



THE JAMES A. BAKER III  
INSTITUTE FOR PUBLIC POLICY  
OF  
RICE UNIVERSITY

NEW ENERGY TECHNOLOGIES IN THE NATURAL GAS SECTORS:  
*A POLICY FRAMEWORK FOR JAPAN*

UTILIZATION OF NATURAL GAS IN JAPAN: TRENDS AND CHALLENGES  
SUMMARY REPORT BY THE PETROLEUM ENERGY CENTER OF JAPAN

HIROSHI HASUIKE  
*DEPUTY DIRECTOR, RESEARCH AND DEVELOPMENT DIVISION  
THE INSTITUTE OF APPLIED ENERGY*

AKIRA MIYAMOTO  
*SENIOR RESEARCHER, RESEARCH INSTITUTE FOR CULTURE, ENERGY AND LIFE  
OSAKA GAS CO., LTD.*

EISUKE MUTO  
*SENIOR RESEARCHER  
PETROLEUM ENERGY CENTER*

YOSHIKI OGAWA  
*GENERAL MANAGER, THE SECOND DEPARTMENT OF RESEARCH  
THE INSTITUTE OF ENERGY ECONOMICS, JAPAN*

PREPARED IN CONJUNCTION WITH AN ENERGY STUDY SPONSORED BY  
THE CENTER FOR INTERNATIONAL POLITICAL ECONOMY  
AND  
THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY  
RICE UNIVERSITY – NOVEMBER 2001

## **Introduction**

The utilization of natural gas in Asia, which is located far away from large gas fields, was first introduced through the liquefaction of natural gas and the importation of the product by sea. This pattern contrasts with the U.S. where abundant natural gas fields can be found in nearby locations and the use of natural gas as an energy source has been in place for a relatively long time through pipelines. Liquefied natural gas (LNG) prices to Asian markets have generally averaged about 40% higher than Western prices where pipeline gas is sold under competitive terms.

Through technical innovation and development of new supply methods, the natural gas supply-and-demand structure in Asia is showing signs of change. Firstly, costs have been reduced through technical innovations involving the production of LNG. Construction of new plants is rapidly increasing, and more competition is expected in this market. Secondly, with the progress made in liquid fuel manufacturing technologies, it is possible that liquid fuels can be commercially manufactured from gas fields and sold in end-user markets. Thirdly, falling costs for construction of long-distance gas pipelines has raised the possibility of new transnational natural gas pipelines in Asia.

This report explores the environment surrounding natural gas in Asia and lays out the options that are becoming available to Asian consumers. In particular, this inquiry investigates how emerging technologies in LNG, Gas to Liquids manufacturing, DME processes, and Methanol conversion may impact development of Asian natural gas markets. Finally, discussion addresses the impact pipeline gas will have on the Japanese and other Asian markets for natural gas.

## **Natural Gas Supply and Demand Trends in Asia**

Energy demand in Asia (including Japan) is expected to increase at a rate of around 4% per annum until 2020 from 2.35 billion tonnes of oil equivalent in 1999 to between 5.2 billion and 5.8 billion tonnes of oil equivalent in 2020. This growth will increase Asia's share of world

energy demand to 35.37% by 2020, up from 24.5% in 1999.

Asia has lagged behind other regions in the utilization of natural gas. The use of natural gas as an energy source in Asia in 1999 was 10%, which was substantially lower than the world average of 23%. However, natural gas is expected to play an increasingly large role in meeting rising Asian energy demand given the priority of environmental conservation now emphasized by many Asian governments. On the supply side, a series of large-scale LNG projects have been initiated, and it is currently forecast that the world's supply capabilities until 2020 will exceed demand despite its growth.

It is anticipated that governments will intervene to promote the wide spread utilization of natural gas in Asia to meet both environmental needs and supply requirements. Even in Japan, where energy consumption is not expected to increase substantially, emphasis will be placed on expanding the natural gas use in ways that are economical. Such a policy fits policy goals of energy security, rational price formation and environmental protection. In China, where coal is currently the focal point of the national energy strategy, the construction of natural gas pipelines running across the country from east to west has already begun and is considered a high priority in China's energy and economic development strategy.

#### *Current State of Affairs Regarding Natural Gas Resources and Modes of Supply*

Proved natural gas reserves are increasing at a faster rate than oil reserves. In 1970, proved natural gas reserves were 48% of those of oil, but in 2000 the rate reached 101%, surpassing that of oil (equivalent to 65 years of supply at the level of demand in 1999). While global oil reserves are highly concentrated in the Middle East at 65%, natural gas reserves in the region comprise 34% of overall capacity, while the former Soviet Union contains 39% of global gas reserves. Gas reserves in the Asia and Oceania regions, on the other hand, account for slightly less than 8% of the global gas reserves.

About 40% of the natural gas fields in these latter two regions are small and medium-sized fields

of less than 3 trillion cubic feet (Tcf) each. In addition, offshore gas fields comprise 60% of all of the Asian and Oceania gas fields. There are only a few LNG plants being used effectively at small and medium-sized gas fields in Asia today. The technical development of small-scale floating-type LNG plants or liquid fuel manufacturing plants could enhance commercial development of these smaller fields.

LNG imports are the primary mode of supply in Asia (particularly Japan, South Korea and Taiwan) but had played a smaller role in the U.S. and Europe. However, increasingly, LNG businesses are developing in Atlantic Basin markets, raising the proportion of LNG supply being sold in the U.S. and Europe. LNG may also be introduced to new markets in Mexico and Brazil. It is expected that the LNG supply capabilities will exceed Atlantic Basin demand by 2010, changing the structure of LNG markets and trade. Large-scale LNG plant construction for the Asian market is also expected to exceed estimated demand. It will have a supply potential of between 3.8 to 4.3 Tcf in 2010, of 2.7 Tcf in 2015, and 1.0 Tcf in 2020. The expected surplus in Asian gas supplies is spurring an interest in the development of other technologies for utilizing this gas, including gas to liquid (GTL) and dimethyl ether (DME), that do not compete with LNG.

#### *Current State of Affairs Regarding Natural Gas Prices*

Since natural gas supply and demand is fixed, prices have differed considerably depending on the market characteristics of each region. In Europe, fuel competition has focused on low-sulfur (LS) heavy oil, among other fuels, and gas prices trend with this fuel. In the U.S., gas on gas competition has intensified since the 1980s when there was a rapid increase in the development of domestic gas spurred by the elimination of price controls. As a result, prices of domestic pipeline gas and of imported pipeline gas from Canada developed at levels substantially below the equivalent value of high-sulfur (HS) heavy oil, and LNG prices have followed suit.

On the other hand, LNG prices for the Asian market are determined by a formula that is linked to crude oil prices (equivalent value of crude oil: average price of about \$3.5/mmbtu in the 1990s).

Asian prices have ranged about 40% higher compared to the equivalent value of heavy oil in Europe and spot natural gas values in the U.S. (about \$2.5/mmbtu). High Asian prices reflect a market structure where buyers had to cover large initial investments made for LNG manufacturing plant and equipment. However, although LNG construction and operational costs have declined, Asian LNG prices have not yet followed suit. In fact, there is even a tendency to add an environmental premium to LNG prices in the region.

### **Technical Innovation of LNG**

Because construction of LNG plants requires considerable initial investments, a “take or pay” provision (a stipulation that obligates the purchase of a certain amount of LNG and payment before shipment) and long-term fixed price setting have been adopted in Asia. However, with the recent development of innovative technologies, LNG costs are clearly declining.

Specifically, the upsizing of plant and equipment and fuel economization are worth noting. At the beginning of the 1980s, LNG trains had a capability of between 1 million to 1.5 million tonnes. Recently, LNG trains have been upsized to a capability of between 2.5 million to 3 million tonnes. Through upsizing and fuel economization, construction costs and transportation costs of LNG ships have also been reduced. As a result, liquefaction costs of LNG have been reduced by 33%, construction costs of LNG ships by nearly 50%, transportation costs by 40%, and regasification costs by 20%. Therefore, the current LNG supply costs have declined by at least 30% compared to the level in the 1970s (according to data provided by Shell, the reduction is estimated at 55%).

With this cost reduction in mind, new LNG projects initiated in Africa and Central and South America for the European and the U.S. markets are expected to compete with the equivalent value of heavy oil despite intense competition with pipeline gas. Even if much of the cost reduction can be attributed to the efforts made by suppliers, still Japanese and Asian buyers cannot be justifiably asked to continue to purchase LNG at prices that are well above the standard prices of LNG in the rest of the world. During the revision period of the second round

of a long-term contract, a price setting method that takes into consideration the world market conditions should be introduced. The number of suppliers that one can choose from should also be increased to encourage price competition.

Among technical innovations that may increase the number of LNG supplier options, “compact LNG,” “floating LNG plants,” and “regasification terminals aboard ships” are noteworthy. Compact LNG and floating LNG are downsized, movable LNG plants that will promote a reduction in delivery time periods and overall costs. Their maneuverability should contribute to the development of small- and medium-size gas fields in Asia. For regasification terminals aboard ships, an LNG tanker is remodeled to allow regasification onboard the tanker. They may minimize costs for building reception bases and for situating reception points more flexibly.

### **Liquid Fuel Manufacture and Other New Technologies for Natural Gas Utilization**

If technologies for converting natural gas into liquid fuels at gas fields at reasonable costs are developed, they would significantly change the fuel supply and demand structure involving the replacement of petroleum fuels from the point of view of the growing concern for environmental conservation. In particular, petroleum fuels such as gasoline and light oil have virtually prevailed as the primary transportation fuels because of the convenience of storage and transportation. It is preferred that transportation fuels take the form of liquid kept at ordinary temperatures. If natural gas can be imported after converting it into ordinary-temperature liquid fuels, the use of gas in this area would substantially increase.

In Asia, there is also a particular need for liquid fuels manufactured from natural gas. Oil demand in Asia is expected to almost double from 17.58 million barrels a day (b/d) in 1996 to 34.99 million b/d in 2020. Of this, the increase in the middle distillates such as light oil is expected to be 6.26 million b/d. This boost is significantly larger than an expected increase in heavy oil of 2.41 million b/d, and it is thought that the increase in demand will be tilted heavily toward middle distillates. Therefore:

1. The level of Asia's dependence on the Middle East for oil imports is very high -- between 80 to 90% -- and to depend solely on the unstable Middle East for future demand, which is expected to double -- would be a serious energy security problem. There is a need for varying the distribution of primary energy sources where possible.
2. Oil refineries in Asia's developing regions are mainly toppers, and such regions are lagging behind in introducing secondary devices such as hydro-cracking units. Additional costs will be required for taking measures against the rapid expansion of demand for middle distillates. Liquid fuels originating from natural gas could become a promising option.
3. Regulations on automotive exhaust gas emissions are steadily being tightened, and costs on petroleum fuels for responding to this situation are steadily rising. Natural gas based liquid fuels do not contain sulfur or aromatic hydrocarbon, and in this respect they have a competitive edge. It is also a beneficial option for Asia's developing countries where environmental degradation is a concern as they prepare themselves for full-scale industrialization and motorization.
4. Liquefied petroleum gas (LPG) is a fuel that is indispensable for consumer use in rural areas of Asia where the required energy supply infrastructure has not been prepared. LPG, however, is relatively expensive. Its prices are subject to large fluctuations and it has significant influence on people's lives. This is because the Middle East maintains a strong influence on LPG supply and price formation, a role that is even more powerful than its impact on crude oil supply and pricing. Therefore, there is a need for a fuel option that can directly replace LPG.
5. The average number of years of recovery from natural gas fields in the Asia and Oceania regions is 37. Many of the gas fields, however, are of small and medium-size and are not suited to LNG production, which requires large-scale investments, and they have not been used effectively. Liquid fuel manufacturing plants do not need to be

large scale and are an effective option for using nearby gas fields.

The above are reasons why the technical innovation of GTL, DME, and other liquid fuels manufactured by using natural gas as a raw material is eagerly anticipated, particularly in Asia. We will examine the state of development of these liquid fuels below.

### GTL

GTL is an ordinary-temperature, hydrocarbon, liquid-fuel that is synthesized by mixing CO and H<sub>2</sub>. Its properties make it a suitable replacement for petroleum middle distillates such as light oil, kerosene, and jet fuel. Because it does not contain sulfur, nitrogen, aromatic substances, or heavy metals, its properties are extremely suited for zero pollution emissions, unlike present automotive fuels. In particular, there are strong expectations for replacing the light oil used for diesel cars, as low sulfurization is to be adopted ahead of the original schedule of around 2005. Light oil will be modified to meet this regulation by ultra depth desulfurization, and GTL will face cost competition with this. It is believed that GTL will not have any problem being used in existing engines either singularly or by mixing it in light oil, and because smoke emissions will be small, it can improve the output performance.

GTL barely contains any aromatic substances and is suited as a jet fuel oil because it has a high level of combustibility, good engine start-up properties, and little risk of blowout. As a replacement for home-use kerosene, its properties, which include a high level of complete combustion, are well suited as GTL reduces air pollution and odors inside buildings.

Regarding the development of synthesis technologies, Sasol (South Africa) commercialized a synthesis method from mixed gas using coal as a raw material in 1955. Later, Shell (Malaysia) and Exxon (the U.S.) carried out the development of synthetic technologies from natural gas and have commercialized some of those technologies. The companies have announced that they will not make their patents public. From 2001 to 2003, other companies are planning to build four demonstration and commercial plants that use different methods. In Japan, a six-year



technical development project, commissioned by Japan National Oil Corp., was undertaken in 1998.

The distribution infrastructure of GTL fuels will not be a problem because the existing facilities used for petroleum products can be used without modification. A rapid increase in the use of GTL can be expected when significant production amounts are achieved by improving on manufacturing costs. For the mid-term, it will be of significance in replacing middle distillates from petroleum with fuels manufactured by using natural gas and coal as raw materials.

Let us examine this more specifically from the viewpoint of costs and other factors. At a large-scale manufacturing plant using natural gas from large-size gas fields as a raw material, GTL manufacturing costs are estimated at between \$25 and \$30/bbl. At a small-scale manufacturing plant using gas from small- and medium-size gas fields as a raw material, the costs are estimated at between \$30 and \$35/bbl. However, it is expected that demand for petroleum products in Asia will expand rapidly in ways that are heavily concentrated on middle distillates. In order to meet this demand by oil supply alone, facilities for the desulfurization and removal of aromatic hydrocarbons and the construction and remodeling of hydrocracking units, etc. will be required. The capacity of such facilities is expected to be equivalent to 2.5 million b/d in 2015 and between 5 million and 5.5 million b/d in 2020. The GTL premium allowance for this facility introduction is estimated at \$12/bbl in 2015 and \$16/bbl in 2020 at an oil price of \$20/bbl. If environmental and quality regulations become more stringent, the costs of upgrading petroleum products would increase and would enhance the cost competitiveness of GTL.

For GTL manufacturers, it appears that Asia's small- and medium-size gas fields will not participate in the market in the short-term because large-size gas fields are more cost competitive. However, should the price of GTL reach \$25/bbl, the amount of natural gas required to produce GTL for the Asian market will be 4.6 trillion cubic feet (Tcf) in 2010, 10.0 Tcf in 2015, and 18 Tcf in 2020. Should the cost rise to \$30/bbl, the amount of natural gas required is estimated at 2.3 Tcf in 2015 and 10.2 Tcf in 2020 although the amount of surplus gas available for GTL

production from large-size gas fields used for LNG is estimated between 3.8 and 4.3 Tcf in 2010, 2.7 Tcf in 2015, and 1.0 Tcf in 2020. Therefore, there is a high probability that it will be necessary to utilize natural gas from small- and medium-size gas fields in Asia after 2015 from the supply capabilities perspective. Because GTL plants can be smallscale, the use of natural gas currently flared in petroleum and gas producing countries may also be considered. This plan is being carried out in Nigeria where 70% of the natural gas is flared; this gas can be used as a quantitatively limited supply source. The raw material cost for this gas is close to zero, and if supply reaches a certain level, it could become a significant factor in the formation of GTL market conditions.

### DME

DME takes a gaseous form at ordinary temperature and pressure but becomes liquid when several atmospheric pressures are added. It is a synthetic fuel with a heating value between 60 and 70% of hydrocarbon fuels such as propane and butane (per weight). The technologies for synthesizing DME via methanol by mixing CO and H<sub>2</sub> have already been established. However, the method of synthesizing DME directly from the mixed gas is still in the experimental stage, and the earliest completion of a commercialization plant is aimed for 2006. The costs for the synthesis of methanol are higher than the manufacturing costs of LNG, and as long as methanol is used as a raw material, DME will not be cost competitive with conventional fuels. However, with the currently developed direct synthesis method, it is estimated that if a plant has a production capacity of 750,000 tonnes a year and if the cost for raw material natural gas is \$0.5/mmbtu, the cost of DME would be \$22/bbl (crude oil equivalent) upon arrival in Japan.

Because its properties are similar to those of propane and butane, there are expectations that DME will be in demand as a replacement for LPG, or at least be cost competitive. LPG is currently utilized as a fuel for automobiles and power generation, along with industrial and home use. There are expectations of the wide utilization of DME as a replacement fuel in these areas.

**DME Compared To Properties Of Other Fuels**

	<b>DME</b>	<b>Propane</b>	<b>Butane</b>	<b>Methane</b>	<b>Light Oil</b>
Chemical formula	CH <sub>3</sub> OCH <sub>3</sub>	C <sub>3</sub> H <sub>8</sub>	C <sub>3</sub> H <sub>10</sub>	CH <sub>4</sub>	-
Boiling point (□)	-25.1	-42.0	-0.5	-161.5	180-370
Fluid density (g/cm <sup>3</sup> , 20□)	0.67	0.49	0.57	0.43	0.84
Specific gravity of gas [ratio to air]	1.59	1.52	2.00	0.55	-
Latent heat of vaporization (kcal/kg)	111.7	101.8	92.1	121.9	60
Flammability limit (%)	3.4-17	2.1-9.4	1.9-8.4	5.0-15	0.6-6.5
Cetane value	55-60	5	10	0	40-55
Low calorific power (kcal/Nm <sup>3</sup> -gas)	14,200	21,800	28,300	8,600	-
Low calorific power (kcal/kg)	6,900	11,100	10,930	12,000	10,000

*Power Generation*

The basic technical considerations for the utilization of DME as a power-generation fuel have already been explored. DME can be used with a boiler or gas turbine, and can be combusted with LPG, LNG, or petroleum. In many cases, the initial costs for the preparation of transportation and manufacturing plant infrastructure and securing enough demand to cover those costs become an obstacle when a new fuel is introduced into the market. However, because large-volume users such as electric power companies can use DME in mixed fuel combustion, which does not require large investments in plant and equipment, the risks incurred on the part of DME providers are reduced. Because it is better for electric power companies to expand their fuel options and have the flexibility of selecting fuels with the greatest cost advantage, DME, which can be stored and transported easier than LNG and produces less environmental pollutants than petroleum, could become a promising alternative energy source if manufacturing costs can be lowered to a point that is cost competitive with other fuels.

*Other Industries*

Other industries use heavy oil, LNG, and LPG for fuel depending upon their particular industrial properties and site conditions. In the future, environmental costs will become increasingly important in industries that consume large volumes of fuel; therefore the conversion from heavy

oil to LNG and LPG is expected to progress. If DME prices become cost competitive, an increase in the number of companies that would utilize DME, or that would consider using DME for mixed fuel combustion with other fuels, would be expected.

### *Household Use*

Because DME can easily be transported and stored, it is expected that DME will be in demand as an alternative to LPG for use in households. The combustion heating value of DME, however, is about 70% of LPG, and adjustments will need to be made when using DME in household LPG equipment. If the heating value is increased by either mixing DME with propane or butane, or by mixing a certain amount of DME in LPG, there are possibilities for using DME in LPG equipment without any adjustments. As for distribution facilities, dedicated facilities are required when using 100% DME, but by mixing DME in LPG it is possible to take advantage of existing LPG facilities. If DME could be introduced into the LPG market as a competing product that could be used in LPG equipment, it would greatly benefit LPG price formation. The general trend in household gas is shifting to natural gas, but natural gas supplies require pipelines and are conditional on the density of demand. The role of LPG or DME suited for small-volume distribution is expected to remain significant beyond the next 20 years.

### *Automobile*

The utilization of DME as a replacement fuel for LPG cars (used widely in taxis) immediately comes to mind, but DME is considered unsuitable for use in LPG cars because it has a low octane value and easily causes the engine to knock. DME use in diesel engines has also been explored. It has been confirmed that its thermal efficiency is equal to light oil and produces fewer particulate wastes. However, if issues related to lubricity and high-pressure injection technologies can be solved, it is believed that NO<sub>x</sub> and aldehyde emissions from DME will be more controllable than light oil. Since hydrogen can be extracted from DME through a low-temperature reforming reaction at around 300 degrees Celsius, DME also has possibilities as a fuel for fuel-cell cars.

DME, like other new fuels for use in automobiles, has problems such as the preparation of delivery systems and relatively expensive vehicle prices. The question will be to what extent it is possible to have an initial introduction of DME in a dual-fuel method with other fuel types such as gasoline or light oil.

In the final analysis, for DME to replace LPG, the biggest and most common challenge is to establish technologies for direct synthesis, thereby lowering DME prices to a competitive level. In Japan, however, there is also a legal issue. To promote the use of LPG, strict regulations of the High Pressure Gas Safety Law have been relaxed by enacting a special law called the Liquefied Petroleum Gas Law. Since DME is a new substance, it is not covered by the Liquefied Petroleum Gas Law and will be subject to the stricter regulations of the High Pressure Gas Safety Law. The legal inequality in using fuels of similar risks to meet common demands must be removed by legislation.

Conditions for expanding the demand of DME include the reduction of manufacturing costs and the supply of a stable volume. If this can be realized, it would result in the lowering and stabilizing of LNG prices. DME can easily be liquefied and is easier to handle than natural gas. In addition, it is an energy source that produces little CO<sub>2</sub>. Therefore, the establishment of low-cost DME synthesis technologies should have the effect of synergistically enhancing the utilization of good quality energy.

### Methanol

Methanol is a liquid at ordinary temperatures and can easily be synthesized by using natural gas as a raw material. Using methanol as a fuel has been considered since the 1970s. The methanol synthesis process used today, however, is complex and is hindered by several difficulties. There is also a need to recycle a large volume of unreacted gas. As a result, the size of a plant is limited to 2,500 tonnes per day, and manufacturing costs are relatively high. Because its combustion energy efficiency is inferior to those of competing fuels, the use of

methanol as a fuel has been limited. Like DME, hydrogen can be extracted from methanol at a reforming temperature of around 300 degrees Celsius, making it usable in fuel-cell cars. Driving tests are being conducted for putting it into actual use. However, if the method for direct synthesis of DME is accomplished, methanol is expected to be inferior to DME in terms of price as plant costs and energy conversion costs are 15% higher.

### Fuel Cells

Besides using natural gas directly as a fuel, technologies for using natural gas as a raw material for the production of hydrogen are being promoted. Fuel cells generate power through the reaction of hydrogen with oxygen in the air. Extracting hydrogen from natural gas or from fuels derived from natural gas is considered most promising.

Substantial technical developments have been made on fuel cells, and there are expectations that fuel cells will become highly efficient energy conversion devices in the near future. In particular, from the point of view of zero polluting emissions, attention has been focused on the use of fuel cells in automobiles. There may be a variety of ways of supplying the fuel hydrogen to the automobile. Liquid fuel such as methanol, DME, gasoline, etc. would be carried onboard where it would be reformed into hydrogen, which would be used to power the vehicle. Since the reforming temperature of gasoline is high (between 700 and 800 degrees Celsius), the use of gasoline would be technically more difficult compared with methanol or DME. Using a fuel with new specifications having GTL as a base material for adjustment and use in fuel-cell (FC) cars is also being considered. If hydrogen were to be directly loaded into a FC car, hydrogen would then be manufactured and supplied at a fuel station. In such a case, city gas (LNG), LPG, naphtha, kerosene, etc. could be used as a raw material. As discussed above, there is a high probability that natural gas would in any case be used as the primary fuel.

There are also expectations for the use of stationary fuel cells for power generation and as a cogeneration-type distributed power source; the development of stationary fuel cells is presently being advanced. With regard to cogeneration-type distributed power sources, research is also

being made on the use of micro gas turbines as small power generation devices. In each case, there are expectations for new possibilities in the field of natural gas demand, but as has been previously pointed out, the ill-equipped legal system may become an obstacle in advancing the use of these technologies. Because these power generation devices have virtually no record of actual use, they are defined as “electric work piece for use in business” by the Electric Power Industry Law and are subject to the same regulations that apply to in-house power generation of medium scale and above. Therefore, a chief boiler/turbine engineer or a chief electric engineer would be required, and the power plant would have to be continuously monitored and be equipped with system interconnection and protection devices. These conditions cannot be met in small-scale applications and limit the fields of demand considerably. If a rigid legal framework were the only response to technical innovations designed to enhance safety and operability, it would be a substantial loss to the national economy. At the same time, it would hinder motivation for such technical innovation. The legal system needs to be reviewed so that it would provide incentives and flexibility for technical innovations.

### **Introduction by Pipelines**

In examining changes in the supply-and-demand structure of natural gas in Asia, discussion is also needed to address the fact that the introduction of natural gas in its gaseous state is taking shape in ways that are economically viable through the use of pipelines.

### **Natural Gas Pipelines in the East Asia Region**

The East Asia region is underdeveloped in the construction of pipelines for the natural gas supply infrastructure. Although negotiations between Japan and the former Soviet Union on the development of natural gas in Yakut and Sakhalin began in the 1960s, the negotiations were broken off with the exacerbation of the Cold War in the 1980s. Since the collapse of the former Soviet Union, plans for the export of natural gas from that region to China and Japan through pipelines are again being pursued. Specifically, there are four main projects under construction or consideration. They include:

1. Development of gas fields in Central Asian countries such as Turkmenistan and Kazakhstan.
2. Extension of existing pipelines from gas fields in West Siberia.
3. Development of gas fields in Krasnoyarsk, Kovykta, Yakut, etc. in East Siberia.
4. Development of gas fields in the Sakhalin continental shelf.

The first three proposed projects are mainly targeted for China, while 4 is targeted for Japan and eventually China.

A problem related to the planning of pipelines from Central Asia and West Siberia to China is the vast distance between the regions of supply and the areas of demand (big cities and coastal regions). To realize exports from gas fields in Central Asia and Western Siberia to China, the connection of the “East-West pipeline,” which is currently being constructed in China, will be the key. For the extension from Kovykta in East Siberia, a plan to supply natural gas to Beijing and South Korea is taking definite form in a joint project involving Russia, China, and South Korea. The feasibility study is expected to be completed in 2003, and exports are expected to start around 2008. For the development of gigantic gas fields in East Siberia and Sakhalin (total potential reserves: 43,790 billion cubic meters (bcm)), the Russian Government has plans to construct export lines from 2010 to 2015 and to build a network from 2015 to 2020. With regard to a pipeline plan from the Sakhalin continental shelf to Japan mentioned above, the LNG equivalent of 2 million tonnes per year is expected to be supplied to Hokkaido around 2008 in Phase 1. In phase 2, pipelines are expected to extend to the Tokyo metropolitan area for the export of LNG equivalent to 6 million tonnes per year.

### **Natural Gas Pipeline Plans in China**

China’s “East-West gas pipeline” plan is being carried out as a core project of the “West Development Project” with construction expected to start in 2001. This plan intends to transport natural gas from major gas fields in inland China in three stages. First, a 1,500-km pipeline will be constructed from Shaanxi to Shanghai for completion in 2003. A 500-km pipeline from



Gansu will be added in 2004, and then the pipeline will be extended for 2,000 km to Xinjiang for completion in 2006. Ultimately, the pipelines will extend for a total of 4,000 km from Tarim Basin in Xinjiang to Shanghai, and will transport 12 trillion cubic meters of natural gas a year. The cost of natural gas upon arrival in Shanghai is estimated at 1.304 yuan per cubic meter, which is about the same as the current LNG wholesale price of 1.3 yuan per cubic meter (\$4.36/mmbtu) in Shanghai and within a range between \$4 and \$5/mmbtu, which is necessary to compete with the use of coal in thermal power generation. However, because of declining coal prices in the inlands and because energy price policies differ from region to region, there are considerable energy price differences in China. There are concerns whether or not pipeline gas will be cost competitive in the inlands even though costs are lower than those upon arrival in Shanghai.) Gas supply contracts have already been concluded with industrial users in Jiangsu Province, Zhejiang Province, Anhui Province, and Henan Province, but there is a need to have a framework for further binding long-term demand. To secure construction funds for this project, foreign ownership greater than 50% will be required. In order to attract foreign capital for this kind of a long-term project, it will require the long-term reliability of the yuan or a system that mitigates the risk taken in addition to insuring the long-term capability of customers to purchase the gas or a system to guarantee payment.

## **Natural Gas Pipelines in Japan**

### *Current State of the Natural Gas Supply Infrastructure*

Ninety-seven percent of natural gas in Japan is imported in the form of LNG, and there are 23 LNG reception bases around large cities. More than 70% of the LNG used for thermal power generation is consumed in areas close to the reception bases, which has inhibited the need for pipeline networks. City gas providers supply the remaining 30% to general households through low- and intermediate-pressure pipeline networks. The total length of the low- and intermediate-pressure pipeline networks is some 210,000 km, which is close to Britain's 265,000 km. However, whereas Britain has 18,000 km of high-pressure pipeline networks for transportation, Japan only has a total of 3,000 km of high-pressure pipeline networks. Included

are those that city gas providers installed for looping LNG reception bases and those that developers and wholesalers of domestically produced natural gas (which accounts for 3% of all natural gas), constructed for transporting natural gas to the city gas providers and other high-volume users. Provincial gas providers' LNG demand is increasing, but lorries, railroads, and coasters are used for the transportation of LNG, and the construction of additional high-pressure pipelines is not a preferred option for three main reasons:

1. There are no laws and regulations that serve as direct standards for high-pressure pipelines.
2. The construction of high-pressure pipelines is considered costly and economically inferior from the viewpoint of the use of land for construction.
3. The complexity of procedures required for authorization, etc.

There is a similar situation when trying to introduce international pipelines for imports. However, if natural gas were imported in its gaseous state through international pipelines, which is an important energy option, it would significantly change the supply-and-demand structure, promote price competition, and increase the possibility of beneficial effects on the national economy. The legal and procedural obstacles to building high-pressure pipelines make it necessary, in terms of energy security and the national economy, to prepare and improve the laws and regulations that serve as standards for their construction.

#### *Technical Standards for Japan's Pipelines*

Let us then examine pipeline-related laws and regulations, and particularly, their technical standards. With regard to domestic natural gas pipelines, city gas providers are governed by the Gas Industry Law; electric power providers are governed by the Electric Power Industry Law; and oil and gas developers by the Mine Law and the Mine Safety Law. In other words, there are no unified laws and regulations. Therefore, in proposing gas pipelines, we have a strange situation where different technical standards are employed depending on the type of industry. Moreover, in terms of international pipelines and underwater pipelines -- with which Japan has

no experience -- a decision has not been made on which technical standards should be adopted or whether it is appropriate to use international standards.

In Europe and the U.S., where pipelines are well developed, individual countries set their own technical standards. In April 2000, however, ISO standards were established, and are beginning to be widely accepted as international standards. When compared to Japanese standards, in terms of tubing, design coefficient, inspection methods, quakeproof guidelines, etc., the international standards generally encompass new technical progress while allowing for freedom and flexibility in designs depending on different situations. If measures beneficial to expanding energy options are hindered by the legal system and procedures, the situation must be ameliorated as soon as possible to meet the important goals of energy security and national economic expansion. To take it a step further, preferential land use should be recognized for pipeline construction, and energy policy considerations should be made for establishing a pipeline construction law in harmony with the Road Law, the River Law, the Natural Parks Law, the Port and Harbor Law, and various other laws.

### **The Influence of Pipeline Construction on Energy Markets**

What effect will the introduction of imported pipelines have on the national economy? Firstly, it could be a factor in lowering natural gas prices to the level of international prices. Currently, Japan's natural gas prices are decided by a formula that is linked to the CIF price of crude oil arriving in Japan (crude oil equivalent; about \$3.5/mmbtu on average in 1990s). The trend in world natural gas prices, however, is heavy oil equivalent (\$2.5/mmbtu on average in 1990s), and Japanese prices are about 40% higher than world prices. This is a result of the initial price system created to recover the significantly large initial investments in LNG manufacturing plants and equipment. On the other hand, through technical progress, liquefaction and transportation costs have declined by 30% to 55% compared with initial levels. However, because LNG is the only option, there is no momentum to reduce prices. Furthermore, there are moves to increase the price by adding an environmental premium. The import of pipeline gas will be an excellent opportunity to introduce competition to this pricing system.

Secondly, in terms of market structure, the use of imported pipelines will increase natural gas demand and promote competition with other fuels. Along imported pipelines, large-volume end-users can enhance their corporate competitiveness by purchasing pipeline gas directly at lower prices. Areas where city gas networks are not currently available (areas using LPG) could see an increase in businesses using natural gas as a raw material. With a reduction in retail prices, distributed power sources such as gas cogeneration may spread, promoting competition with petroleum products and electric power. Preparing high-pressure pipelines for domestic gas transportation would also enhance the effectiveness of introducing imported pipelines. Developing domestic transportation pipelines will create a unified natural gas market (including pipeline gas and LNG) and would become a factor in increasing competition. At the same time, it could provide an opportunity for gas providers to hedge against the risks involved.

It should be noted, however, that this argument is based on the assumption that investments in the construction of high-pressure pipelines can be recovered within a certain time and is sold at prices competitive with LNG. In order to recover the vast investment to construct these pipelines, it will be necessary to minimize construction costs (to insure that the sales price is competitive) and secure long-term sales agreements. In order to prevent unreasonable construction costs, obstacles to the development of high-pressure pipelines in the legal system and the procedures mentioned above need to be removed. In terms of demand, the relaxation of industry regulations would allow electric power and oil companies, through increased price competition, to select natural gas as a fuel and develop a comprehensive energy business. In addition, the expansion of the supply-and-demand structure of natural gas is necessary to provide for energy security and environmental conservation.

The introduction of new fuels such as GTL and DME, and the construction of international pipelines were not considered in the formation of existing laws, regulations, and procedures. An effort to adapt these products and the building of pipelines to existing laws, regulations, and procedures, will likely result in a good deal of confusion and many delays. Such existing laws, regulations, and procedures may hinder the introduction of new fuels and facilities in areas that

are not essentially important. However, as it has been illustrated above, the introduction of new fuels and facilities will increase the number of options related to the utilization of natural gas in Japan, as well as contribute to setting reasonable natural gas prices while at the same time enhancing the goal of environmental conservation. While the introduction of new fuels and facilities is desirable for the national economy, what will ultimately decide this will be a corporate decision on whether or not it will be profitable. Energy is subject to international competition, and excessive system-related costs will increase energy prices, thereby affecting the economic competitiveness of that society. At the minimum, the preparation of new laws, regulations, and procedures should not be allowed to impede the efficient introduction of new fuels and the expansion of natural gas pipelines. Energy-related laws should be reviewed and adjusted to allow for the flexibility to easily adapt to technological advances and changes in international standards.