March 23, 2012

Conservation at 70s Levels Could Cut Energy Consumption by 20%

– Industries Pursuing Energy Efficiency to Grow Most –

JCER Middle-Term Economic Forecast Team*

In the case that Japan's nuclear power plants are not brought back online, higher costs owing to the switch to thermal power will weigh heavily on industry. We have analyzed conditions in Japan from the 1970s through the first half of the 1980s, when energy prices rose sharply, in order to determine whether there may be room in the future for energy conservation and industry restructuring.

Key Points

(1) The oil crisis precipitated improvements in energy efficiency throughout Japanese industry as a whole and made the manufacturing industry more efficient in conserving energy (improving the ratio of energy inputs required for each unit of output). Energy-intensive industries boosted efficiency quite rapidly, and those manufacturers which succeeded in conservation became more competitive and ultimately accounted for a larger share of industry.

(2) Owing partly to the decline in oil fossil fuel prices from 1990, improvement in energy efficiency slackened, but after the turn of the millennium, conservation efforts advanced once more as natural resource prices rose sharply. Increased efficiency following from the widespread use of information technology (IT) may have helped facilitate this progress.

(3) If future energy savings are proportional to those made in the seventies, Japan could cut energy consumption by about 20% versus fiscal year 2010 (April 2010 - March 2011) levels by FY2020. A shift to non-energy intensive industries such as nonmanufacturing would be necessary, although the labor productivity of such industries is lower than that of manufacturing. In order to compensate for this, efforts to harness IT and other means to boost productivity in the nonmanufacturing industries would be critical. In the manufacturing industry, meanwhile, Japan will need to shift to machinery, which is strong in both energy efficiency and labor productivity. These steps will pave the way to improved energy conservation and enhanced competitiveness.

(*) In computing and estimating the future trend of energy efficiency for each individual industry, the present report uses the ratio of energy inputs to real production (added value, 10kcal/yen)[1].

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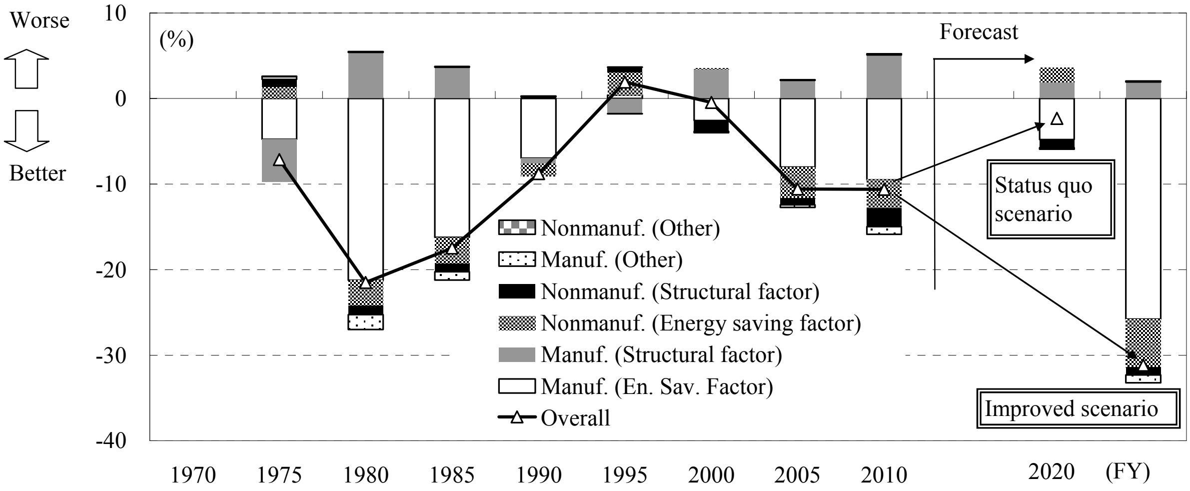
Figure 1. Conservation at Oil Crisis Levels Could Yield Substantial Improvement in Energy Efficiency (Change in energy efficiency given for five-year periods; Contribution by industry; Negative figures indicate improvement)



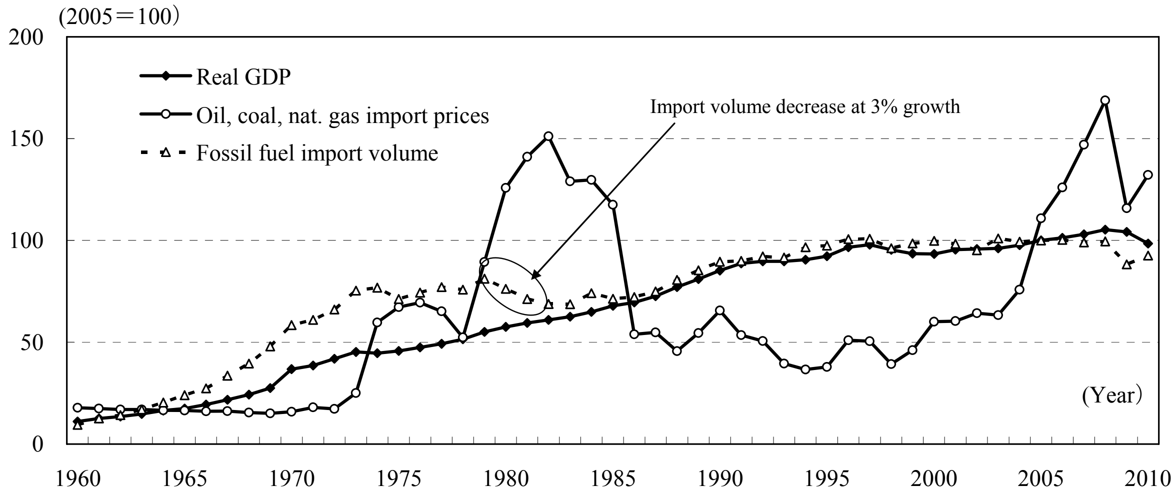
Note: Manufacturing industries exclude oil and coal products; nonmanufacturing industries exclude agriculture, forestry and fisheries, mining, electric power, gas and water services industries, as well as government services. Energy efficiency equals energy conservation factors plus structural and other factors. In addition to energy conservation efforts by each industry, energy conservation factors include industry structural changes within the manufacturing and nonmanufacturing industries. Structural factors represent efficiency improvements from changes in the composition of the manufacturing and nonmanufacturing industries.
Sources: *System of National Accounts*, Institute of Energy Economics Japan, *Energy Data and Modeling Center, 2011*.

[1] Figures on real production from the 1970s are based on 68SNA data (base year = 1990) from the *System of National Accounts* (SNA) (calendar years) for years data is available, while figures for 1999 and thereafter are extrapolated from the most recent 2005 base year growth rates. Figures for energy inputs are based on Energy Balance Tables (fiscal years).

1. Energy Conservation and Growth both Achieved during Oil Crisis

During the 1970s, the first oil crisis occurred in the fall of 1973 and the second, sparked by the Iranian revolution, occasioned a spike in oil crude prices from the end of 1978. Although the Japanese economy contracted for the first time since its postwar recovery, this proved temporary, and the economy ultimately grew at an average annual pace of 3.9% between 1975 and 1985. The high prices precipitated efforts to reduce dependence on fossil fuels, and in the 1980s, Japan was able to achieve economic growth at the rate of 3% while also reducing imports of fossil fuels (see Figure 2).

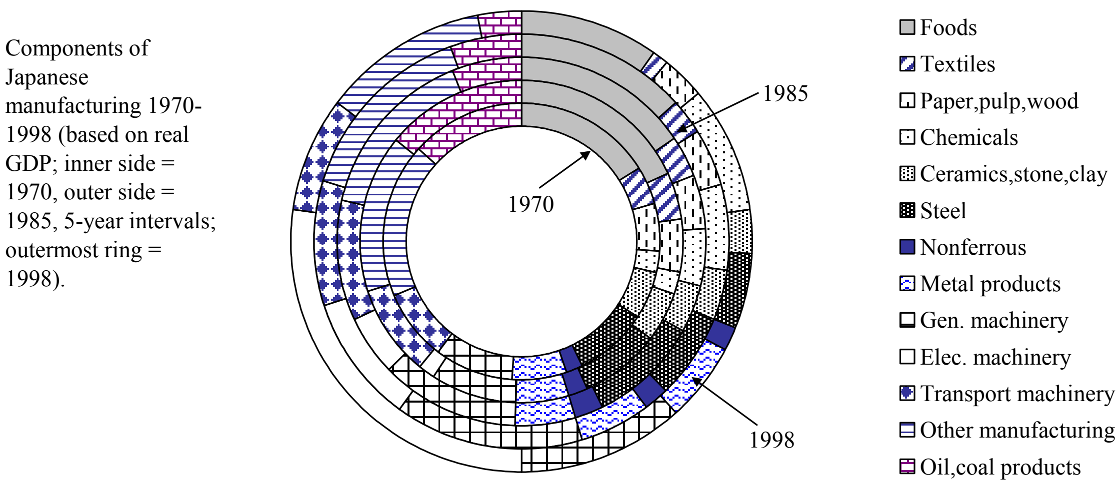
Figure 2. Economic Growth and Fossil Fuel Prices, Import Volume



Source: *System of National Accounts*; Bank of Japan, Corporate Goods Price Index (CGPI); Ministry of Finance, *Trade Statistics of Japan*.

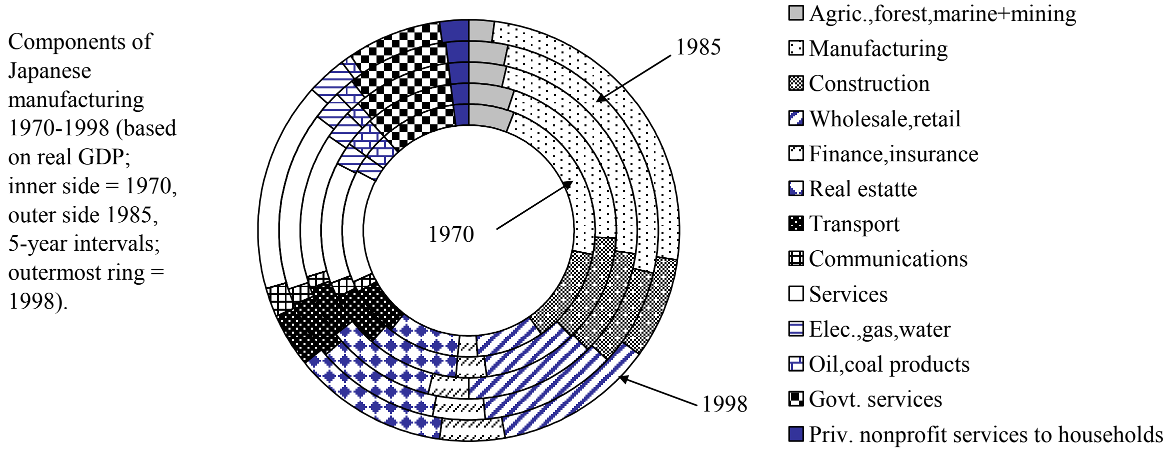
In addition to thoroughgoing energy conservation efforts on the part of each industry, the structure of Japanese industry itself changed, with manufacturing shifting away from heavy materials-based industries primarily toward electronics and other high-tech industries (Figures 3-1 and 3-2).

Figure 3-1. Manufacturing Industry Structural Change (Components of Real GDP)



Source: *System of National Accounts* (68SNA).

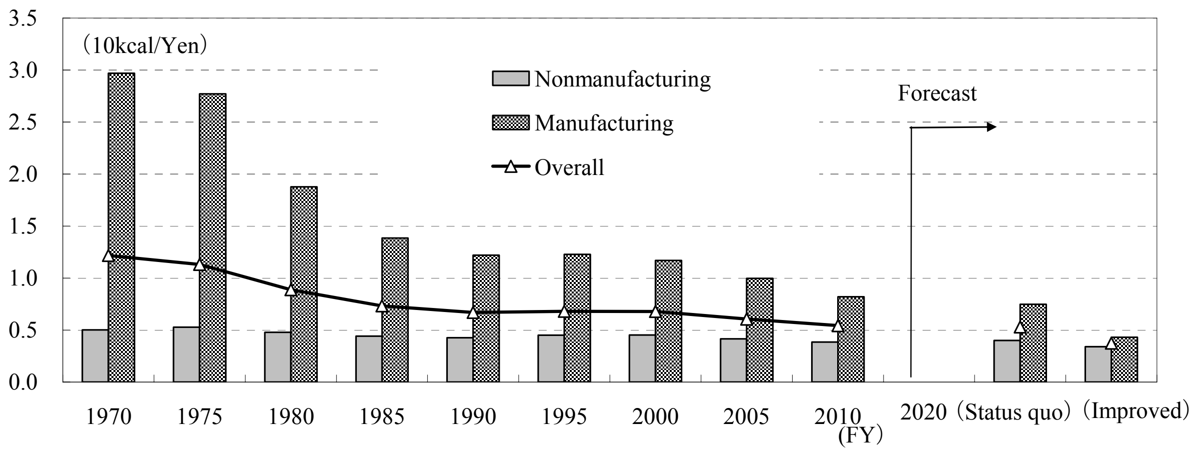
Figure 3-2. Overall Industry Structural Change in Japan (Components of Real GDP)



Source: *System of National Accounts* (68SNA).

Below, we have compared energy conservation efforts and structural changes in industry as factors in changes in energy efficiency across principal industries. Energy efficiency in both manufacturing and nonmanufacturing have improved, with an average of 3% improvement achieved annually through FY1990 (Figure 4; projections for each industry are given later in this report).

Figure 4. Energy Efficiency (Level) Comparisons



Source: *System of National Accounts*; The Institute of Energy Economics Japan, *Energy and Data Modeling Center 2011*.

2. Better Energy Efficiency Could Improve in Energy Consumption 30% by FY2020

The present report analyzes the energy efficiency of Japanese industry from the perspective of energy conservation (efforts) and industrial structure (or composition) as factors. Energy conservation factors indicate the degree to which each industry can reduce energy inputs while maintaining output, and structural factors reflect the impact which changes in the relative composition of individual industries with differing levels of energy efficiency have on energy efficiency overall. Japanese manufacturing industries made progress in energy conservation during the 1970s, and energy efficiency improved as well. As a result, these industries stayed competitive despite high natural resource prices. Meanwhile, Japan’s nonmanufacturing industry boosted energy efficiency, and since it also accounted for a lower share of industry overall, it reduced its total energy consumption. Below, we present two future scenarios with regard to the state of Japan's energy efficiency in FY2020 (with reference to the following analysis, please see Figure 1).

Status Quo Scenario (Medium-Term Forecast)–Greater share for manufacturing, efficiency improvement limited

In projecting the outlook for FY2020, we have adopted the estimates made in our 38th Medium-Term Forecast[2] for the growth rates of real output in each industry between FY2010 and FY2020 and the growth rates of real production (amount of added value) for each industry. We have then assumed that the rate of energy efficiency for each industry will remain unchanged at FY2010 levels. As a result, the derived efficiency for Japan overall in FY2020 will be due to the impact of changes in industrial structure. Since there will be an increasing shift toward machinery industries (having high energy efficiency) supporting exports as projected for the medium term, efficiency in the manufacturing industries would improve. Nonmanufacturing would account for a smaller share of the whole and the associated energy consumption would decline in tandem, but energy conservation would not progress. As a result, energy efficiency for Japanese industry overall in FY2020 would improve by just 2.3% over FY2010 levels.

Improved Energy Efficiency Scenario – Striking improvements centered in the manufacturing industry

In our projections for FY2020, we have considered improvements in energy efficiency made during the 1970s, during the period of the oil shocks. For FY2010 and after, we have made our forecasts using the rate of improvement in energy efficiency based on real output for the years 1970 – 1980 except for transportation industry, where we have used FY2000 - FY2010 data (transportation was the only industry whose energy efficiency improved during this period). We find that efficiency in FY2020 should improve by not less than 30% overall compared to FY2010. In the nonmanufacturing industries, the improvement through FY2020 would be only 12%, but that of manufacturing would improve by 47%, fueling the overall improvement. If we then compute the amount of energy savings in FY2020 using the growth rates of our Medium-Term Forecast based on these improvements in efficiency, we find that there would be not less than a 30% reduction in energy consumption compared to the Status Quo Scenario and a reduction of not less than 20% compared to FY2010 levels.

3. Individual Industry Analysis

The following analysis will focus on the structure of energy consumption for the manufacturing and nonmanufacturing industries.

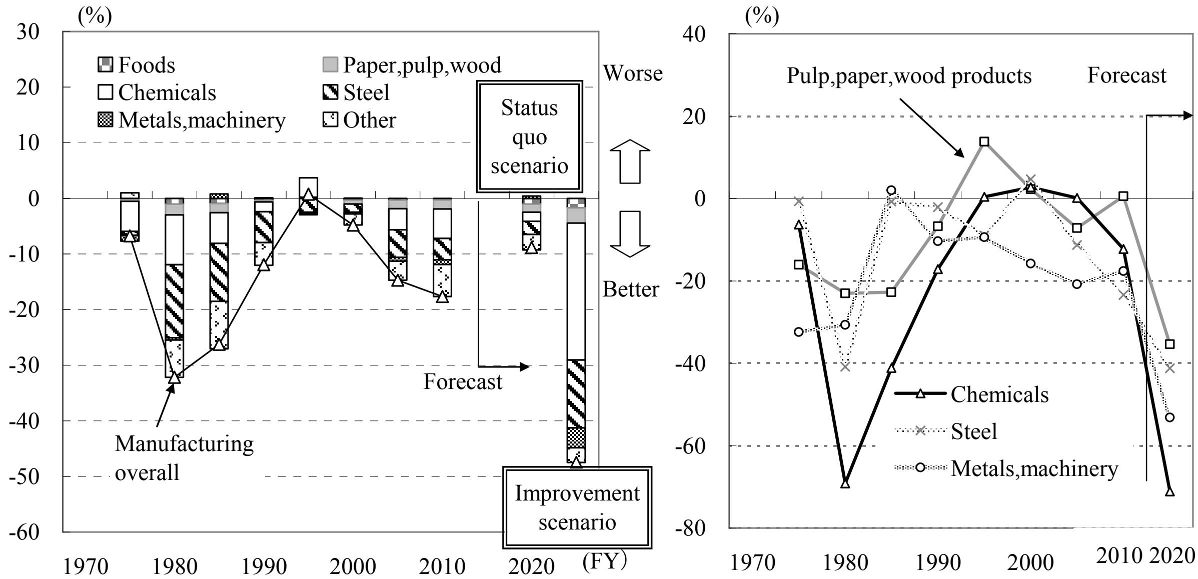
3-1. Manufacturing–Dramatic improvements in chemicals and steel during the 1970s

With the exception of FY1995, energy efficiency in the Japanese manufacturing industry has for the most part improved consistently. During the 1970s, dramatic improvements in efficiency were seen in the energy intensive industries of chemicals and steel. The reasons for this included the appearance of new manufacturing methods and advances in harnessing

[2] 38th Medium Term Forecast for the Japanese Economy : 2011-2020（http://www.jcer.or.jp/eng/economic/medium.html）

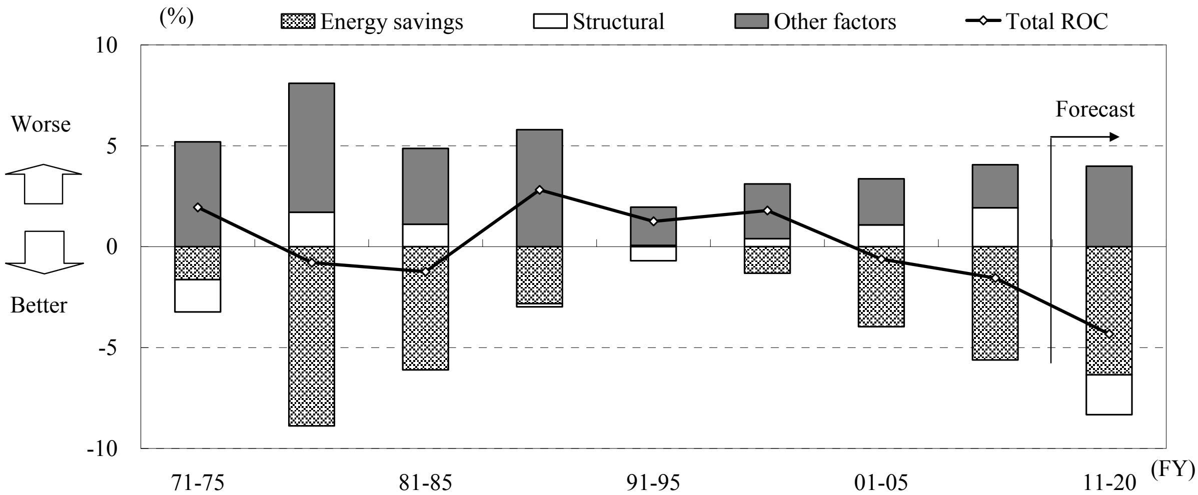
waste heat through the use of factory complexes. As symbolized by disappearance of aluminum refining from within the country, another factor was the shift toward high-tech industries and away from materials as the mainstay in manufacturing. Energy efficiency in the manufacturing industry in FY2020 could double under the Improved Energy Efficiency Scenario. In view of the fact that no substantial improvements in energy efficiency have recently been made outside of the metals and machinery industries, however, it will be necessary to shift to machinery, an industry in which further integration can be expected thanks to high technology. Meanwhile, it may be unavoidable that some hollowing out may occur in some energy-intensive industries as happened during the oil shocks (Figures 5, 6).

Figure 5. Manufacturing Industry Energy Efficiency [components, left panel; rate of change right panel] (Figures for rates of change in energy efficiency to follow below; All growth rates for periods of five years)



Note: Growth rate projections in the right panel based on Improved Energy Efficiency Scenario.
Sources: *System of National Accounts*; Institute of Energy Economics, *Energy and Data Modeling Center 2011*.

Figure 6. Manufacturing Industry Energy Inputs: Breakdown of Factors



Note: 1. Comparison of averages for 5-year periods; FY1971-FY1975 compared to FY1970. 2. Computations are made the same way for each industry discussed below. 3. Projections based on Improved Energy Efficiency Scenario.
Source: Institute of Energy Economics, *Energy and Data Modeling Center* 2011.

3.1-2 Metals and machinery – Drivers of future improvements in efficiency?

The metal products and machinery industries are assigned the same classification in the Energy Balance Tables, but the machinery industry (including general machinery, electric machinery and transport machinery) is the main subject of analysis. Energy efficiency between FY1970 and FY2010 improved, with energy consumption by FY2010 falling to one fourth the level of FY1970.

One underlying factor was the rise of electric machinery, including semiconductors. From 1970 and after, demand for general and electric machinery rose with increasing application of high technology in various industries, these products being indispensable to the energy conservation efforts being made in various industries. As a result, they came to account for a rising share of industry overall. In recent years, the Japanese household appliance industry has struggled in the face of competition from South Korean and Taiwanese rivals, but Japan's electronic components and production machinery have not only remained competitive but in the future are expected to enjoy rising demand and advances in energy conservation at the same time.

Given the maturity of the domestic market for transportation machinery, it is hard to expect further expansion, and in light of the shift to offshore production, exports are not likely to raise either. In the field of low fuel consumption and next-generation cars, however, Japan has a lead over Europe and the United States. This field may therefore see expansion depending on the trend toward greater environmental awareness and efforts to cope with global warming.

Since metals and machinery are industries in which the revolution in energy conservation technology is advancing, energy inputs are unlikely to rise sharply, and efficiency improvements are likely to continue (Figures 7-1 and 7-2).

Figure 7-1. Energy Efficiency (left) and Energy Inputs (right), Breakdown of Factors

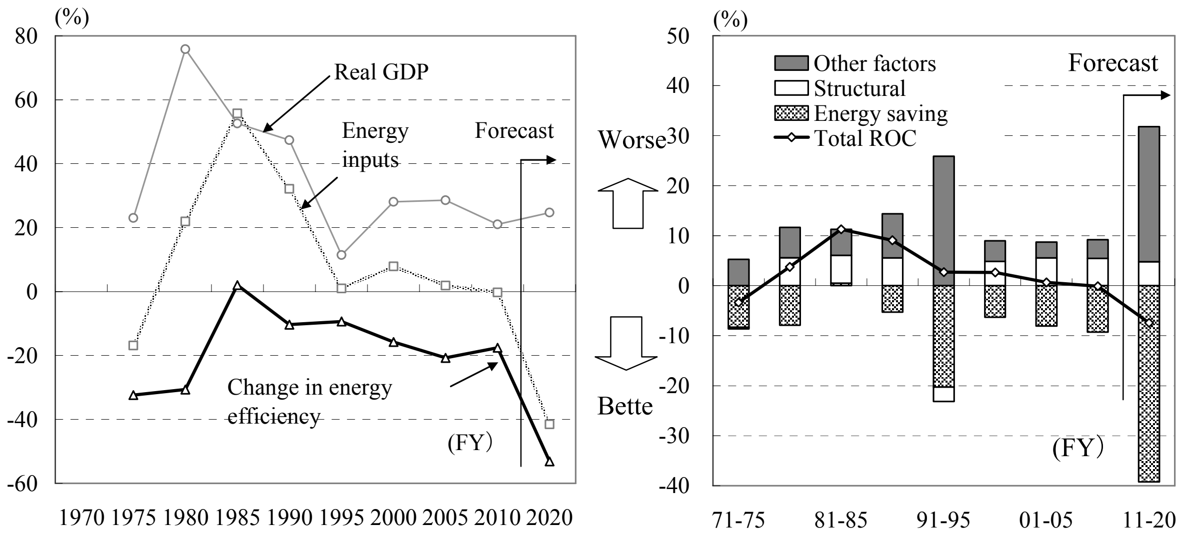
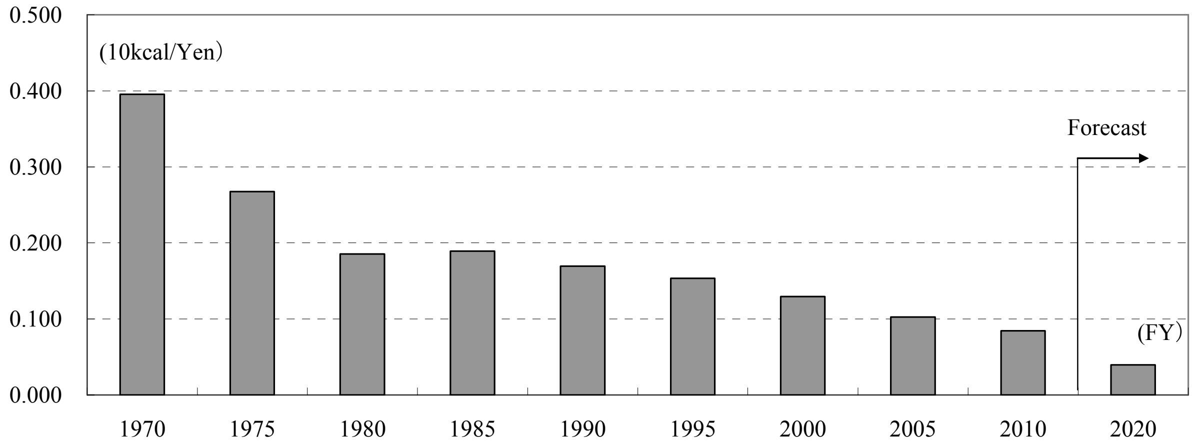


Figure 7-2. Energy Efficiency in the Metals and Machinery Industries



Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3.1-3 Food Products – High-mix production to make greater efficiency hard

Due to a rise in spending on processed foods and the food-service spending, real production increased more than energy inputs, yielding improved energy efficiency, but this trend stalled from FY1990 onward (Figure 8). In recent years, product types have diversified in response to consumer tastes, leading to an increase in energy inputs. Energy inputs are expected to increase as diversification continues in the future. However, this is a domestic-demand oriented industry, and given the rising share of the elderly in Japan's population, production volumes will not grow substantially, which will make it very unlikely that an improved energy efficiency scenario will be realized.

Figure 8-1. Energy Efficiency (left) and Energy Inputs (right), Breakdown of Factors

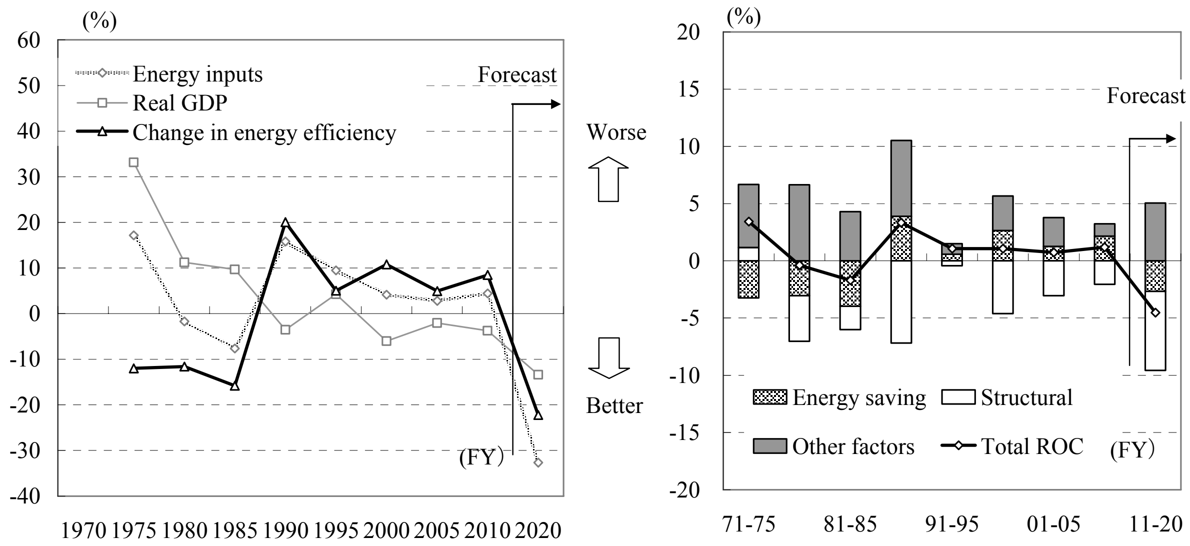
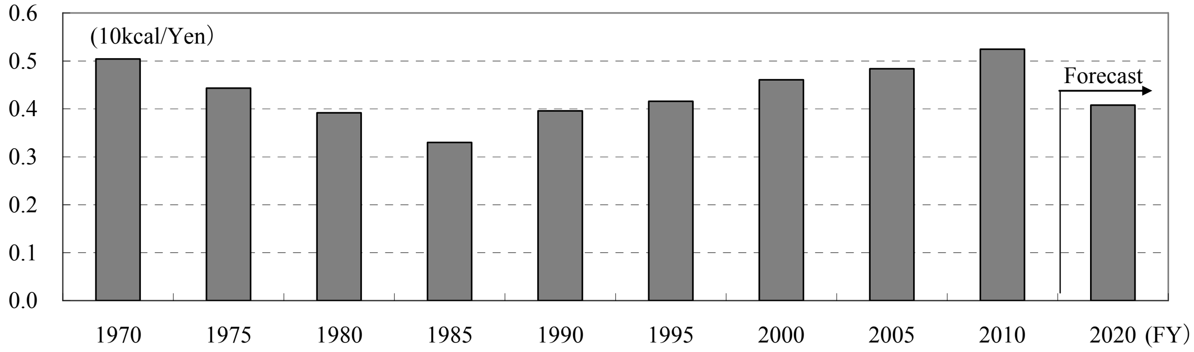


Figure 8-2. Energy Efficiency in the Food Industry



Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3.1-4 Chemicals – Technical innovation in manufacturing processes necessary for energy conservation

From FY1970 through FY1990, real production grew, supported among other things by a shift to high value added products. Precipitated by environmental problems in the 1970s, significant improvements in energy input volumes were made following transformations in production methods, improved efficiency in plant equipment, harnessing of waste heat and other factors. As a result, energy efficiency of the industry increased rapidly through FY1990, and its share in the nation's industry overall rose as hollowing out was avoided.

Real production continued to rise thereafter as Japanese business firms focused on high-performance and specialized fields, but adoption of energy saving technology slowed, such that further improvements in efficiency were only modest (Figure 9). Owing to higher prices for naphtha (a raw material in chemistry) and competition from other Asian countries, no rapid increase in real output for the chemical industry can be expected. Japan is already a world class player in energy saving technology, which means that further improvements in energy conservation will get harder, making wider use of innovative manufacturing methods in the development stage critical in boosting energy efficiency.

Figure 9-1. Energy Efficiency (left) and Energy Inputs (right), Breakdown of Factors

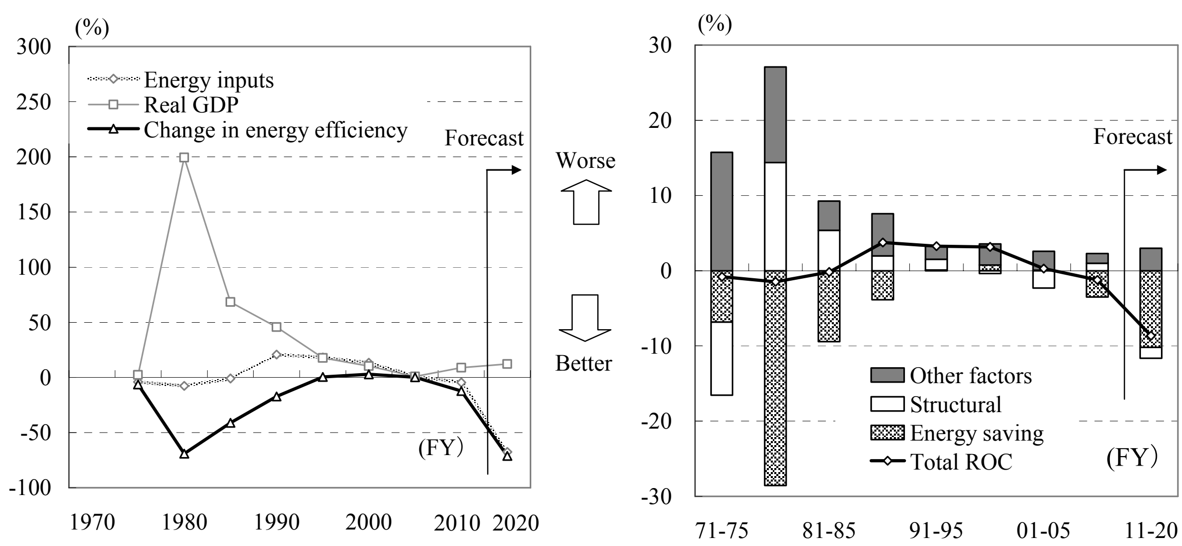
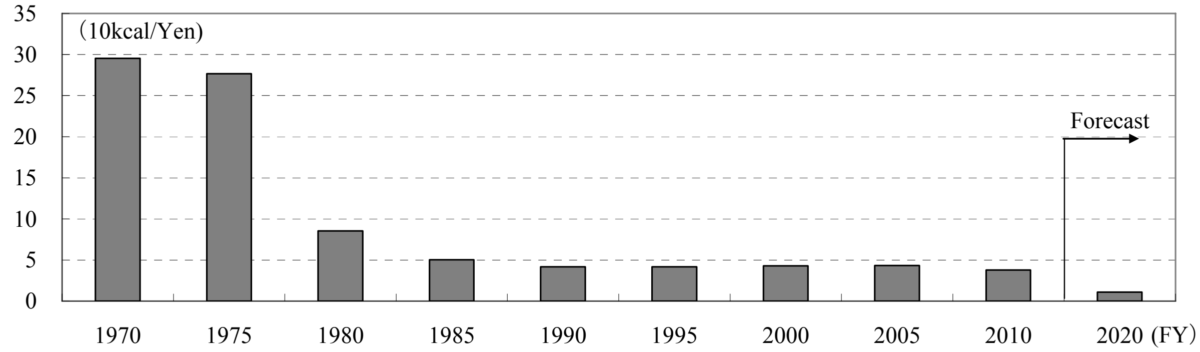


Figure 9-2. Energy Efficiency in the Chemical Industry



Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3.1-5 Steel – Energy inputs and output maxed out

As the social infrastructure of Japanese society advanced during the rapid economic growth period, real production rose. In addition to energy conservation through improvement of manufacturing facilities and production processes, Japanese companies made effort to utilize waste heat and waste plastic, which helped cut energy consumption by about 20% between FY1975 and FY1985. As in the chemical industry, the steel industry succeeded in garnering demand fueled by the energy saving investments made by various other industries and thus increased its share in industry overall. Subsequently, export demand also increased mainly from other Asian nations, but owing to competition from rivals such as Korea, real output stalled. Energy saving technologies played out, so efficiency remained unchanged (Figure 10). There is unlikely to be any sharp increase in domestic crude steel production over the medium to long terms. In light of intensifying competition from Korea and other countries overseas, it will remain difficult to boost steel production significantly. Meanwhile, Japanese companies are expected to continue shifting production to bases overseas, so no significant increase in energy inputs is likely. There is unlikely to be an increase in either energy inputs or real production, and energy efficiency will likely remain around the 2010 level. Achievement of the Improved Energy Efficiency Scenario will require far-reaching technical innovation in steel manufacturing methods.

Figure 10-1. Energy Efficiency (left) and Energy Inputs (right), Breakdown of Factors

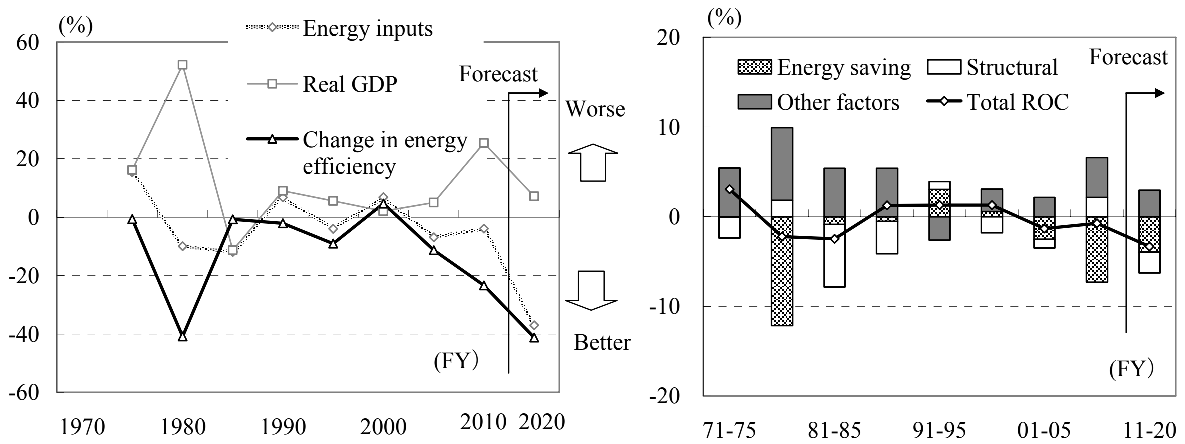
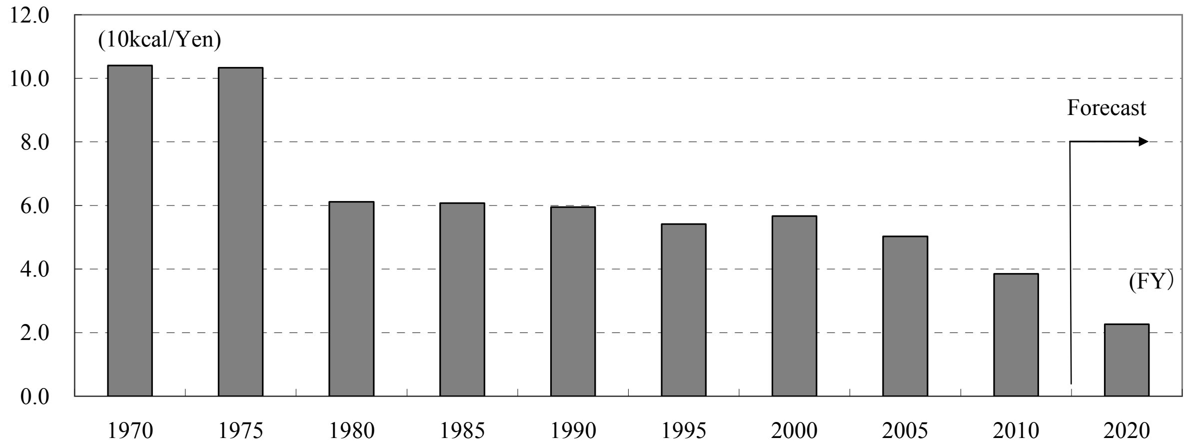


Figure 10-2. Energy Efficiency in the Steel Industry

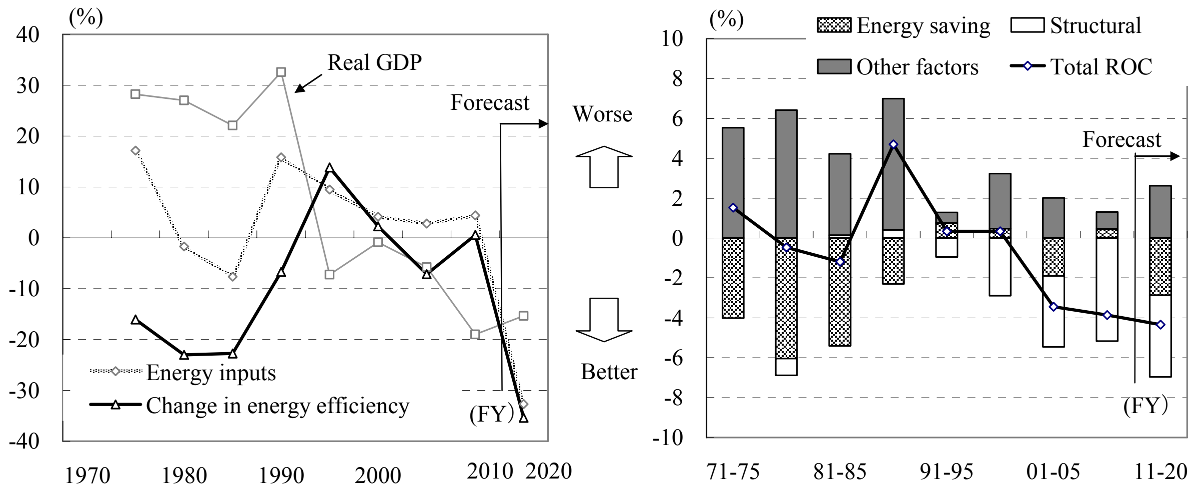


Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3.1-6 Paper/Pulp – Recycled Black Liquor and other Improvement Measures Limited

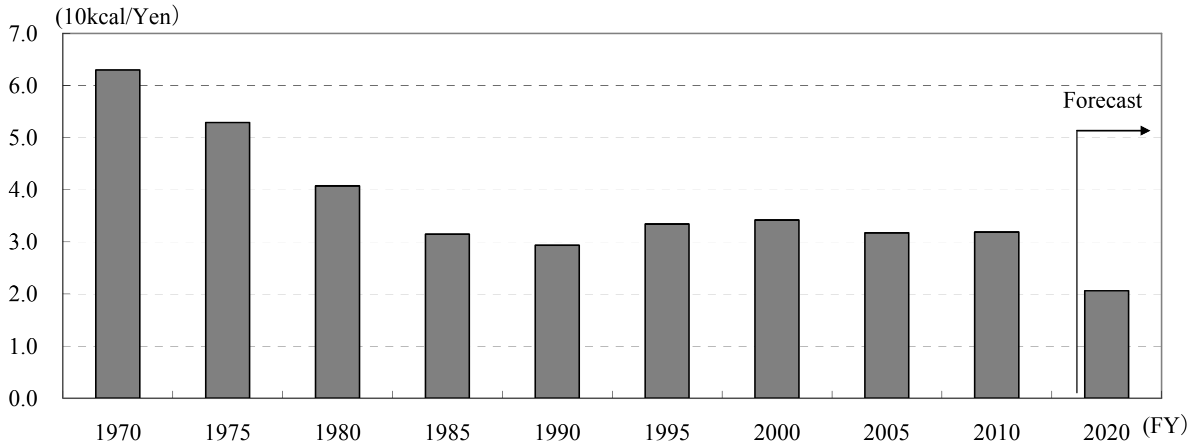
Real production in the paper/pulp industry grew through FY1990 along with the growth of the domestic economy. Although production rose with the use of renewable forms of energy (recovered black liquor), wastepaper use technology and advances in energy savings, energy consumption did not increase, so the efficiency of energy inputs improved[3]. Growth in paper demand also slowed drastically after the collapse of Japan's asset bubble, and adoption of energy saving technology to improve energy efficiency has run its course. The domestic Japanese economy is not expected to grow at a fast pace, and manufacturers are also expected to step up moves to shift production offshore. No significant growth in paper/pulp demand can be expected. As for energy inputs, further energy conservation will be difficult, and in view of recent trends, it is even possible that efficiency will improve less from energy conservation efforts than from hollowing out (Figure 11).

Figure 11-1. Energy Efficiency (left) and Energy Inputs (right), Breakdown of Factors



3 Black liquor is the spent cooking liquor produced during the paper manufacturing process. As in the case of waste wood and waste tires, the high energy content of black liquor is a hallmark of the paper/pulp industry

Figure 11-2. Energy Efficiency in the Paper/Pulp Industry

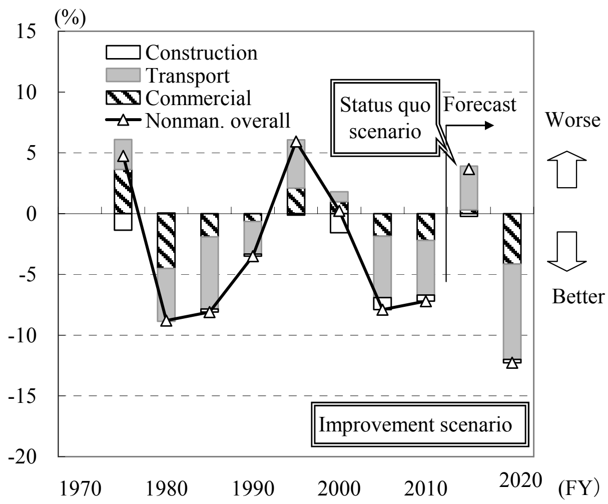


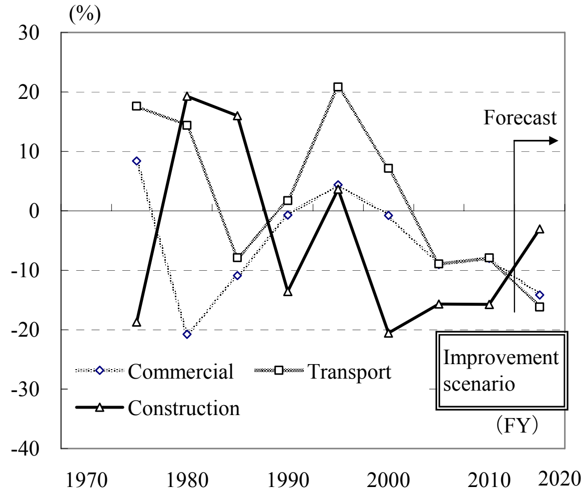
Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3-2. Nonmanufacturing – Commercial Sector[4] Driving Better Efficiency

Business and transportation have a large impact with regard to the improvement of energy efficiency in the nonmanufacturing industry. This is because the industry quickly benefits from rationalization made possible by the application of information technology and from improvements in auto fuel consumption. Energy efficiency in the nonmanufacturing industry in FY2020 will only improve by about 1% even under the improved energy efficiency scenario (based on its track record for FY1970-FY1980), but if improvements seen in recent years continue, the energy efficiency scenario might even be exceeded (Figure 12).

Figure 12. Energy Efficiency in the Nonmanufacturing Industry (Components and Rate of Improvement)





Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

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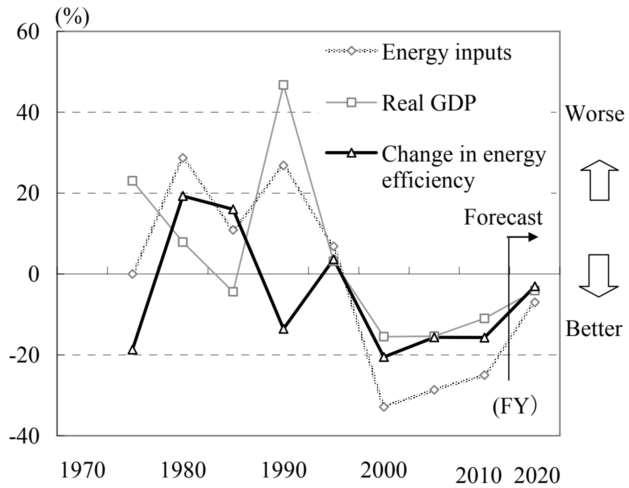
[4] Under SNA classifications, the "commercial" sector includes wholesale and retail, finance and insurance, real estate, telecommunications and services.

3.2-1 Construction – Energy consumption could fall as industry shrinks

Real production of the construction industry increased between 1970 and 1990 on increased urbanization and the growth of public investment for building infrastructure and economic stimulus. Energy inputs also rose, and little improvement in energy efficiency was made. From the second half of the 1990s, construction machinery became more energy efficient, while lower spending on public investment and other factors contributed to shrinkage of the industry itself, which in turn led to a reduction in energy inputs (Figure 13).

Figure 13-1. Energy Efficiency (left, rate of change) and Energy Inputs (right), Breakdown of Factors



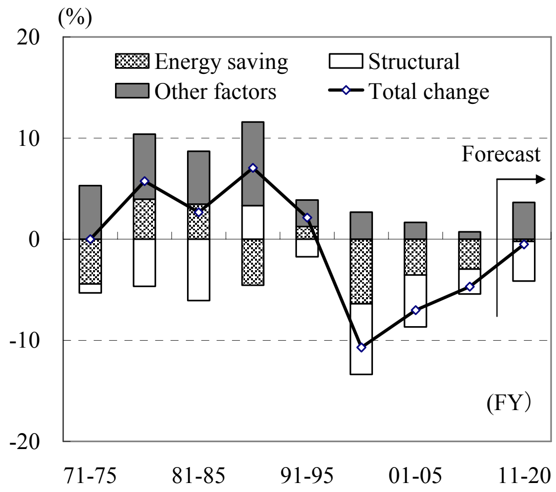
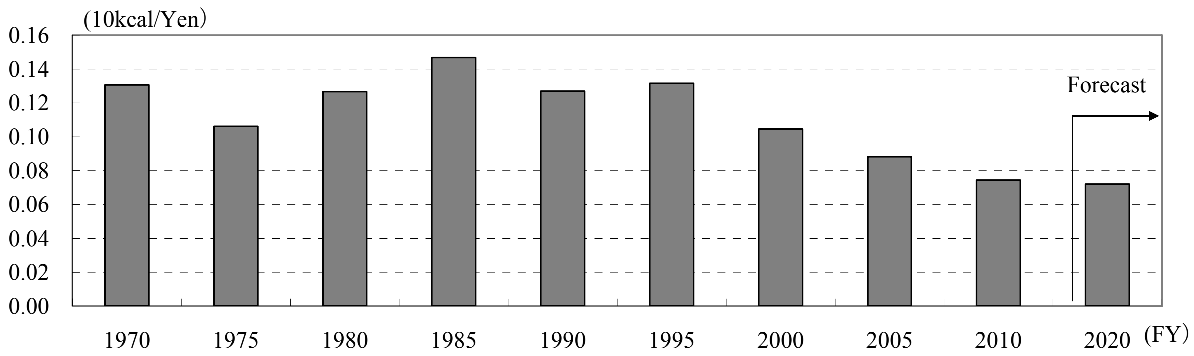


Figure 13-2. Energy Efficiency in the Construction Industry

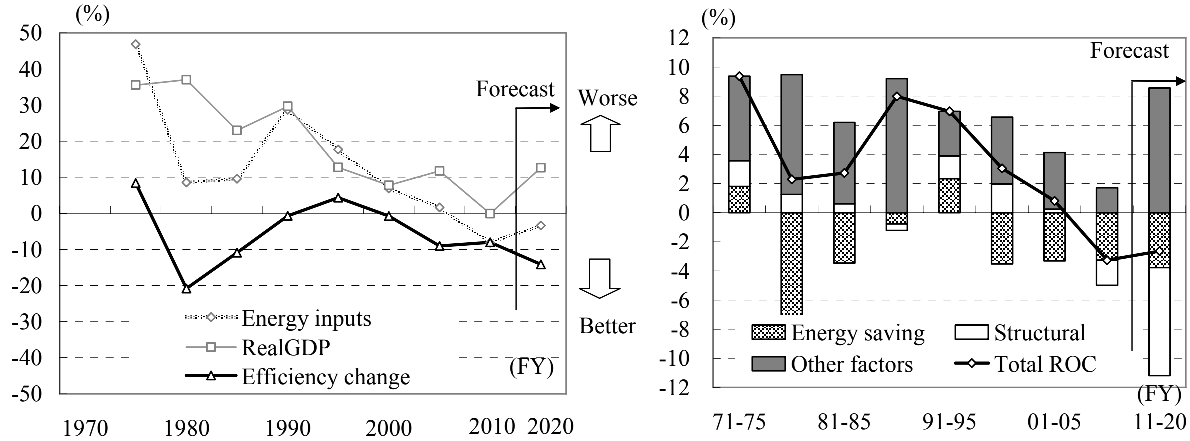


Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

3.2-2 Commercial Sector–Energy saving hopes from IT

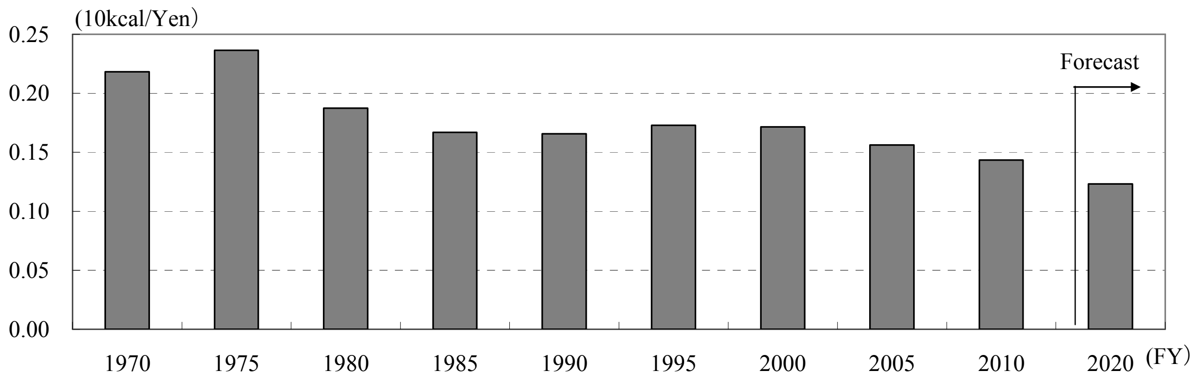
Energy inputs rose through FY1990, but since the pace of growth exceeded the increase in inputs, efficiency improved. Energy inputs increased even further in the 1990s when department stores and supermarkets lengthened their business hours and the number of convenience stores increased. As a result, efficiency stopped improving (Figure 14).

Figure 14-1. Energy Efficiency (left, rate of change) and Energy Inputs (right), Breakdown of Factors



Note: Projections based on Improved Energy Efficiency Scenario.
Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

Figure 14-2. Energy Efficiency in the Commercial Sector



Sources: System of National Accounts; Institute of Energy Economics, Energy and Data Modeling Center 2011.

The Energy Balance Tables do not provide energy consumption data by individual industry, so in the following analysis we have used Input Output Tables. Between 1970 and 1980, energy efficiency in the wholesale sector improved. (The wholesale sector includes trading companies which benefited from high natural resource prices and expanded their operations.) In addition, energy efficiency in telecommunications and broadcasting also improved since it quickly benefits from technical innovations in electronics (Figure 15).

Figure 15-1. Energy Efficiency in Commercial Sector: Comparison (1970-1980, 1970=1)

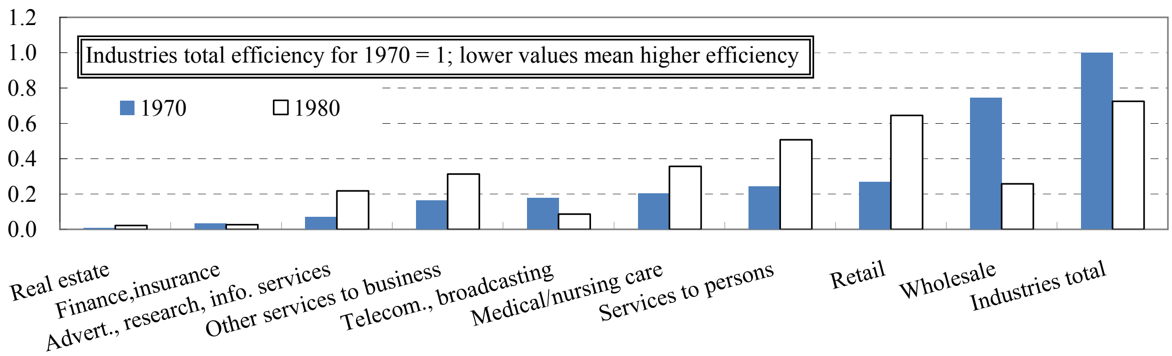
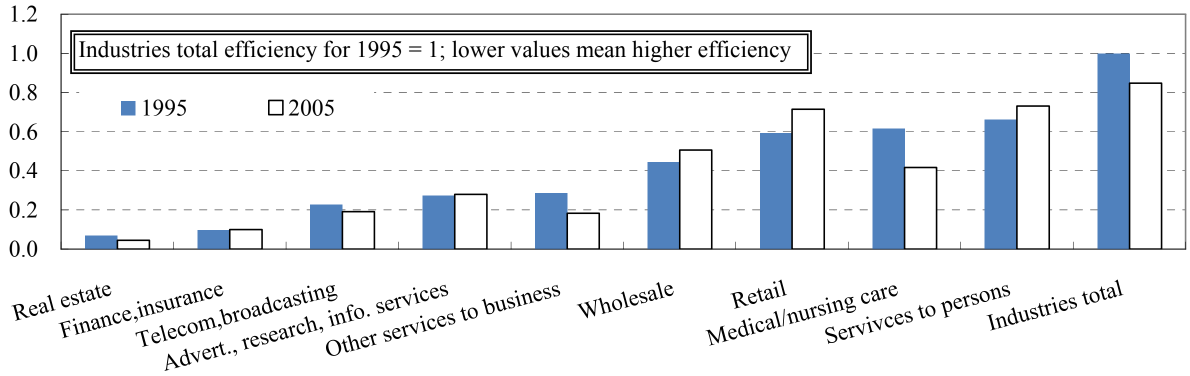


Figure 15-2. Energy Efficiency in Commercial Sector: Comparison (1990-2005, 1970=1)



Note: We have assigned a value of 1 to the industries total energy efficiency for the years 1970 and 1995, respectively. Smaller numbers indicate higher levels of efficiency.
Source: Input Output Tables.

Energy efficiency in medical and nursing care health care has recently improved (1995-2005), one possible reason perhaps being that, the industry is expanding at a faster pace than is the growth of energy inputs used for mechanization.

Figure 16-1. Energy Efficiency Improvement in Commercial Sector (Contributions, 1970-1980)

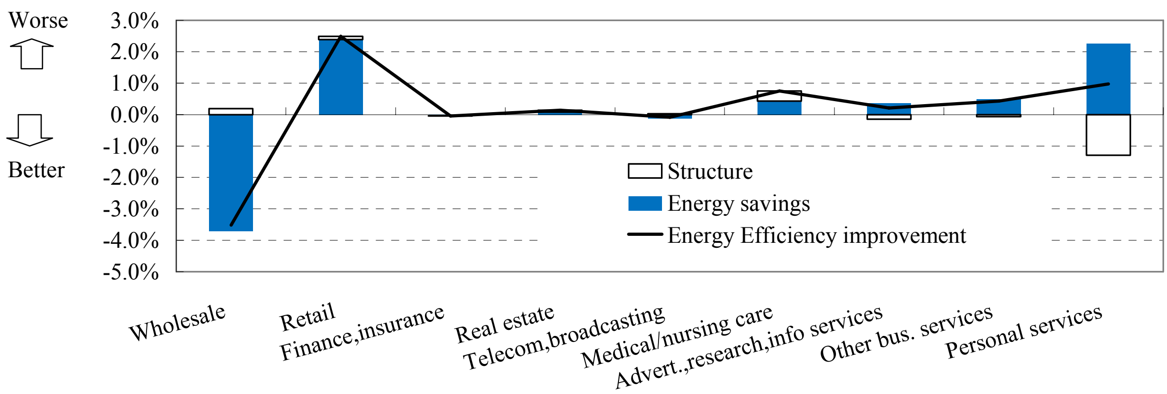
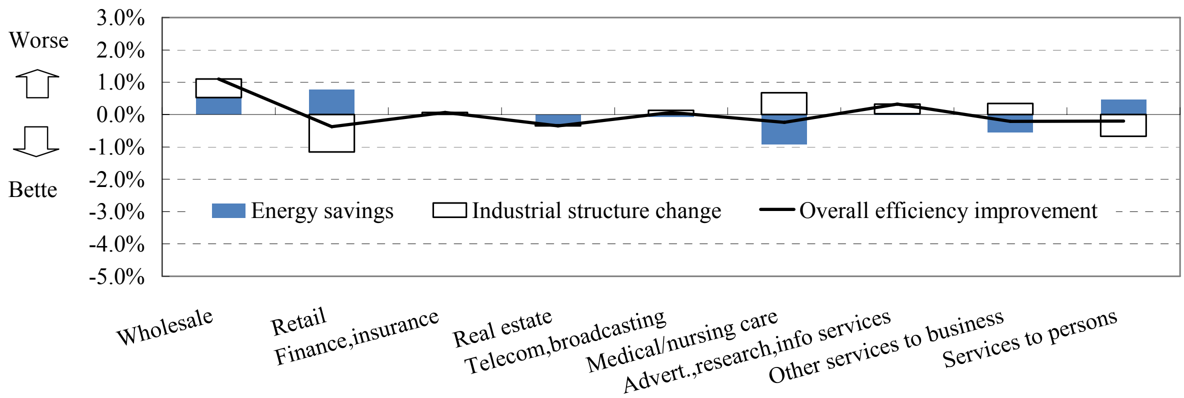


Figure 16-2. Energy Efficiency Improvement in the Commercial Sector (1995-2005)

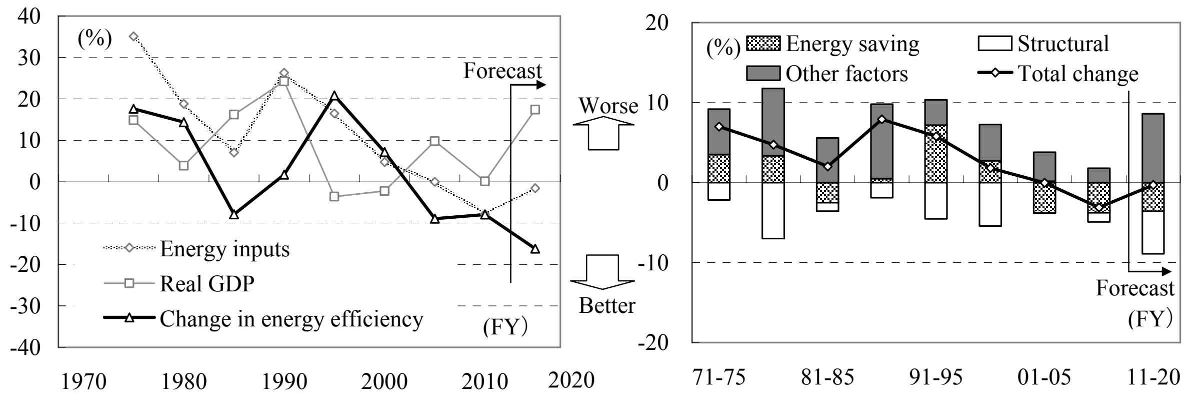


Note: Structural contributions are found by subtracting the contribution of energy savings from contributions overall.
Source: Input Output Tables.

3.2-3 Transportation–Benefits from improvements in auto fuel efficiency

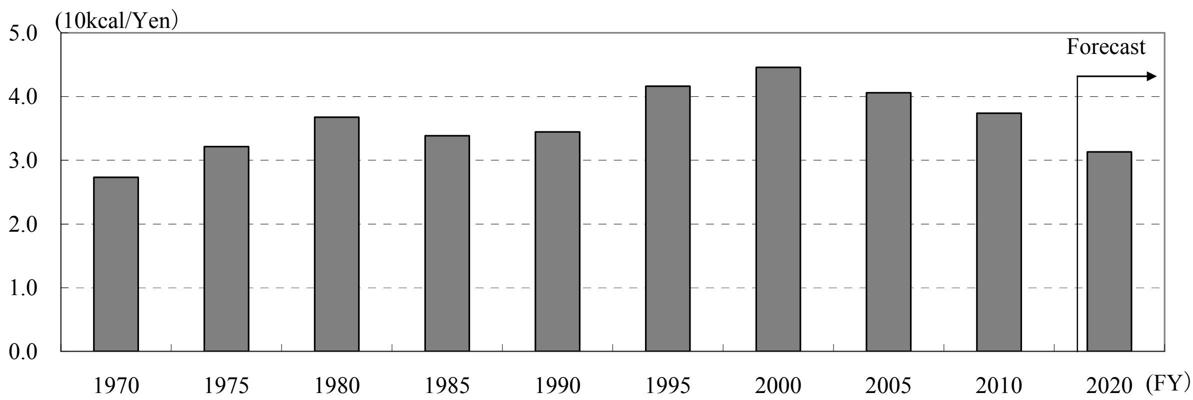
Truck transportation predominated between 1970 and 1990, and energy efficiency in the transportation industry deteriorated. As symbolized by the rapid expansion of package delivery services in the 1990s, efficiency deteriorated further, exacerbated by lower fossil fuel prices. After the turn of the millennium, energy consumption advanced thanks to improved auto fuel efficiency and transportation infrastructure. Transportation driven by domestic demand is not likely to expand rapidly in the future, and improvements in efficiency on rising GDP will be difficult. However, if auto fuel efficiency continues to improve, the Improved Energy Efficiency Scenario could be achieved (Figure 17).

Figure 17-1. Energy Efficiency (left, rate of change) and Energy Inputs (right), Breakdown of Factors



Note: Projections based on Improved Energy Efficiency Scenario.
Sources: *System of National Accounts*; Institute of Energy Economics, *Energy and Data Modeling Center 2011*.

Figure 17-2. Energy Efficiency (level) in the Transport Industry



Sources: *System of National Accounts*; Institute of Energy Economics, *Energy and Data Modeling Center 2011*.

4. Can prosperity and energy efficiency both be achieved?

In the manufacturing industry, possible efforts to further reduce energy consumption in such energy-intensive sectors as materials have nearly been exhausted, so a key requirement to improving energy efficiency in the future will be shifting to the more energy-efficient machinery industry (Japan's flagship industry). Although steel and chemicals were energy efficient and remained competitive, Figure 18 shows that the machinery industry increased its relative share during the oil crisis as energy saving efforts moved ahead. It also indicates that the shift to the high-value added machinery industry has not only improved energy efficiency but also made exports more competitive (Figure 19).

Figure 18. Manufacturing: Rapid Growth of Machinery Industry

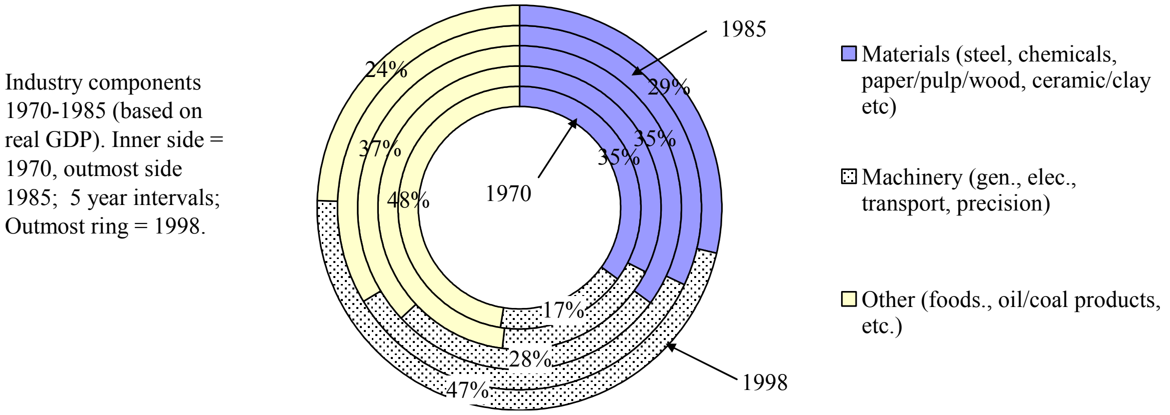
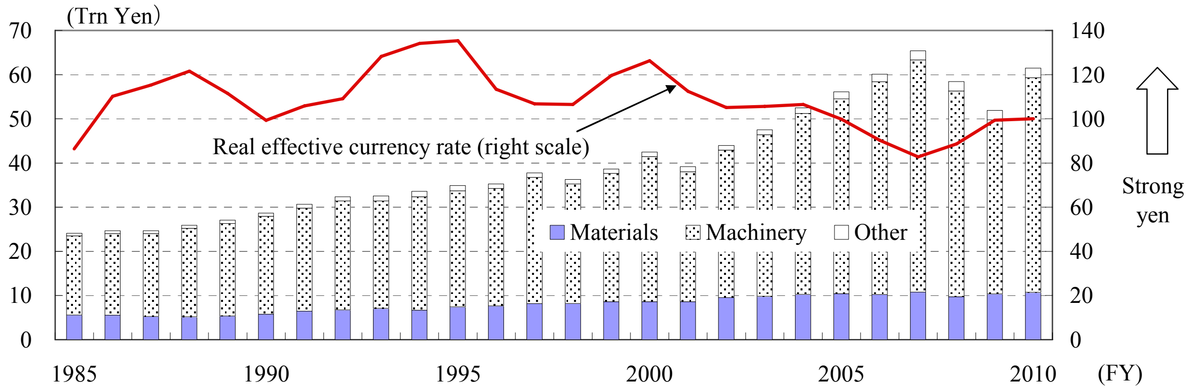


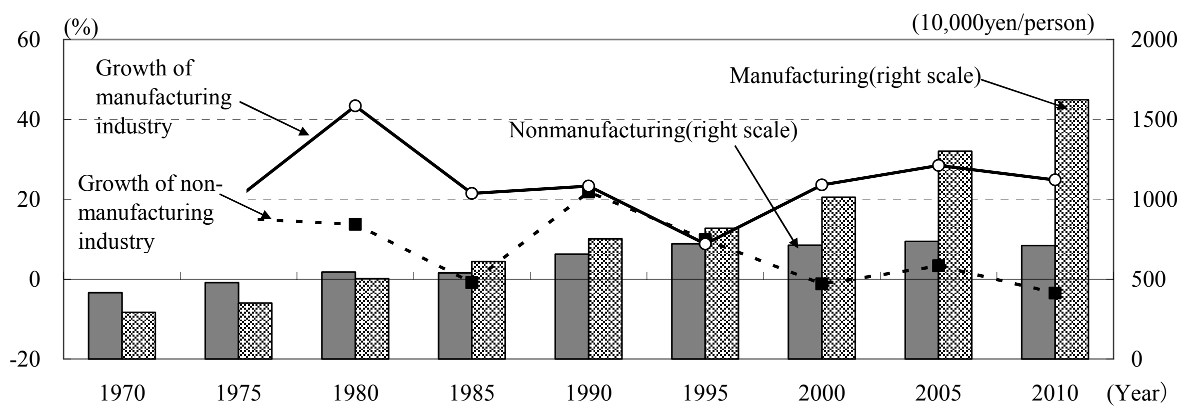
Figure 19. Real Exports: Led by Machinery, Rose Despite Strong Yen



Note: Real exports are computed by dividing nominal exports by the export price index.
Source: Trade Statistics of Japan, Corporate Goods Prices.

Some observers believe that restructuring the economy so that it is centered more on the tertiary industries, mainly nonmanufacturing, would improve energy efficiency. However, caution is needed here. Such a move would not necessarily lead to an improvement in labor productivity (real production per head), which is directly tied to the expansion of wealth.

Figure 20. Manufacturing Beats Nonmanufacturing in Labor Productivity Growth



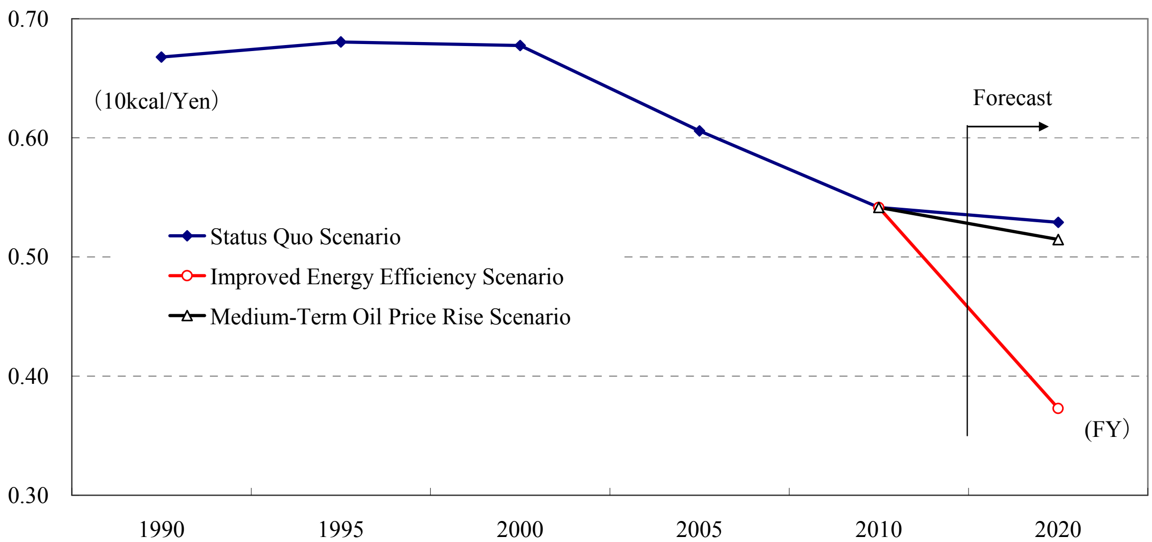
Source: *System of National Accounts*

Figure 20 compares labor productivity in the manufacturing and nonmanufacturing industries and shows that productivity in the manufacturing industry has risen significantly owing to technical innovation, surpassing the nonmanufacturing industry. Meanwhile, it has failed to grow in the nonmanufacturing industry, meaning that even if a shift from the manufacturing industry to the nonmanufacturing industry increases energy efficiency, labor productivity will fall.

In an age when energy prices are rising, efforts will be needed to harness information technology in such industries as services, which are labor intensive, with a view to making business more efficient and labor more productive. In the manufacturing industry, meanwhile, shifting from the materials industry to very high-added value machinery industry is needed all the more. In this effort, it will be critical to strengthen technological development capabilities in order to prevail in the competition with other advanced and emerging countries.

Figure 21 estimates the future improvement in energy efficiency from the relationship of past energy prices and energy efficiency. It indicates that while energy efficiency would improve more than under the Status Quo Scenario, the Improved Energy Efficiency Scenario would be hard to achieve if crude oil prices rise as projected in our 38th Medium Term Forecast for the Japanese Economy (more than $150/barrel by 2020). It would therefore seem advisable to effect tax changes and deregulation with a view to supporting energy conservation by business firms.

Figure 21. Energy Efficiency (Level)



Note: The scenario of rising crude prices represents values derived from the relationship (shown in the following formulae) between past fossil fuel import prices and energy efficiency.
Source: *System of National Accounts*; Institute of Energy Economics, *Energy and Data Modeling Center 2011*.

<The following is an explanation of computation methods used in the present report regarding the impact of energy efficiency and industry structural changes on the improvement of energy efficiency overall.>

For explanatory purposes, two industries and two periods are expressed in the form of equations, as follows. Aggregate output *Y* in period *t* is expressed as $Y = Y_1 + Y_2$ representing the output of two industries (Industry 1, Industry 2).

For present purposes, the share of added value of each industry in the whole is expressed as follows.

$$w_{1,t} = \frac{Y_{1,t}}{Y_t}\ , \quad w_{2,t} = \frac{Y_{2,t}}{Y_t}$$

If the energy efficiency of each industry is expressed as,

$$E_{1,t} = \frac{P_{1,t}}{Y_{1,t}}, \quad E_{2,t} = \frac{P_{2,t}}{Y_{2,t}}$$

Then the energy efficiency as a whole will be *E*, as follows:

$$E_t = w_{1,t} * E_{1,t} + w_{2,t} * E_{2,t} = \frac{P_t}{Y_t}$$

Thus,

$$\frac{\Delta E_t}{E_t} = \frac{(w_{1,t+1} * E_{1,t+1} - w_{1,t} * E_{1,t})}{E_t} + \frac{(w_{2,t+1} * E_{2,t+1} - w_{2,t} * E_{2,t})}{E_t}$$

Next, we rearrange the expression to show changes in the share of added value of each industry in the whole and changes in energy efficiency:

$$\frac{\Delta E_t}{E_t} = \frac{\Delta w_{1,t} * E_{1,t} + \Delta w_{2,t} * E_{2,t}}{E_t} + \frac{w_{1,t} * \Delta E_{1,t} + w_{2,t} * \Delta E_{2,t}}{E_t} + \frac{\Delta w_{1,t} * \Delta E_{1,t} + \Delta w_{2,t} * \Delta E_{2,t}}{E_t}$$

Rearranging the above with regard to the generalized industry *n* gives:

$$\frac{\Delta E_t}{E_t} = \frac{\sum_{j=1}^{n} \Delta w_{j,t} * E_{j,t}}{E_t} + \frac{\sum_{j=1}^{n} w_{j,t} * \Delta E_{j,t}}{E_t} + \frac{\sum_{j-1}^{n} \Delta w_{j,t} * \Delta E_{j,t}}{E_t}$$

The respective terms on right side of the equation are then interpreted as follows:

The first term indicates the effect of a change in the share of the output of a given industry under conditions in which the energy efficiency of each industry remains unchanged (the “structural change factor”).

The second term indicates the effect of a change in the energy efficiency of a given industry under conditions in which the share of the output of each industry remains unchanged (the energy “savings factor”).

The third term represents the cross effect arising from changes in both and indicates the portion lost from the first term and the second term (the “other factor”).

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