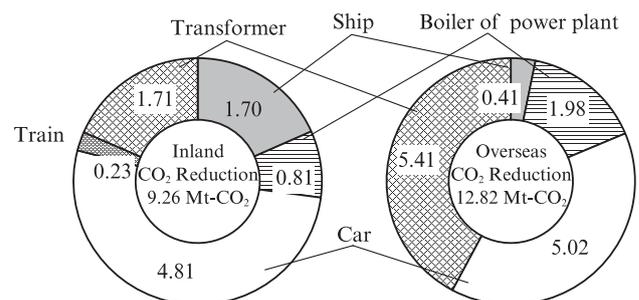


Fig. 3 CO<sub>2</sub> reduction by using steel products<sup>1)</sup>

of life cycle assessment (LCA) viewpoint and assessing the contributions of products in the use stage.

## 2.4 “Eco Solutions”

As mentioned previously, the Japanese steel industry possesses the world’s highest level energy saving technologies. The aim of “Eco Solutions” is to reduce CO<sub>2</sub> at the global scale by developing and transferring those technologies to other countries.

Outstanding energy saving technologies and equipment which were developed and commercialized by the Japanese steel industry, for example, CDQ and top pressure recovery turbine for power generation at the blast furnace (TRT), have been introduced in many other countries. However, looking only at the equipment which has been installed by the Japanese steel industry and is currently in operation, the CO<sub>2</sub> reduction effect of these main energy saving plants reached 43.41 million t-CO<sub>2</sub>/year in FY 2011.

To encourage improvement of energy efficiency and reduction of CO<sub>2</sub> emissions in the steel industries in other countries, the Japanese steel industry also participates in international activities, where it plays a leading role. For example, the Japan-China Steel Industries Conference on Exchange of Advanced Technologies on Environmental Preservation and Energy-Saving, which was first held in July 2005, is a bilateral platform for important efforts by the sectorial approach by Japan and China. The Global Superior Energy Performance Partnership (GSEP), which succeeded to the work of the Steel Task Force of the Asia-Pacific Partnership for Clean Development and Climate (APP), is promoting government-private sector activities with a focus on improvement of energy saving and environmental performance. The World Steel Association, or worldsteel, which is an association of the world’s leading steel industries, established methods for calculating the amount of CO<sub>2</sub> emissions and unit emissions. Based on this, standardization in the International Organization for Standardization (ISO) was proposed under Japanese leadership, and the new standard (ISO14404) was issued in March 2013. Moreover, Japan is also participating in the CO<sub>2</sub> Breakthrough Programme in worldsteel.

As outlined above, a total CO<sub>2</sub> reduction of approximately 83 million t-CO<sub>2</sub> is foreseen as a result of the three “Eco” contributions. This is equivalent to about 7% of Japan’s total CO<sub>2</sub> emissions (FY 1990).

In order to achieve a more drastic reduction in CO<sub>2</sub> emissions in the future, the Japanese steel industry is developing a number of innovative technologies, exemplified by “Ferro-Coke,” which is a promising new blast furnace raw material, and “COURSE50 (CO<sub>2</sub> Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50),” which aims at a broad

reduction in CO<sub>2</sub> emissions. Although the JISF’s Voluntary Action Program was concluded in FY 2012, a new Action Plan for Achieving a Low-Carbon Society has been drawn up, and CO<sub>2</sub> emission reduction activities are continuing toward FY 2020. Powerful promotion of this plan is expected, both in Japan and in other countries.

## 3. Energy Saving/CO<sub>2</sub> Reduction Activities in JFE Steel

### 3.1 History of Energy Saving/CO<sub>2</sub> Reduction Activities

Energy saving activities at JFE Steel began after the First Oil Crisis in 1973, and were mainly aimed at cost reduction. Subsequently, the Kyoto Protocol was ratified by COP3 in 1997, and the JISF had already adopted its Voluntary Action Program during the previous year, in December 1996. Based on those moves, energy saving activities took on a new aspect which envisioned reduction of CO<sub>2</sub> emissions in addition to energy saving for economic reasons. As a result, development to new processes and new technologies was necessary. **Table 1** shows the main technologies and equipment applied for the purposes of energy saving/CO<sub>2</sub> reduction in each steel manufacturing process. In addition to the conventional approaches of waste heat recovery and improvement of thermal efficiency, conversion to fuels with a lower-CO<sub>2</sub> load and other new techniques began in 2000.

As a result of these initiative, unit energy consumption in crude steel production has decreased by 18% since 1990 (**Fig. 4**), and a 20% reduction has been achieved in the unit CO<sub>2</sub> emission (**Fig. 5**). Thus, JFE Steel is continuing to maintain the world’s highest level of energy efficiency.

### 3.2 Concrete Examples of Energy Saving/CO<sub>2</sub> Reduction Measures

This section introduces concrete examples of energy saving and CO<sub>2</sub> reduction measures, particularly since 2000.

#### 3.2.1 New shaft furnace

As part of global warming measures implemented by JFE Steel, a “New shaft furnace” was blown in at the Ohgishima Area of East Japan Works (Keihin) in August 2008. This is a plant in which the recycled resource scrap is recycled with high energy efficiency by applying advanced sensor technology, off-gas recovery technology, and others developed in blast furnace operation, etc. **Figure 6** shows an outline of the shaft furnace. With a scrap melting capacity of 500 000 tons/year, this is the

Table 1 Overview of energy conservation technologies

|                           |  |   |   |   |  |   |                                   |   |  |
|---------------------------|--|---|---|---|--|---|-----------------------------------|---|--|
| Counter-measures-Facility |  | Coke dry quenching (CDQ), Coal moisture control (CMC), Combustion control | Sintering cooler waste heat recovery, Ignition furnace line burner, Super-SINTER® | Waste plastics feeding, Pulverized coal injection, Top pressure recovery turbine, Hot stove waste heat recovery, Fuel gas preheating, Shaft furnace, City gas injection | Gas recovery, Gas sensible heat recovery, Nitrogen jet heater, Ladle heating | Regenerative burner, Direct charging, Low-temperature extraction, Fuel switch from oil to gas | Endless rolling, Process coupling | Waste heat boiler, Rotary regenerative heat exchanger | Selection of transportation mode, Shortening of transportation distance, Improvement of load efficiency, Modal shift, Application of information technology (IT) |
|---------------------------|--|---|---|---|--|---|-----------------------------------|---|--|

Gas turbine combined cycle power plant, Power plant fuel preheating device, High efficiency air separation equipment

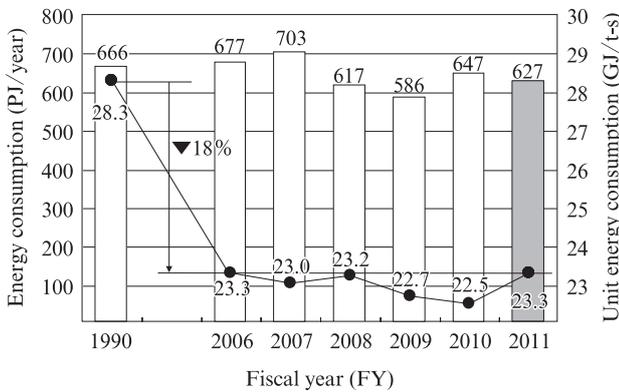
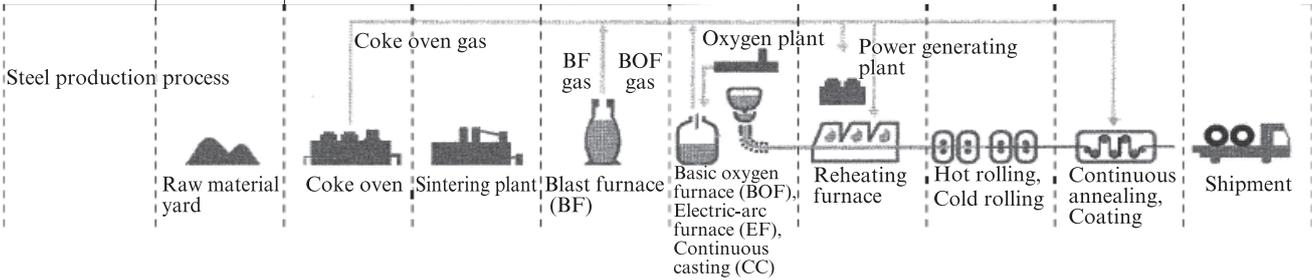


Fig. 4 Trend in total and unit energy consumption of JFE Steel

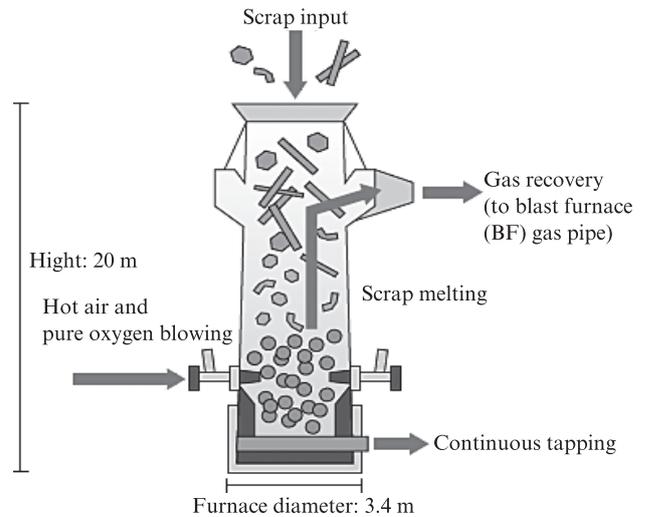


Fig. 6 Structure of new shaft furnace

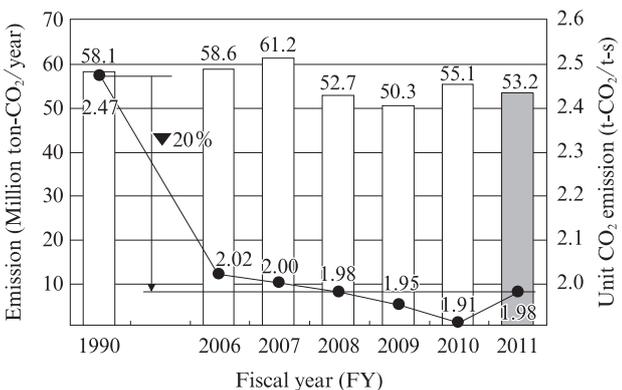


Fig. 5 Trend in total and unit CO<sub>2</sub> emission of JFE Steel

largest equipment of its kind in Japan.

### 3.2.2 Super-SINTER™

“Super-SINTER™ (Secondary-fuel Injection Technology for Energy Reduction)” is a technology in which part of the coke breeze normally used in the sintered ore production process is replaced with a hydrogen-based gas, such as natural gas or the like, which has a lower CO<sub>2</sub> emission load than carbon-based coke. This technology was initially introduced at East Japan Works (Keihin) in January 2009, and introduction at all JFE Steel Works was completed in FY 2012.

In the sintering process, coke breeze as an agglomerating agent is mixed with powdery iron ore and limestone, after which this sinter mix is charged to the sintering machine and ignited, and the sintering reaction is promoted, resulting in agglomeration of the mixture. In order to produce high quality sintered ore, it is necessary to maintain a combustion temperature of 1 200°C to 1 400°C. Below this temperature, it is not possible to obtain the necessary sinter strength because the raw materials are not adequately melted, and if the temperature exceeds 1 400°C, quality will deteriorate due to increased formation of low strength glassy minerals.

In the Super-SINTER™ process, a hydrogen-based fuel gas (city gas) is blown onto the top of the charged raw materials (sintering bed) as a partial substitute for coke breeze. Because the hydrogen-based fuel has a different ignition point from coke, it is possible to maintain the optimum sintering reaction temperature for an extended period of time without increasing the maximum combustion temperature. As a result, the energy efficiency of the sintering process is substantially improved, and it is also possible to reduce CO<sub>2</sub> emissions.

This technology won the FY 2009 “Low CO<sub>2</sub> Kawasaki Brand Award,” the Grand Prize in the 2011 Nikkei Global Environmental Technology Awards (sponsored by Nikkei Inc.), and the 38th (FY 2011) Iwatani Naoji Memorial Award (The Iwatani Naoji Foundation).

### 3.2.3 High efficiency power generation/power use equipment

The iron and steel industry not only consumes large amounts of electric power, but also large amounts of oxygen, nitrogen, etc. which are produced using electric power as an energy source. For this reason, JFE Steel is promoting high efficiency in power-intensive equipment. Beginning with modernization of high pressure oxygen and nitrogen compressors to high efficiency types, JFE Steel has also continuously modernized a number of oxygen plants to higher efficiency types at each of its works. The object plants are Keihin No. 4, Chiba No. 14, Kurashiki No. 12, and Fukuyama No. 15 (the Keihin and Fukuyama oxygen plants are operated by JFE Sanso Center).

At East Japan Work (Chiba), JFE Steel is constructing a 150 MW class gas turbine combined cycle (GTCC) non-utility power plant as part of efforts to save energy and reduce CO<sub>2</sub> by improving power generating efficiency. The new plant is scheduled to begin operation in 2015.

Following the Great East Japan Earthquake of March 2011, power shortages were an urgent problem for Japanese society, and particularly for manufacturing industries. Against that background, JFE Steel also plans to

modernize the power plants at its other works.

### 3.2.4 Development of global warming countermeasure technologies

As a core member of the innovative technology development project “COURSE50,” which aims to reduce CO<sub>2</sub> emissions from blast furnace steel manufacturing, JFE Steel is developing a CO<sub>2</sub> separation and recovery technology using the pressure swing adsorption (PSA) process and a technology for recovery of unused waste heat from steel slag.

The PSA process is a technology which separates and recovers the CO<sub>2</sub> contained in blast furnace byproduct gas by using zeolite as an adsorbent. JFE Steel is developing this technology and has constructed a 3 t-CO<sub>2</sub>/day scale pilot plant at West Japan Works (Fukuyama).

In order to achieve a drastic reduction in CO<sub>2</sub> emissions in the future, JFE Steel is now developing the production process technology for “Ferro Coke,” which is an object of high expectations as a new blast furnace raw material, and has constructed a pilot plant with a ferro coke production capacity of 30 t/day at East Japan Works (Keihin) as a part of the project, “Development of Innovative Ironmaking Process Technology for Strengthening Resource Response Capabilities”, sponsored by New Energy and Industrial Technology Development Organization (NEDO).

In the Japanese steel industry, long-term and stable resource procurement is one of extremely critical issues; at the same time, large reductions in CO<sub>2</sub> emissions are demanded in the mid- and long-term. In order to solve these problems, the industry is targeting the development of practical technologies through joint industry, government, and academia projects.

## 3.3 Trend of Energy Saving/CO<sub>2</sub> Reduction Investment

Figure 7 shows the trend in cumulative capital investment for energy saving and CO<sub>2</sub> reduction by JFE Steel since FY1990. The amount of investment to realize the world’s highest level of effective utilization of energy had reached a cumulative ¥427.5 billion by FY2011, and planning for large-scale projects with a

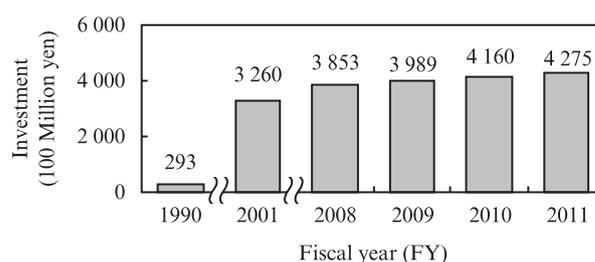


Fig. 7 Trend in total amount of energy saving and CO<sub>2</sub> reduction investment of JFE Steel since 1990

value of ¥10 billion/item, such as modernization of power plants, etc., is now in progress.

## 4. Environmental Conservation Activities

### 4.1 Strengthening the Environmental Management Function

In FY 2005, JFE Steel organized the environmental control department independent from operating departments and strengthened its leadership capacity. An environmental auditing system by the Auditing Department was also introduced, and the environmental control function has been improved by implementing business audits.

The environmental education system in each job category/level has been also improved in order to heighten awareness and knowledge of environmental conservation. JFE Steel encourages employees in technical positions to acquire qualifications as Pollution Control Managers, which is a national government qualification. Since FY 2005, a total of 1 074 employees have acquired this qualification, contributing to improvement of the quality of environmental activities.

### 4.2 Activities on Reducing Environmental Loads

Following the environmental problems of Japan's high economic growth era, technical development and introduction of equipment for reducing emissions of dust, sulfur oxides (SOx), and nitrogen oxides (NOx) were actively promoted, and since FY 2000, measures to reduce atmospheric emissions of other chemical substances have also been implemented. **Figure 8** shows the trend in the cumulative amount of capital investment in environmental conservation equipment since FY 1973. The amount of these environmental conservation investments between FY 1973 and FY 2011 reached a cumulative total of ¥580.4 billion. At present, JFE Steel is engaged in various voluntary activities for reducing environmental loads, and is continuing to invest more than ¥10 billion/year in this area.

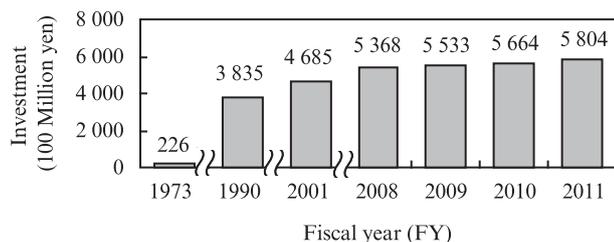


Fig. 8 Trend in the total amount of environmental conservation investment of JFE Steel since 1973

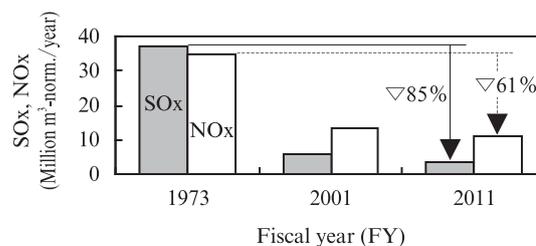


Fig. 9 Trend in SOx and NOx emission of JFE Steel

#### 4.2.1 SOx and NOx measures

JFE Steel has introduced desulfurization equipment for coke oven gas, desulfurization/denitrification equipment for sintering machine off-gas, etc., which are used in the steel works. Since FY 2000, JFE Steel has continued its efforts to reduce these emissions by equipping sintering machine with active coke method off-gas treatment equipment having a desulfurization function. **Figure 9** shows the trend in SOx and NOx emissions since FY 1973. In FY 2011, SOx and NOx had been greatly reduced in comparison with FY 1973, by 85% and 61%, respectively.

#### 4.2.2 Reducing releases of chemical substances

Since FY 2000, JFE Steel has voluntarily reduced benzene, dioxins, and other chemical substances.

Measures for reducing benzene included reducing gas leaks from coke ovens by adoption of a high efficiency door cleaner, introduction of combustion treatment and active carbon adsorption treatment for gases emitted when charging coal into coke ovens, introduction of vapor recovery and combustion treatment equipment for crude light oil tanks, and others. **Figure 10** shows the amounts of benzene emissions in FY 2001 and FY 2011. In FY 2011, emissions had been reduced by 70% in comparison with FY 2001.

Regarding dioxins, as off-gas countermeasures for

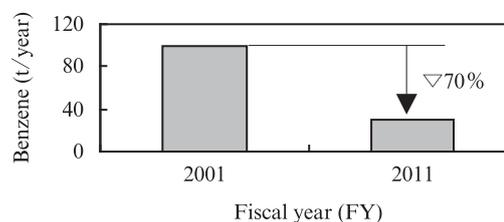


Fig. 10 Trend in Benzene emission of JFE Steel

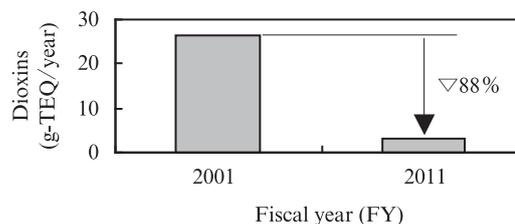


Fig. 11 Trend in dioxins emission of JFE Steel



Photo 1 Windbreak of coal stock yard

the sintering machine, which is the main emission source, JFE Steel enhanced wet-type electrostatic dust collectors to improve dust removal efficiency and took measures to reduce emissions of Cl from sintering materials, as Cl is the main factor in dioxins. **Figure 11** shows the amount of dioxin emissions in FY 2001 and FY 2011; an 88% reduction was achieved in comparison with FY 2001.

#### 4.2.3 Preventing dust scattering

JFE Steel has taken various measures to prevent dust scattering since an early date, such as increasing the number of dust collectors and enhancing their performance, sprinkling water and coating materials with scattering prevention agents in raw material yards, general cleaning and road sprinkling in the steel works, and others. In addition to these activities, since FY 2000, windbreak fences have been installed at East Japan Works (Chiba) and West Japan Works (Kurashiki and Fukuyama). **Photo 1** shows examples of the windbreaks at Kurashiki and Fukuyama. Water sprinkling equipment has also been upgraded at East Japan Works (Keihin). Points where countermeasures should be implemented are selected based on simulation analyses, enabling intensive and effective implementation of equipment improvements. As a result, the amount of scattered dust has been significantly reduced.

### 5. Resource Recycling Efforts

#### 5.1 Reducing Discharges of Byproducts

The steel manufacturing process produces iron and steel products from inputs of raw materials, which consist primarily of iron ore, coal, and limestone. The manufacturing process also produces various byproducts, particularly slag, which consists of oxides of the nonferrous components in raw materials, dust generated from combustion furnaces and other facilities, and sludge generated in wastewater treatment. **Figure 12** shows the material flow at JFE Steel in FY 2011. The manufacturing process consumed approximately 68 million tons of raw materials as inputs, and generated about 15 million tons of byproducts.

JFE Steel recycles the byproducts generated in its steel works as raw materials for steel manufacturing,

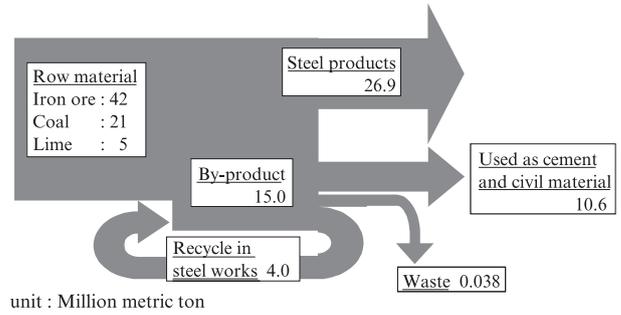


Fig. 12 Resources recycling flow of JFE Steel (Fiscal year 2011)

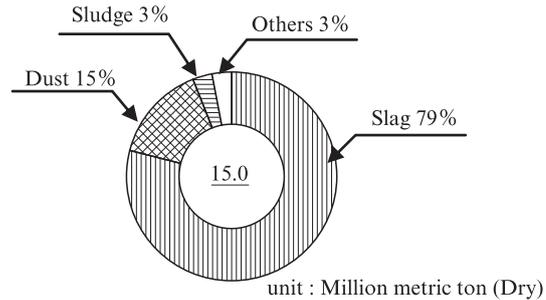


Fig. 13 Breakdown of steelworks byproduct of JFE Steel (Fiscal year 2011)

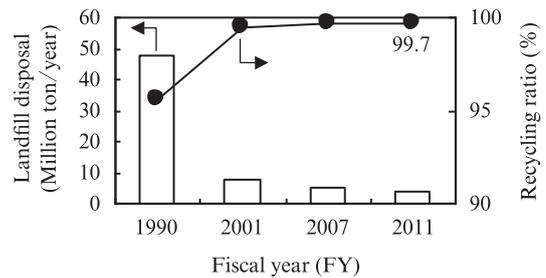


Fig. 14 Transition of landfill disposal/recycling ratio of JFE Steel

materials for civil works and construction, etc., and has taken exhaustive measures to minimize the amount of waste which must be treated by landfill disposal. **Figure 13** shows a breakdown of steel works byproducts in FY 2011; **Fig. 14** shows the transition of the landfill disposal amount and the recycling ratio since 1990. In FY 2011, the byproduct recycling ratio reached 99.7%.

#### 5.2 Promoting Technology Development for Byproduct Recycling

Steel slag is the largest byproduct generated by the steel manufacturing process. Since an early date, steel slag has been sold as products such as a material for blast furnace cement, raw material for cement, roadbed material, material for use in port and harbor construction, agricultural fertilizer, and the like, and 100% recycling has been realized. At present, JFE Steel is developing new applications, including a material for restoration of marine environments which utilizes the calcium oxide and iron oxide components contained in steel slag, and a

technique for restoration of coral reefs using Marine Block™, in which steel slag is fixed with carbon dioxide, among others.

Dust and sludge have high iron contents and are often valuable resources for steel manufacturing, but depending on the process in which they are generated, they sometimes contain zinc and other impurities that are difficult to recycle to the steel manufacturing process. JFE Steel is promoting on-site recycling by introducing recycling equipment such as a dust refining furnace which removes and recovers Zn from dust, making it possible to recycle the dust as a steel manufacturing material (2008; West Japan Works (Fukuyama)), and a roasting furnace which removes the oil component from oily sludge (2009; West Japan Works (Kurashiki)).

### **5.3 Contributing to a Recycling Society by Using the Steel Manufacturing Plant**

Because steel manufacturing plants have large-scale, high temperature combustion furnaces and melting furnaces, JFE Steel is developing recycling technologies which utilize this infrastructure to recycle industrial waste plastics from outside the steel works, as well as container and packaging plastics, which are a component of general municipal waste.

In 1996, JFE Steel began using waste plastic for blast furnace feed, which was the first practical application of this technology in the world. Following this, in 2007, JFE Steel succeeded in developing and commercializing

a technology for pulverizing container and packaging plastics, and has realized advanced use of this material as a reducing agent for iron ore in the blast furnace. These technologies have won a high evaluation as outstanding recycling technologies from outside organizations, beginning with the “Award for Resource-Recycling Technologies and Systems” of the Minister of Economy, Trade and Industry in FY 2004.

## **6. Conclusion**

Global warming prevention countermeasures in the Japanese steel industry, and initiatives by JFE Steel in the areas of energy saving, CO<sub>2</sub> reduction, environmental conservation, and resource recycling were introduced. Although the condition of regional environments, such as air pollution in areas around factories and along main highways, has improved dramatically since the era of high economic growth, the environmental issues remain an important concern for local residents.

As both a global corporation and a citizen of the local community, JFE Steel will continue to implement a diverse range of environmental initiatives on an ongoing basis in order to contribute to realizing a sustainable society.

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