研究論文

Impacts of Oil Production Decline on Japanese Food Supply

– Prospects toward sustainable human societies –

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Abstract

Explosive expansion of human activities has resulted in a possible crisis of the sustainability of human societies due to natural resource deficits and environmental degradations against human existence. We focused on a possible decline of world oil production and its impacts on the food supply of Japan, and illustrated that the oil supply deficit might result in a possible shortage of food calorie supply due to lack of transport energy rather than that of energy for agricultural productions. The discussion suggested a difficulty in analyzing and projecting the overall consequences of the natural resource deficits. This also suggested a necessity to review the direction of the research and technological development toward the fulfillment of the sustainable human societies by taking account of both direct and indirect effects of the deficits.

Key Words: Environment, Food, Fossil fuel, Humanosphere, Sustainability

1. Introduction

Rapid growth of human population and economy has led to the acceleration of natural resource deficits and serious environmental degradations against human existence in various scales, and we, in consequence, face a possible crisis of the sustainability of human societies. As one of solutions to the shortage of fossil energy sources, it is indispensable for us to develop alternative energy sources to compensate this possible deficit. At the same time, it is also essential to understand and forecast the actual effects of the fossil energy source deficits on human societies so that we could find the most effective solutions toward the achievement of the sustainability of human societies. Forecasting the actual impacts of the deficits, however, is not a simple task since almost every aspect of the modern societies heavily relies on the fossil energy sources in a very complex and interrelated manner. Therefore, it may be possible that indirect effects rather than direct effects of the deficits might cause serious consequences on human societies. Although it is equally important for us to understand both direct and indirect effects, the impacts from indirect effects on human societies have not been well acknowledged and sufficiently studied.

In this paper, we examined the essential dependence of the food supply on transport energy in order to illustrate the serious impacts of a transport energy deficit as an indirect effect of the fossil energy source deficits. We first reviewed the world energy supply, a great dependence of human societies on oil as an energy source, and a possible deficit of world oil production in the near future. We next estimated the energy balance of food supply in Japan, and showed that lack of transport energy may cause a devastative effect on the security of the Japanese food supply. We finally discussed about a necessity to review the direction of the research and technological development by taking account of both direct and indirect effects of the deficits.

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2. World total primary energy supply and total final consumption

First, we review the current world supply and consumption of energy sources, and their projections in 2030 based on the report published by International Energy Agency [(1), (2)]. We refer to conventional oil as oil throughout sections 2 and 3. We discuss about the future availability of unconventional oil such as tar sand and oil shale in section 2. We also use Mtoe, million metric-ton oil equivalent, as a unit of energy throughout this paper unless notified.

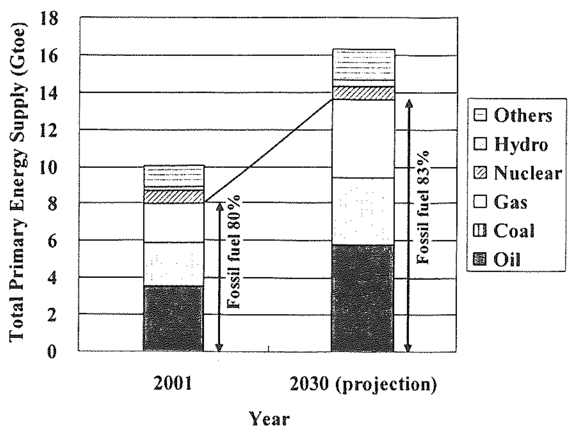

Fig. 1 World Total Primary Energy Supply by Energy Source [(1), (2)].

Figure 1 shows the world total primary energy supply (TPES) by energy source in 2001 and the projection of TPES in 2030. This figure suggests that we are greatly depending on the fossil fuels, oil, coal, and natural gas, as our energy sources by around 80%, and will increasingly depend on them in 2030 by around 83%. IEA forecasted that world demand for oil and natural gas will rise greatly over the next three decades whereas the demand for coal will grow more slowly than that for oil and gas. Though the natural gas demand will grow more greatly than oil, especially in an electricity generation sector, IEA forecasted that oil will remain the primary energy source among the energy sources at least until 2030. It should be noticed that IEA assumed that the fossil energy sources will be still ample at least until 2030.

Figure 2 shows the world total final energy consumption of end-use sectors by energy source in 2001. In this figure, "transport sector" includes fuels for aviation, road, rail, and internal navigation traffic, "other sectors" include commercial and public services, residential, and agriculture, and "non-energy" use covers paraffin waxes, lubricants, bitumen, and other petroleum products. "Other energy sources" include electricity, heat, and renewable energy. We do not include "non-energy" use in the following discussion because of its lower importance than those of the other energy consumptions. It is a striking fact that we depend almost absolutely, by 96%, on oil as transport energy. IEA also forecasted that oil will keep its dominant role by 96% of transport energy even in 2030. No other fossil energy source play or is forecasted to play such a dominant role in a single end-use sector. The physical transportation of any materials is a truly essential activity to sustain human societies. It is worth, therefore, to arouse our attentions to that we almost entirely depend on oil and will continue to rely entirely on oil as transport energy. The forecast of the continuing dominant role of oil suggests that IEA firmly assumed that there will be no risk of oil depletion and no strong incentives for development of alternative transport energy sources at least until 2030. The forecast also suggests that oil is far more efficient, portable and convenient source as transport energy than coal, natural gas, and any other energy source. If the above assumptions were not the case and oil would be depleted much earlier than IEA's projection, the impacts caused by a shortage of transport energy on human societies could be devastative.

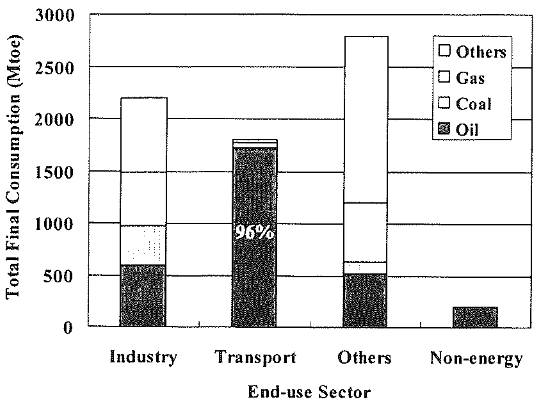

Fig. 2 World Total Final Consumption by Energy Source in 2001 [1].

Figure 3 shows the world electricity generation by energy source in 2001 and the projection in 2030. In marked contrast to the world final energy consumption, the role of oil on electricity generation is significantly minor, 7.5%, in comparison with the other energy sources, 38.7% for coal and 18.3% for gas. IEA forecasted that the contribution of oil to the electricity generation will continuously decrease to 4.2% of the total energy for electricity generation in 2030, whereas coal and gas will remain the major sources of electricity generation, 36.8% and 31.5%, respectively. The minor role of oil on electricity generation suggests that an impact of a possible oil deficit on electricity supply might be avoidable by a preventive introduction of energy sources alternative to oil such as renewable energy to meet the future electricity demand.

3. Possibility of depletion of fossil energy sources

In the previous section, we reviewed IEA's forecast that oil will remain its dominant position on transport energy sources at least by 2030. This projection can be meaningful only if the assumption that there will be no risk of oil depletion by 2030 would be valid. In order to examine the validity of this assumption, we discuss below how long we can safely rely on fossil energy sources.

Table 1 shows the ratios of global proved reserves to production (R/P ratio) of the fossil energy sources in 2003 [3], which are often referred as a measure of the depletion times of fossil energy sources. This table apparently suggests that oil will be depleted by 2050 and significantly earlier than other sources, however; the R/P ratio is a tricky measure to interpret a time of depletion since the estimate of global proved reserves necessarily contains significant uncertainties. The global proved reserves are defined as quantities that can be recovered in the future from known reservoirs under

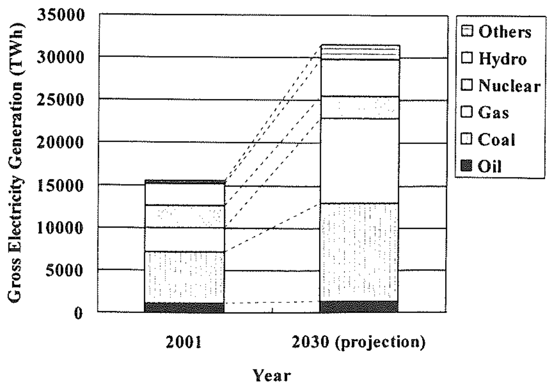

Fig. 3 World Electricity Generation by Energy Source [1, 2].

Table 1 Reserve to Production (R/P) Ratio of Fossil Energy Sources in 2003 [3].

Fossil Energy Sources	R/P ratio (year)
Oil	41
Coal	192
Natural Gas	67

existing economic and operating conditions with reasonable certainty [3]. In fact, the world proved reserves have generally increased since 1980 because of the continuous increase of recoverable oil with the progress of recovery technology and discovery of new oil fields while the world oil production has generally increased in the same time. The R/P ratio has consequently remained almost constant from 40 to 45 years since 1986. The R/P ratio, therefore, may not be an appropriate measure to estimate an accurate time of fossil fuel depletion. Instead, we focus on the ultimate recoverable reserves which include possible and probable reserves which might be recoverable with the future possible technology and economic situations. We also discuss below only on oil, which is generally regarded as the earliest depleted fossil fuel than the other sources. The estimate of the ultimate recoverable reserves of oil has been a greatly controversial issue. Some analysts take a pessimistic position and others take an optimistic one. It is not easy to determine which position is more realistic because of uncertainties in the assumptions on their estimates. We review these controversial estimates on the possibility of the future world oil production, which can be regarded as a measure of the ultimate recoverable reserves.

Some analysts have an optimistic view of the future world oil production. As described in the previous section, IEA [2] estimated that global oil supply will be ample at least until 2030. Energy Information Administration (EIA) of the U.S. Department of Energy [4] also presented the similar projection to that of IEA on the world energy supply and demand by 2025. EIA also seems to agree with the assumption that there is no risk of the oil depletion at least until 2025. Odell [5] also asserted his optimistic vision that the global oil reserves are still ample and that the peak of world oil production will not reach until in the early 2030's.

Other analysts insist that the world oil production is now reaching its peak and will decline thereafter. Hubbert is a geophysist who pioneered a method to estimate the peak of oil production [6]. He made a projection that the U.S. oil production would peak in the early 1970' with his original model in 1956. Though his projection was hardly accepted then, the peak actually occurred in 1971. His method is based on the two empirical assumptions that; (1) oil production history would fit a symmetrical bell-shaped curve and (2) oil discoveries would follow an identical bell curve which is shifted in time from the production curve by fixed years. Several analysts have applied Hubbert's method to forecast the peak of the world oil production. Campbell and Laherrère [7] estimated that the world oil production will reach its peak around by 2010 and decline after the peak. Deffeyes [6] also estimated the peak year as the projection similar to Campbell.

One reason why their estimates branched into the opposite conclusions is different prospects in the future technology for oil recovery. Optimists claim that future technological innovations will significantly increase the recoverable amount of oil on which we do not count as the ultimate recoverable reserves. On the other hand, pessimists rebut that we already had huge investments for the technological development and there is little possibility to recover such a significant amount of oil from the existing oil fields. Another reason is different estimates on the possibility to discover new giant oil field. Optimists argue that new giant oil fields will be discovered in the areas to which we do not have access due to the current political or technical difficulties. Pessimists contrarily claim that all giant oil fields were already discovered with great efforts in the past and there is little possibility to find new one in the future. The estimate of the peak of world oil production has been a very controversial issue. Though it has been discussed through various media, it seems that we have not yet reached a single reliable conclusion. Considering the seriousness and urgentness of this issue, it may be worth taking time to watch the information on the trend of world oil production which is readily available via Internet and other media. If the world oil production could continuously meet the increasing demand in the coming several years, we may have certain evidence which side of estimates would be the case.

The other important issue on the future oil production is the possibility of unconventional oil, tar sand and oil shale, which might be able to compensate the future deficit of conventional oil. Both optimists and pessimists agree that there exists a great amount of potential reserves, however; the estimates of the future contribution of unconventional oil to the world energy supply are still controversial. Optimists expect that the future supply of unconventional oil will significantly compensate the deficit of conventional oil. They forecast that technological development will be strongly promoted as the peak production of conventional oil approaches, and unconventional oil will become available with a reasonable price. Pessimists, on the contrary, argue that the technological development will not be achieved enough to compensate the deficit of conventional oil, and its future supply will be limited due to an economic reason, a high cost to extract the liquid oil, and an environmental reason, its high sulfur content. The key factor here is again a technological breakthrough. Continuous research would be required for a reliable projection of the future production of both conventional and unconventional oil.

4. Impacts of oil production decline: food supply of Japan

We reviewed IEA's projection that we will almost absolutely depend on oil as transport energy at least until 2030. We also discussed that it is possible that the world oil production would peak before 2030. If the world oil production would decline before we prepare alternative energy sources, the consequences will be definitely devastative to human societies. The possible impacts of the oil production decline differ from country to country. Some countries will seriously suffer from the decline, and others will suffer much less. By way of example, we discuss below the impacts of the oil production decline on the food supply of Japan.

The total primary energy supply of Japan was 520 Mtoe in 2001, and the contribution of oil to the total energy supply reaches almost a half of the total, 256 Mtoe [1]. The domestic oil production of Japan is almost neglectable in comparison with the total demand, and the oil self-sufficiency of Japan, in consequence, attained only 0.3% in 2001. Considering the essential role of oil in all end-use sectors and its small self-sufficiency, a decline of the world oil production would cause devastative impacts on Japan. The following sub-sections selectively discuss the impact of oil deficit on food calorie supply of Japan. Our interest here is to illustrate that the oil depletion will make the direct (i.e.

energy for production) and indirect (i.e. energy for transport) impacts on food supply of Japan.

4.1 Food calorie supply

The food self-sufficiency in calorie of Japan has continuously decreased from 73% in 1969 to 40% in 2002[8]. The average daily per capita calorie supply in 2002 was estimated as 2,599 kcal, and only 1,048 kcal was supplied from the domestic food supply. The total population of Japan in 2002 was 127 million, and the total food calorie supply of Japan is calculated as 12.1 Mtoe in 2002. Considering the self-sufficiency, we can estimate that 4.8 Mtoe was from domestic food supply and 7.2 Mtoe was from import food.

4.2 Energy for domestic food production and transport

The direct energy input in a domestic agricultural sector of Japan was estimated as 6.51 Mtoe in oil and 0.14 Mtoe in electricity, total of 6.65 Mtoe in 2001 [9]. The direct energy input mainly consists of the fuels for operation of agricultural machinery, dehydration, and heating, and does not include the indirect energy to produce and transport fertilizers and other agrochemicals such as pesticides and herbicides. Inoue [10] estimated that the indirect energy for the rice production in Japan was around twice the direct energy, and the vegetable production required the indirect energy one to five times the direct energy in 1995. Though the indirect energy varies with the type of agricultural products and managements, we roughly estimate here that the indirect energy is twice the direct energy. We therefore estimate the total energy input for agricultural production as 20 Mtoe in Japan.

The transport energy for domestic distribution of agricultural products in Japan may be estimated from the following statistics; (1) total energy for freight transport was 35.6 Mtoe in 2002 [11], and (2) the proportion of food products for total freight shipment in weight was 9.9% [12]. From these figures, we could roughly estimate the domestic transport energy of agricultural products as 3.5 Mtoe.

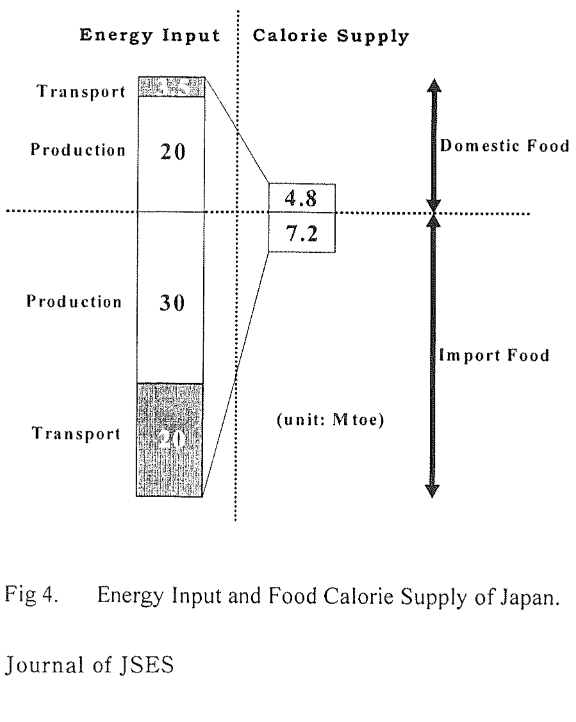

Fig 4. Energy Input and Food Calorie Supply of Japan.

4.3 Energy for production and transport of import food

It is not easy to estimate the total energy input for agricultural production in the countries which export food to Japan. Assuming that the energy input for agricultural production is proportional to the amount of calorie contents of the products, we approximately estimate the total energy input for the import food production in the exporting countries as 20 * (60/40) = 30 Mtoe.

Nakata [12] evaluated an environmental impact of food distributions, CO_2 emission through food transportation, in some countries in terms of "food mileage" that is calculated as a summation of the product of food weight and its transport distance for distribution. Nakata estimated the total of overseas food import of Japan as 58 million metric-tons and the food mileage of import food as 900 billion metric-ton· km in 2001. Assuming that transport energy by ship is 220 kcal/metric-ton/km [13], we approximately estimate that the total transport energy for food import to Japan was around 20 Mtoe in 2001.

Figure 4 presents the summary of energy input for food production and transport, and food calorie supply of Japan. This figure also shows a food energy balance between input (production and transport energy) and output (food calorie supply) of Japan. This figure may illustrate the unbalanced situations in Japanese food supply as the followings; (1) the total energy input for food production and transport was 6.1 times the total energy output as food calorie supply, (2) the food transport energy reached by 47% of the energy for food production, and (3) the energy for ship transport of import food took 85% of total transport energy. It should be noticed that the food transport energy took 0.67% of the world primary oil supply in 2001, 3,510 Mtoe [1].

5. Discussion

Even from this simplified discussion, we found a serious fragileness of the Japanese food supply which may be caused by an indirect effect, the transport energy deficit, rather than a direct effect, the food production energy deficit. We can conclude that the food transport energy plays an indispensable role to maintain the Japanese food supply. Even if we have alternative energy sources to compensate the oil deficit for agricultural production, we will not be able to attain a required food calorie supply without means of food transportation. We might experience hunger even though food is abundant somewhere in the world.

The 40% of Japanese food self-sufficiency does not necessarily mean that the agricultural productivity of Japan is essentially limited to supply only 40% of total food calorie demand. One of the major factors to continuously decrease the food self-sufficiency is the increasing proportion of fat and meat in the Japanese diet, which are mainly imported from foreign countries. A potential food-sufficiency of Japan may be estimated as follows. The arable land in Japan has continuously decreased from 6.1 million ha in 1961 to 4.8 million ha in 2002 [14]. Assuming that the potential arable land is 6.1 million ha, the area of arable land per capita is estimated as 4.8 a for the population of 127 million in 2002. Supposed that cereal calorie content is 3,000 kcal/kg and daily per capita food calorie supply is 2,600 kcal, it is estimated that 6.6 metric-ton/ha/year of agricultural productivity is required to sustain the assumed food calorie supply in Japan. Considering that average productivity of paddy rice of Japan was around 4.7 metric-ton/ha/year in 2003, it is not easy, if it is not impossible, to raise and maintain the overall agricultural productivity to 6.6 metric-ton/ha/year. It is considered that, therefore, food import will remain in the essential position to sustain the robust food security of Japan. We should also remember that the intensive energy input plays an essential role to maintain the current high productivity of the Japanese agriculture.

Since the Japanese food supply essentially depends on overseas food import and the transport energy is almost entirely fueled by oil, it is necessary for Japan to secure means of overseas transportation in order to maintain the food supply in the case of the possible oil shortage. In spite of the possible serious impacts, the alternative transport energy which could compensate the possible oil deficit is not yet well discussed. For example, IEA projected that the world transport energy will still depend on oil by 96% even in 2030 [(2)]. The above discussion suggests that we may have to review the direction of the research and technological development on the future energy resources in order to maintain the safety and security of our life. It is also obvious that the transport energy deficit will result in a devastative consequence not only to the Japanese food supply but also to any activities of human societies in the world which are based on the material trading. As an example, we may be able to predict the following impacts of the transport energy deficit on global food supply and demand; (1) instability of the global food trading due to surging transport costs, (2) shift of agricultural production from cash crops for export into energy crops for domestic energy demand, and (3) instability of a balance of domestic food supply and demand in many countries. These impacts may extend to an acceleration of natural gas shortage and an escalation of environmental degradations from the increasing coal or unconventional oil utilization.

It is a challenging task to develop a global transport network system driven by alternative energy sources which is globally distributable and have a large energy capacity. Such an alternative energy supply system on a global scale may be constructed by the Solar Power Satellites [(15)]. Though a proposal of detailed design of the system is beyond the scope of this paper, a distributed network of power receiving stations located on islands in the ocean to sustain long-distance ship transportation driven by the electric power might be an example system.

6. Conclusion

We have realized that explosive expansion of human activities, which are supported by a great amount of energy input, has led us to approaching limits of natural resource availabilities and the environmental capacity of the Earth. Since almost every aspect of the modern societies heavily relies on the fossil energy sources in a very complex and interrelated manner, it is not easy to forecast the overall impacts of the deficits. If we consider the impacts only from direct effects of the deficits, we may not be able to find solutions toward the sustainable societies to overcome the crisis. In this paper, we focused on the possible deficit of world oil production in the near future and its impacts on the Japanese food supply in order to illustrate that the transport energy deficit as an indirect effect of the oil deficit may cause a truly serious problem.

Academic communities of energy-related fields have often discussed about direct effects of natural resource deficits on human societies and proposed technological solutions to the problems. However, indirect effects of these problems may be more serious and urgent for human societies than direct ones in certain situations. We would like to emphasize the importance of considering not only direct but also indirect effects of these problems in order to find effective solutions. As these problems would become more visible, the general public would demand contributions of scientists in any scientific fields to overcome these difficulties. We hope that the discussion in the academic communities would open up on our possible contributions and prospective research directions for solutions toward the sustainability of human societies.

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