The Formation of Natural Gas Transportation Systems in the Northeast Asia

— From an Environmental and Economic Viewpoint —

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1. Introduction

Economic development threatens to bring about, or rather has already brought about many environmental problems in the Northeast Asia, a major part of which could be ascribed to much use and consumption of energy. In such circumstances, natural gas is attracting general attention as comparatively more eco-friendly than the other energy resources.

Its price, however, must be not necessarily lower than those of the other usual energy resources, that is to say, coal, oil, etc., judging from accompanying public investment for infrastructure that usually causes national contribution and load. Moreover, comprehensive transportation cost takes up a high percentage. The construction of reasonable transportation systems could reduce the cost and increase the use of natural gas, which leads to reducing the environmental pollution and disruption by energy consumption, and further, to contributing to economic sustainable growth by systematic, stable and environmentally sound supply of energy. Here, the thought of the "optimal natural gas transportation systems in the Northeast Asia" is to be discussed in the form of the rational combination of NG (natural gas) pipeline system and LNG (liquefied natural gas) tanker or carrier system, from economic and geopolitical viewpoint.

This paper is partly based on the invited report presented by the writer at the "United Nations Symposium on *Natural Gas Transport and Utilization in Northeast Asia*" held in Peking (Beijing), China, 4-6 December, 2000.

2. The Environmental Meaning of Natural Gas and its Transportation System in the Northeast Asia

The Northeast Asia is located in the middle latitude. There, westerlies caused by Coriolis effect are dominant and air masses usually move from west to east. For instance, an air mass moves in a few days from China to Japan. Moreover, winter monsoons blow from the Continent of Asia to Japan, ranging from late autumn to early spring. We often see yellow sand phenomena here in Japan in early spring, which are, of course, brought from the

Key Words :
eco-friendly energy resources, natural gas, NG pipeline, LNG tanker, natural gas transportation system

Continent of Asia. If the air over the continent is to be polluted by burning coal, the polluted air moves to Japan, bringing pollutants, and consequently the meteorological atmosphere covering Japan will be polluted. If the air contains SOx (sulfur oxide), NOx (nitrogen oxide) etc., acid rain could be brought about. That tendency is being enhanced by the economic growth of the Northeast Asian countries. One of the easiest way to resolve the problems is to arrange measures to demand that their economic growth should be checked to an extent, appealing to environmental reasons. That seems, however, not necessarily to be a happy choice, judging, for example, from recent mutual relations between Japanese and Chinese economy.

Japanese economy is now beginning to take a favorable turn. Japan owes that to China to a great extent. The recent great economic growth of China is exerting a positive influence on Japanese economy. When we exert a positive or negative effect on Chinese economy, it could rebound upon Japanese one. We should not neglect the reactive effect, and may as well observe and deal with the situation from the synthetic viewpoint.

Japan has developed a first-rate environmental technology. If it is to be offered to China, it will have the effect to decrease pollutants that might otherwise be brought over to Japan, and to remove the factors that might otherwise prevent Chinese economic growth possibly to contribute to Japanese economic growth as well. Moreover, environmental technology often coincides with energy conservation and resource-saving technology. The transfer of environmental technology from Japan to China contributes also to resource saving and sustainability of human society in the end.

On the other hand, energy resources or materials themselves must be examined and assessed in the above-stated context. Generally speaking, we can arrange coal, oil and natural gas according to how pollutive they are to the environment. Now in China, coal accounts for 75 per cent of energy sources in consumption. They are striving to expand the share of natural gas. However, there are some objective conditions to clear up in order to realize that aim. One of the most serious problems for the realization is the comparatively high market price of natural gas including social costs. The price is one of the most important factors to prescribe or determine the employment of natural gas. The lower the price is, the more natural gas is used, and the conditions of environment will get better so much.

The market price of natural gas is basically related to the market system and technical problems. The former is often conventional and varies according to the history and custom of each country or each region. It will take rather much time to make a reasonable restructure. On the other hand, the latter is comparatively easily and reasonably resolved. Among those technical problems, the one related to the transportation has an important meaning to integrate and systematize the major parts of the technology relevant to the use of natural gas, from the geopolitical and geoeconomical point of view. Recently, there is a conception to lay natural gas pipeline network to cover the major part of the Northeast Asia. The conception will much contribute to improvement of the environment of the area. In that relation,

the transportation problems will increase its importance. The Sakhalin-Japan pipeline project could form a part of the conception.

As to natural gas transportation, there is another way, that is, the one by an LNG (liquefied natural gas) tanker or carrier. So far in Japan, natural gas was imported from remote areas across the sea, that is, mainly from Indonesia, Malaysia, Australia and Brunei, and LNG tankers were exclusively used. Hence, the Northeast Asian comprehensive natural gas transportation system should be thought through the combination of NG pipeline system and LNG tanker service system. That whole system should be formed and reformed from the viewpoint of maximization of social welfare through efficiency, safety and environmental soundness.

3. The Costs of the NG Pipeline and the LNG Tanker

Here, transportation cost is to be discussed between the NG pipeline and the LNG tanker, referring to the geographical features of the Northeast Asia.

a. Transportation by the NG Pipeline and its Cost

The cost of transportation by the NG pipeline is ascribed to the following ones. One is related to their construction including that of boosting and pumping equipments. Once built, a pipeline itself is as durable as it could be said to be semi-permanent. If the pipeline is to be used semipermanently by continuing to repair and maintain, the cost relevant to the construction will consist of the sum of the everlasting interest including imputed one (generally akin to the German concept "Zusatzkosten" in accounting theory) on the construction cost possibly never withdrawn and everlasting reparation and maintenance expenses, which could be divided by the volume of natural gas transported during a certain term, in calculation of the final transportation cost per unit. Another is also the sum per volume of the general and administrative expenses for running the pipeline. The third is the land purchase cost or rent for the construction, which could be included into the construction-relevant cost. The forth is the value per volume of the loss of natural gas in the transportation. The major part of the transportation-relevant cost is the one relevant to pipeline construction itself.

In Siberia the steel materials of the pipeline must resist the severe meteorological atmosphere. It is pointed out that the NG pipelines laid out in the tundra zones have been damaged and natural gas often leaked out so far in Siberia. The pipes are apt to be embrittled in low temperature in addition to hydrogen embrittlement. Moreover, the pipes are apt to be distorted when the seasonally frozen topsoil melts and break. The chief ingredient of natural gas is usually methane (CH_4), and methane has greenhouse effect about 12 times greater than carbon dioxide. That effect is external diseconomy and comes to be a social cost. In order to defend against those incidents the steel material of pipes must be improved. Recently, special steel is being developed. Of course, the cost for that is to be taken into account in assessment as well.

Japan is remote from the Continent of Asia. If an NG pipeline is to be extended from the

continent to Japan, the extended part must be laid down on the sea bottom. The construction cost of a submarine pipeline has been rather higher than that of overland ones so far. Recently, however, the technology for the submarine construction has made much progress and the relevant technological knowledge and know-how has been accumulated. On the other hand, purchasing cost of land is negligible in this case, though land prices are generally high in Japan, but there is such cost as compensation for fishery rights. They are comprehensively assessed in the end. Finally, there comes to be selection between submarine NG pipeline and LNG carrier systems.

b. Transportation by the LNG Tanker and its Cost

The cost relevant to transportation by the LNG tanker includes liquefaction cost in the exporting country and regasification cost in the importing country besides transportation cost proper. The transportation cost proper consists of freightage, insurance and storage. Freightage is finally ascribed to the following costs and expenses. One is the construction and reparation cost, minus scrap value, of the LNG tanker and the interest to the whole investment including imputed one, divided by the cubic or thermal volume of natural gas transported during the life of the tanker, which is usually said to be 20 years. Precisely, the value of the scrap must be evaluated against the cost. Construction cost per term must precisely be distinguished from depreciation expenses. Another is the sum per volume of the variable cost including the fuel cost, the general and administrative expenses for navigation, of the shipping company or the gas or electric power company if it the owner of the tanker.

In Japan, LNG tankers have exclusively been used for import of natural gas as referred to earlier. Concerning the inland transportation in Japan, NG pipeline network has not yet been developed, which is rare in the other developed countries. It is said that the total length of Japanese NG pipelines is 1/140 as great as that of American and 1/20 as great as that of German ones. The greater part of natural gas is being transported by trucks in the form of LNG (liquefied natural gas) in Japan. Therefore, the LNG transportation system by combination of NG tankers and trucks has an important meaning in Japan, so far, and the stock or capital value relevant to that system could not be neglected. The major part of the stock or capital consists of LNG tankers, transportation and transportation-relevant facilities.

Liquefaction facilities (in an exporting country) and regasification facilities (in an importing country, Japan here) are the most important part of the transportation-relevant facilities. The cost and expenses are finally ascribed to the following ones. One is also the construction and reparation cost of the plants, minus scrap value and the interest including imputed one, divided by the volume of natural gas processed by the plants during their life time. Another is the sum per volume of the cost and the general and administrative expenses for their operation.

The liquefaction plant is usually run by the companies in the LNG exporting country. Liquefaction cost partly depends on the relevant technology of the exporting country, and partly depends on the operating rate of the

liquefaction facilities, and the price of the natural gas in the exporting country, in turn, partly reflects the liquefaction cost there.

Regasification in the importing country could be used for power recovery from LNG or power generation "combined with regasification", production of liquid nitrogen, oxygen, argon, carbon dioxide including dry ice, refrigeration in the ultra-low temperature warehouse, etc., as outgrowths with LNG regasification. If, in the Northeast Asia, liquefaction and regasification are economically and technically closely to be combined to each other across the Sea of Japan, new employment could be induced in the Japan Sea Rim areas.

Finally, above-mentioned costs and expenses are to be aggregated, and coordinated by adding the negative value per volume of the loss of natural gas in transportation and regasification. In addition, the natural gas lost away into the air causes a greenhouse effect, which brings about a social cost as external diseconomies. The loss in liquefaction could be considered by the companies in the exporting country. The value of the coordinated, aggregated costs and expenses could be the finally assessed cost per volume of transportation by an LNG tanker. It reflects on the price of natural gas in the imported country. In the end the price of natural gas in the imported country consists of the original price of natural gas itself in the exporting country which contains liquefaction cost, the above-mentioned transportation cost, regasification cost, the distribution cost in the importing country and profit, per volume unit. From the social or national viewpoint, social cost of the relevant infrastructure construction and maintenance must be taken into account.

4. The Comparison of NG Transportation Costs between the Pipeline and the Tanker

So far, the transportation cost of natural gas has been discussed theoretically and abstractly. One important point is in what range to think the constituent elements of the transportation cost are. Actually it is difficult to find the examples of the assessment of transportation cost strict to the theoretical one, but it is necessary to compromise with the present actual state of affairs to an extent for the time being, though a more theoretical assessment must been made in future. Some actual examples seem to be fundamentally based on that, not so theoretically strict. Here, the comparison of the transportation costs is to be made between the NG pipeline and the LNG tanker, adopting one of such concrete examples, and the following examples are to be considered and discussed on.[1)]

The transportation costs, of course, vary according to the distance, whether an NG pipeline or LNG tanker.

(1) $y = 0.45x + 0.54$ the low cost NG pipeline
(2) $y = 0.81x + 0.95$ the high cost NG pipeline
(3) $y = 0.078x + 1.88$ the LNG tanker

y : $ per Mbtu (million British thermal unit)
x : thousand kilometers

The constant in the right side of the equation means the largeness of fixed cost. The fixed cost of the LNG tanker transportation is larger than that of the pipeline transportation.

That suggests that the cost of the tanker itself is high and the equipments at the ends or terminals of the LNG tanker transportation route such as the liquefaction and regasification plants cost more money relatively. In contrast, the equipments at the ends of the pipeline transportation route cost less money relatively. In tanker transportation, of course, the longer the distance is, the less the rate of the equipment load per distance unit gets.

The coefficient of x means the rate of cost increase according to increase in distance. The coefficient of the NG pipeline is larger than that of the LNG tanker. That suggests that the transportation cost of the pipeline increases more abruptly according as the distance gets longer. In contrast, that of the tanker increases not so abruptly. In other words, the marginal cost of the pipeline is always larger than that of the tanker. So, the tanker transportation is more advantageous if the distance is long enough.

5. The System of Natural Gas Transportation in the Northeast Asia

The advantage of the long-distance transportation by the LNG tanker is a reason that Japan can import and has been importing, natural gas from the Southeast Asia, the Middle East, Australia and Alaska, not from Russia. The natural gas exportable areas in Siberia and Kazakhstan are far from Japan and there exist lands or terrestrial parts between them and Japan. Consequently, Japan has chosen and adopted the natural gas exporting areas from which LNG tanker transportation is available. Sakhalin alone is near to Japan as natural gas exportable area in Russia and there exists no land between it and Japan. So, Japan has been interested in Sakhalin, and the plan of constructing a pipeline between them, as the distance is short from Japan.

Thinking about the development of the Northeast Asia in future, it is necessary for Japan to cooperate economically and technologically in the development of natural resources including natural gas. That is closely related to Japanese interests in utilizing Russian natural gas at present. So, it is necessary that such a route as the above-mentioned NG pipeline should be developed, so that Japan may use the Russian natural gas, which would lead to or give an opportunity to, Japanese commitment and technical and financial cooperation in development of natural resources at large in the Northeast Asia.

A problem left is which is better, the transportation by a pipeline or that by a tanker. The route from any inland NG drilling part of the Asian Continent to any Asian Continental point including a port on the coast of the Sea of Japan, the East China Sea or the Yellow Sea could not be any other than the pipeline. The very problem is about the distance between those points there and the points on the coast of Japan.

Here, the equations (1), (2) and (3) mentioned in the preceding section are to be considered again. It is necessary to clarify the diverging point of advantages and disadvantages. The diverging point is shown by the intersecting point between any two equations. The coordinate of the diverging point between the equations (1) and (3) is the point (3.6, 2.16), which means that, if the distance is shorter than 3.600 kilometers, the low cost pipeline is more

advantageous than the tanker, and that, if the distance is longer than 3,600 kilometers, the tanker is more advantageous than the low cost pipeline. Likewise, the coordinate of the diverging point between the equations (2) and (3) means that, if the distance is shorter than 1,270 kilometers, even the high cost pipeline is advantageous than the tanker, and if the distance is longer than 1,270 kilometers, the tanker is advantageous than the high cost pipeline.

The distance between Vladivostok in Russia and Niigata in Japan, for instance, is 850 kilometers, that between Pusan in Korea and Fukuoka in Japan is 240 kilometers and that between Talien (Dalian) or Tsingtao (Qingdao) and Fukuoka is 1,000 kilometers each in a straight line. These distances are all within the reach to the diverging point, judging from which it seems that the pipeline is more advantageous there, especially between Korea and Japan.

It is necessary, however, to consider this problem from another point of view. Indeed the distance itself between Korea and Japan is short, but the natural gas transported, for instance, to Fukuoka by the pipeline must again be transported to Osaka, Nagoya, Tokyo, etc. and Fukuoka can not be the terminal from economical viewpoint, as the investment in the construction of subsea or submarine pipeline might be not so small, somewhat higher than usual. The distance between Fukuoka and Tokyo is 1,000 kilometers. It is more advantageous to cover those distances by tanker transportation or navigation right through. It takes much time and much money to secure land for pipeline construction in Japan. If so, it could be said that it is better to cover the total distance right through among Korean coastal points, Tsingtao (Qingdao), Vladivastok, Fukuoka, Tokyo, and so forth, by tanker transportation or navigation system in a circular tour, for the time being, which could make the total distance longer enough across the above-mentioned diverging points, if systematically well connected.

From the long-term viewpoint, however, a pipeline system might get preferable there. That depends upon the future development of the technological, economical and geopolitical conditions. Actually, the technology relevant to the subsea pipeline is making progress recently, which will reduce the cost of its construction, and the thought of practical use of highway grounds for pipelines is generally being recognized in Japan, which will save the time and money for the purchase of land. It is necessary to combine and unite the long-term projects and the short-time ones optimally from economically and econometrically rational, reasonable viewpoint, basically to optimize natural gas synthetic transportation systems and subsystems from the sustainable viewpoint of the maximization of the long-term social utility in the social welfare function.

On the other hand, liquefied natural gas is convenient for storage, and its new combined usages have been found and developed as if they were two-birds-one-stone solution. Among them, there are numerated the production of liquefied nitrogen, oxygen, argon and carbon dioxide including dry ice, the refrigeration in the super-low temperature warehouse, the power recovery from LNG or power generation combined with regasification, etc. as outgrowths

with LNG regasification. Moreover, the relevant technology of the tanker, regasification and liquefaction plants is now rapidly making progress, which is expected to contribute to reducing substantially LNG transportation costs in future. The consideration is also necessary about such a state of affairs. In the end, a comprehensive, synthetic thought of the systematic complex of spatial-temporal subsystems might be important.

6. The Optimal Path of NG Transportation in Relation to Local Economic Effects

The relation between the transportation costs and the distance has been treated as linear so far. Actually, the state of affairs is rather complicated about the relation. Here, the model is to be set up more extended form according to the actual state of affairs and to the thought of transportation system in a non-linear tour.

First, the distance is assumed between a port of the Asian continent and a terminal point of Japan, for instance, Tokyo. The distance is to be covered by either NG pipeline service or navigation of LNG tanker. The demand of natural gas in Tokyo is assumed to be fixed. Natural gas (NG or LNG) can be supplied at anywhere on the way. Here, the supply is assumed to change continuously. The object is to maximize the difference or value between the nationwide total gains and the nationwide total transportation costs, relevant to this natural gas transportation and supply. By the way, the word 'nationwide' suggests that the effects of a natural gas supply could be nationwide, considering indirect and repercussion effects.

Here, a functional and calculus of variations are applied to the model.

$$u = \int_0^T p\left(t, x, \frac{dx}{dt}\right) dt \; ; \; p\left(t, x, \frac{dx}{dt}\right) = r\left(t, x, \frac{dx}{dt}\right) - c\left(t, x, \frac{dx}{dt}\right)$$

where u stands for the total difference or net gains covering the entire distance, p for the gains of the points on the way or the terminal which are assumed to be continuous, t for the distance from a port of the Northeast Asian Continent, x for the quantity of LNG supplied, r for the gross gains or revenue that, of course, includes the gains from power recovery from LNG, etc. as outgrowths, and moreover, gains from the direct and indirect economic effects, or the repercussions of LNG supply, which will increase in future. c stands for transportation cost. As the final procedure, the maximization of u is sought. [2)]

Here, the forms of the functions contained in the equations must be determined and the conditions for the functions must also be examined, in order to apply them as a tool to econometrical analyses. That is to be committed to another opportunity, as that is not the main theme of this paper. Next, the relation between demand and supply needs to be discussed. The distribution of natural gas on the way depends on its industrial actual and potential demands. The latter case means that there basically exists consumption goods demand and potential capital goods demand for their production could be touched off every moment, and the natural gas supply will provide the convenience to purchase it advantageously and actually trigger the capital goods production for the input induced. The natural gas transportation route should be set up, so that the optimal path may

maximize the "total gain aggregated from each economic effect on the way in its maximum," as referred to in the preceding discussion.

Moreover, economic repercussion is caused by the construction and maintenance of the NG pipeline, and its relevant facilities and infrastructure. The repercussion effects might be larger with LNG tanker transportation system than with NG pipeline transportation system. Those matters should be taken into account, too.

7. Economic Effects of LNG Tanker in the Northeast Asian Economic Region

From an extended viewpoint, the LNG tanker transportation system seems to have relatively more effect of inducing new industries along its route and a great meaning related to the whole Northeast Asia. In other words, new investment could be induced on the way of tanker transportation.

Concretely speaking, a tanker loaded with LNG (liquefied natural gas) leaving, for instance, a port in China or the Tumen River triangle zone is to cross the Sea of Japan and to reach a Japanese port. The natural gas transported there is further to be transported to Tokyo and Osaka. In the Tumen River triangle zone and in the zones around the ports on the coast of the Sea of Japan, new industries could be induced, the natural gas brings about added value there and the associated infrastructures could be formed there, those economic effects should not be neglected.

More concretely speaking, liquefaction of natural gas is necessary for LNG tanker transportation. The construction of a liquefaction plant needs a huge amount of investment, which induces associated heavy industries in the exporting country through the construction and ex post facto maintenance and reparation. The regasification of LNG is necessary in the importing country, for instance, in Japan. Regasification could bring about, at the same time, power generation combined with regasification, production of liquid nitrogen, oxygen, argon and carbon dioxide including dry ice, and refrigeration in the ultra-low temperature warehouse, as mentioned earlier, which could form a new industrial zone around the ports on the coast of the Sea of Japan. If so, the liquefaction in the exporting country is to perform a part of, for example, combined power generation, liquid nitrogen production, etc. which leads to regional cooperation, creation of employment and, in the end, mutual prosperity in the Northeast Asia, from the large-scale viewpoint.

From the long-term viewpoint, however, a considerable part of LNG tamker system might be replaced by NG pipeline system according to the changes of technological, economic, political, institutional and legal state of affairs. From that viewpoint, the two systems must optimally complement each other, and the balance between them that will maximize the regional social welfare should be thought elastically in time series and at a long-term economic efficiency.

8. Natural Gas Investment and Regional Economic Cooperation in the Northeast Asia

As for investment, there are private one and governmental one. Private investment is, of course, conditioned by how profitable the object

of investment is. First, the investment in natural gas must be more profitable than the ones in the other energy resources and that must be clear to the investors, and the government must create the conditions for that. A discussion is to be raised mainly according to the cases in Japan. It is necessary to reform the conventional distribution structure, to exclude the administrative prices, to reform the commercial usage or trade custom and to make the market freer and more competitive, in order to lower the domestic price of natural gas. From larger-scale viewpoint, it is also necessary to reduce the import cost, for instance, through adoption of swap trades method among several countries.

Next, if the tanker transportation system is to be adopted for the expanded demand of natural gas, local industrial zones are apt to be formed around the ports. Moreover, the construction of the infrastructures for the ports and the industrial zones is also induced. That is the same, for instance, with the Tumen River triangle zones. It will give opportunities for private investment.

Japanese economy has already reached a maturity stage and the demand-creating Keynesian policy is not so effective as in the past. A new element is sought to induce new investment and to create social demand. The increase in import of natural gas and the formation of the tanker transportation system for it, home and in the near foreign countries will contribute to that purpose, through repercussion effects. Finally, those economic effects should econometrically be analyzed.

From the perspective of the Northeast Asian economic region, the economic development of any part of the region will contribute to that of each other. This recognition will urge the government's investment or finance, including ODA. The government could assist the domestic corporations that invest abroad and give a loan to the foreign countries of the region. The happy economic policy will create new social demand and new investment also in any part of the whole Northeast Asian region.

Of course, the pipeline system has its own merit. The policy is necessary to make the most of the merits of both pipeline and tanker transportation systems. Roughly speaking, pipelines are thought to be effective among China, Mongolia, the Democratic People's Republic of Korea, the Republic of Korea and the Far East of Russia, and the tanker transportation system is thought to be more effective between them and Japan for the time being, unless between Sakhalin and Japan. It is, however, necessary at the same time to continue to discuss the possibility of submarine pipelines between them and Japan, too, according to the expected development of technology and the expected change of the economic conditions. Finally, the large-scale and long-term project is necessary of the Northeast Asian economic region. For that, it is necessary to further the economic and econometric analysis and research and to make the accurate input-output tables of the whole Northeast Asian economic region in future.

9. Financial Problems in the Formation of Transportation Systems in the Northeast Asia

At present, Japan is thought to be the country that is the most feasible for cooperation in funds for the formation of the transportation

systems in the Northeast Asia, considering its positive achievements so far in ODA activities, and the like. So, the financial state of affairs in Japan is to be considered in the first place.

The construction of an LNG tanker does not so frequently occur. So, it is necessary to observe the cases over a considerably long period of time. Among the major examples of financing the construction or purchase of the LNG tanker or carrier, we find the former "Development Bank of Japan" (now merged into "Mizuho Financial Group"). The constructed LNG carrier is sometimes owned by a single corporation and sometimes owned by plural corporations jointly. There is, however, no national special finance for them, whether the applicant is an LNG shipping company, a gas supplier or an electric power company. The financing conditions for them are fundamentally the same as in the other financing cases. Next, the state of affairs in the case of the Development Bank of Japan is to be discussed more concretely and more detailedly.

The condition or premise for financing has been the existence of the contract for purchase of the LNG carrier to be constructed. There the financing rate is 40～60% of the contract amount. The amount of finance is not limited and is decided case by case. The loan term is not limited, either, but the contract of 15 years is common in the case of those matters in Japan. In this case the interest has usually been fixed 2.25 % recently. The loan amount is left unredeemed for three years and afterwards paid off in installments usually spread over 12 years, that is, the loan term is usually 15 years as a whole.

Most of Japanese LNG buying corporations have usually been making contracts for about 20 years with foreign LNG selling corporations. Both of this contract term and the above-mentioned loan term, which is a little shorter than the former, are often said to be originally based on the 20 years life term that has usually been thought to be effective so far, of the common LNG tanker, and the term is also thought to be appropriate for stable LNG supply. By the way, the life of the LNG tanker is getting longer and longer according to the development of the technology of LNG tanker construction. On the other hand, there is appearing the tendency that the long-term contract is partly being replaced with the shorter-term one regarding Japanese buying corporations.

An example of the percentage per item of the LNG tanker costs and expenses is shown below.[3)]

1) Liquefaction plant (nominal processing capacity : 1,000 MMcf/d)		(22%)
details	direct construction cost	<17%>
	spare stock, design cost, royalty	< 2%>
	management expenses, interest	< 3%>
2) Tanker (transportation distance : 6,6oo miles)		(66%)
3) Regasification plant (nominal processing capacity)		(12%)

The percentage of liquefaction plant construction cost is rather great among the LNG transportation costs and expenses.

Most Japanese natural gas buying corporations directly buy liquefied natural gas (LNG), and do not concern themselves in natural gas liquefaction itself. Natural gas liquefaction plants are constructed by the international oil or energy companies, the native or national capital corporations or joint enterprises

between them. In the case of the native or national corporations especially in developing countries, the fund for the construction sometimes comes to be in short supply, and that brings on finance problems. Japan as a developed country is backward in financial help to the developing countries for NG liquefaction plant construction.

A reason for that is the great dependence of Japan on oil or petroleum so far. Now, the Japanese government is under pressure to change its policy also from the environmental viewpoint. Of course, natural gas is environmentally more sound than petroleum. The government can not but turn its attention to natural gas more earnestly than before, and the circumstances will become favorable for the investment in natural gas development including the NG liquefaction plant construction. The Japanese government could come to give financial help directly to the developing countries, including ODA, if it is to recognize and understand that the financial help is consequently to serve the interest of Japan, through positive boomerang effects. The concept of development of the Northeast Asian economic region will contribute to enhancing that tendency.

On the other hand, the Asian Development Bank (ADB), the International Bank for Reconstruction and Development (IBRD) or the International Finance Corporation (IFC) could finance the corporations in the developing countries for NG liquefaction plants construction and finance the governments there for the relevant infrastructure construction for liquefaction plants and shipping points for LNG, judging from long-term perspective. As for the financing problems all-round consideration is necessary.

10. Conclusion

Here, the matters stated so far are to be put in order and reconfirmed with some supplements, and the matters to be study in future for more theoretical development will be made clearer.

Natural gas is environmentally the soundest among energy resources, and important also as chemical industry basic material. Moreover, it could be used as material of hydrogen for a fuel cell car, which is attracting public attention from the environmental perspective recently.

Natural gas so promising has some problems to resolve, on the other hand. Transportation is one of those most important problems.

As for transportation one is how to choose the optimal natural gas transportation route. It is determined in the form of adopting the feasible route that brings about the greatest "gain in its maximum", which has been mentioned in p.59. In order to put the model closer to reality, it is necessary to determine local functions between an investment and its economic effects, based on econometrical analyses, utilizing also local input-output analyses. That is left for the future study.

Another is how to combine NG pipeline system and LNG tanker system to organize Northeast Asian natural gas transportation system as an articulated self-contained, self-integrated whole system. This matter is closely related to technology[4] and its development in future.

The third is financial problems stated just

above. Those are closely related to politics, especially geopolitical relations in the Northeast Asia and the whole international political ones.

Notes

1) Those equations have been made from the data of Fig. 1-4, in *The Symposium on Natural Gas Pipelines*, the Japan Institute of Energy, 1998, p.24. The original of the data seems to be in *Natural Gas Transportation*, IEA/OECD and Jensen Associates, Inc., 1994.
2) The famous 'Euler's equation' will give a hint.
3) Japan Institute of Energy (Transport Subcommittee, Natural Gas Section), *Comprehensible Natural Gas—All about New Energy Resources—*, Korona-sha, 1999, p. 53.
4) ibid. cf. pp. 70-72, 74, 55 et seqq., 89 et seqq. (esp. as to LNG tanker).

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(2004年 8 月 2 日 寄稿受理)

The Formation of Natural Gas Transportation Systems in the Northeast Asia

— From an Environmental and Economic Viewpoint —

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In the Northeast Asia, where environmental pollution and disruption are prevailing as a result of rapid economic growth, natural gas is attracting general attention as one of the most eco-friendly energy resources recently.

Its actual and substantial unit cost or price including social one is, however, not necessarily lower than those of the other energy resources, judging from the accompanying public investment for environmental security and infrastructure. Especially, the comprehensive transportation cost takes up a high percentage. The construction of reasonable and systematic transportation systems could reduce the cost

and stabilize the supply, which increases the utilization of natural gas, leading to the realization of the so-called " sustainable development" of the society. Hence the thought of the "optimal natural gas transportation systems in the Northeast Asia" in the form of the reasonable combination of NG (natural gas) pipeline system and LNG (liquefied natural gas) tanker system, from the economic and geopolitical viewpoint.

The discussion here is limited to the first approach from that viewpoint. The exact model building and the extension to econometric analyses are committed to another opportunity.