The Roles and Functions of Refineries in a Total Energy Industry

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1. Background and Goals

For many years the Japanese energy industry has had a vertically segmented structure in which individual sectors—electricity, gas, and petroleum—have been regulated separately. With the coming of the twenty-first century, each of these energy sectors is being deregulated in order to become more competitive internationally. As a result, cross-involvement among energy sectors and entrance by overseas companies have become possible. Significant changes in the structure of the energy industry are expected, as the industry becomes more borderless and globalized.

With such changes in the business environment, competitiveness in truly competitive markets has become an important issue. There are calls for Japan’s energy industry to be elevated to a so-called “total energy industry.” The petroleum industry is no exception to this trend. While the general orientation for development has already been studied, there is a need for the refining industry to make a more detailed study on the concrete options for the future.

Source: Petroleum Refining and Reserve Division, Agency of Natural Resources and Energy, Ministry of Economy, Trade and Industry, based on the documents from the Petroleum Industry Development Orientation Study Council

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Figure 1 The Trend Toward a Borderless Energy Industry
-- Toward a Total Energy Industry --
With background as such, we have studied “the roles and functions of refineries in a total energy industry” for the twenty-first century, adopting some leading refineries as models. Here we present an outline of some of the technical possibilities and business possibilities we have identified. Since residue as a byproduct of refining tends to inhibit the competitiveness of refineries, we have focused on the gasification technology that can be used to convert oil residue into useful energy. We explored the possibilities of this technology in the context of a borderless energy industry and its potential as an energy conversion hub.

2. Changes in the Business Environment of Energy

There is no question that the most important issue facing Japanese industry today is strengthening of international competitiveness. This can only be achieved by competing in a competitive framework. Thus, deregulation is being pursued eagerly as a method of introducing market principles. The energy industry is no exception to this trend. In fiscal year 2000, the Ministry of Economy, Trade and Industry (METI) reconvened its Advisory Committee for Natural Resources and Energy to debate Japan’s energy strategy and policies for the twenty-first century.

With regard to the deregulation in the electricity and gas industries, the system implemented in fiscal year 2000 will be verified three years later. The petroleum industry, on the other hand, was completely exposed to market forces earlier than other energy sectors were, with the repeal of the Petroleum Industry Law. All constraints, with the exception of regulations related to quality and security, have been lifted. In addition, a review on tariffs is expected some time after 2005, and this will probably result in domestic prices in line with the international price structure. As a result, relative price of fuel oil is expected to fall further, which will surely have a major impact on the profitability of the refining business.

Due to these factors, it is highly likely that the structure of the Japanese energy industry will undergo rapid and far-reaching changes during the first decade or two of the twenty-first century. The degree to which it is exposed to direct international competition will increase as deregulation progresses. International competitiveness will determine the survival of companies, industries, and regions.

On the other hand, the Majors are undergoing a transformation from “Oil Majors” into “Energy Majors” with interests in areas such as electricity and gas. In order to cope with the increasingly borderless nature of the energy industry and changes in energy demand, they are flexibly reorganizing their business activities. Within the business portfolio of the Majors, petroleum refining is positioned as a “marginal business segment” or a “declining business segment.” It is likely that Japanese oil companies, which have almost no business holdings in the upstream sector, find it more and more difficult to sustain stable profitability if the current trend continues.
3. The Need for a Competitive Strategy

The above-mentioned changes in the business environment provide both threats and opportunities. What is essential is a competitive strategy that will enable Japanese companies to survive by gaining competitive advantages against the Majors. There are limits to what can be accomplished merely by making operations more efficient in order to reduce costs, and in any case this alone does not amount to a strategy. The base of the strategy is differentiation, which is equal to strategic positioning. In other words, companies must strive to do things that their competitors cannot imitate, and decide on the operations they will not be engaged in. Michael Porter’s theories on competitive strategy are well-known. He proposes two frameworks for devising competitive strategy: business strategy based on the value chain and regional industrial strategy based on clusters.

3.1. Business Strategy Based on the Value Chain

Michael Porter’s value chain concept sees all operations of an enterprise as “value activities” that generate some amount of added value. His approach aims to identify sources of competitiveness and ideas for business strategies by analyzing how value activities are linked, where and to what degree they provide added value, where they generate costs, where they create synergy, and where they are differentiated.

New strategic possibilities are generated by thinking of a value chain extending from suppliers in the upstream all the way to the downstream, and to the final consumer and creating a business model that makes the most of the company's strengths and maximizes synergy. In particular, it is necessary to re-evaluate and rebuild the value chain when changes occur in the business environment and competitive conditions due to factors such as deregulation.

Major changes are occurring in the energy business due to deregulation. According to Professor Nishimura of Gakushuin University, “It has already been proven from the experience of the United States and many other countries that in the twenty-first century the energy business—electricity, gas, and petroleum—will change from a regulated, inflexible, and vertically integrated industry into a ‘value chain’ type business system in which the existence of the ‘market’ is taken as given.”

3.2. Regional Industrial Strategy Based on Clusters

When some enterprises with strengths in a certain business field are geographically concentrated, along with related industries and support industries, to form a value chain network, and they compete with each other within a cooperative framework, strong international competitiveness is generated that could not be achieved by any single enterprise working alone. Such an arrangement is called a cluster. All of the world’s leading industrial zones has been developed consciously and strategically as clusters, and this is an important viewpoint when considering international competitiveness in the years ahead. According to Michael Porter’s cluster theory, industrial clusters that are competitive at the global level are formed by bringing together four elements: component conditions (production resources and infrastructure), demand conditions (the existence of buyers), support (a concentration of supplier industries and related industries), and a competitive environment (strategic rivalry).
Examples of clusters in the refining and petrochemical industry include the region of the United States on the Gulf of Mexico and the Rotterdam area in Europe. In recent years, Singapore’s Jurong Island has emerged as a chemical cluster and is attracting international interests. Under the leadership of the Economic Development Board of Singapore, a “chemical island” concept was sketched out based on a cluster strategy, and its development began in 1990. The plans call for the construction by 2010 of a system capable of producing 3 million tons of ethylene annually. In spite of the fact that land and labor costs are higher than in neighboring countries, the project has become globally competitive and has attracted many major international players due to its strategic advantage. Jurong Island is well on its way to proving that if the four elements essential to a cluster are strengthened in a well-balanced way, competing industrial zones in low-cost countries such as China or Thailand will not be able to attain competitive supremacy as clusters.

### 3.3. Hints for Reviving Japanese Industrial Complexes: Potential of the Energy-Petrochemicals Cluster

Most of the petrochemical complexes throughout Japan were constructed in the 1960s and 1970s, and they are now beginning to lose their international competitiveness. Cluster theory can serve as a key reference for efforts to revive Japan’s industrial complexes and provide them with international competitiveness, and the case of Singapore offers many useful hints.

1. The individual companies in Japan’s energy and chemicals industries already own an enormous amount of fully depreciated assets (equipment and infrastructure), but they need to rebuild their regional operations into energy and petrochemicals clusters in order to revive their competitiveness. They must move from the old concept based on enterprises or business operations as discrete units toward the one aimed at pursuing international competitiveness by reorganizing the value chain among the enterprises in each region to form clusters.

2. New value chains extending from raw materials through finished products must be created through a re-engineering process involving introduction of new key technologies and the effective combination of existing assets. In addition, infrastructure and support functions, such as supplementary equipment and utilities, should be made commonly available to all and provided as services.

3. Since effective utilization of existing assets and implementation of “scrap and build” operations need to play a central role in the case of Japan, there is a need for flexible alliances between private companies as well as for the formation of a strong commitment by regional enterprises and government to work for the formation of internationally competitive strategic clusters.

4. Leading regional players should discuss policies aimed at regional specialization from the standpoint of maintaining international competitiveness of industrial complexes as clusters. For example, matters such as regional utilities, fire and disaster control systems, and incentives to attract companies should be considered, and efforts should be made to create an attractive climate for investment and operations.
(5) In the area of social regulations the basic philosophy should be to emphasize the principle of corporate responsibility and to minimize the involvement of the national government as much as possible. Regional governments should be given free discretion to implement policies matched to local conditions. In particular, since new transactions involving distribution and energy will arise and new pipelines for raw materials, products, and utilities will inevitably need to be built, relevant deregulation and review on the standards will become necessary with the aim of bringing costs down to the international levels.

4. Vision of a Total Energy Industry

Road to a total energy industry (see Figure 1) in order to cope with the trend toward a borderless energy industry while also achieving international competitiveness has been suggested as a way that should be taken by the Japanese energy industry. This idea envisions business integration beyond the borders between the energy sectors of electricity, petroleum, gas, etc., and collaboration between them. It would be a cooperative arrangement based on a material chain, linking the upstream and downstream petroleum sectors and the chemical sector.

If we examine the energy industry from the standpoint of the value chain, we can say that there is a need to move away from the conventional, closed, and vertically integrated corporate structure in each of energy sectors, toward a value network such as the one shown in Figure 2, in which individual companies with own core competence form alliances to create a complex and horizontally integrated value chain.

Figure 2  Energy Business Value Chain in the Market Era
Freer markets and technological innovations bring about changes in the business structure. In addition to the international primary energy markets, deregulation has brought about new secondary energy wholesale and retail markets. The necessity for vertical integration from the upstream through the downstream sectors disappears and the functions of commercial flows and distribution are divided.

The basic function of distribution—the physical handling of energy resources—is unlikely to undergo substantial change. However, new technologies are emerging on both the supply and demand sides in response to changes in the structure of the primary energy business spurred by evolving environmental demands. For example, new supply side technologies include integrated gasification combined cycle (IGCC) and gas to liquids (GTL). Emerging demand side technologies include distributed power sources employing co-generation, such as micro gas turbines and fuel cells. The area of commercial flows is likely to undergo major changes due to an increase in the volume of market transactions backed by advancements in financial technology (FT) and information technology (IT). Since transactions between functions are subject to market forces, both value transparency and flexibility can be expected to increase.

Along with such changes in the areas of distribution and commercial flows, a combination of strategic options and alliances become possible, resulting in a more dynamic business environment. If companies can construct business models that well fit the value chain from upstream to downstream and form regional clusters, the synergy will enhance the competitiveness of all the participants. In this way, industries previously defined as marginal or declining will have the opportunity to regain their international competitiveness.

5. Redefining Petroleum Refining

5.1. Disintegration of the Refinery Functions

As shown in Figure 3, the functions of refineries can be broken down into main functions and support functions. The main function is crude oil refining, which is the core business of the refiners. This process converts crude oil, a primary energy source, into petroleum products, which are secondary energy sources. However, an actual oil refinery cannot operate by performing the main functions only. It requires a range of infrastructure facilities for items such as utilities, cooling water, wastewater treatment, smoke emissions treatment, and fire control. A system of support services is required that includes personnel with the skills, knowledge, experience, and qualifications to perform these tasks. It also comprises external economic elements such as licenses to handle hazardous materials such as high-pressure gas, rights to obtain industrial water or seawater supplies, and legal regulations covering emissions of smoke and wastewater.
Discriminating between main functions (refining functions) and platform functions (infrastructure and support functions).

Figure 3: Basic Functions of Refineries

The infrastructure and support functions, which will remain largely unchanged even if there is some variation in the raw materials and primary energy sources handled, can be referred to collectively as the “energy platform.” Consequently, we can redefine the functions of a refinery in an abstract sense as consisting of functions for converting primary energy sources into secondary energy sources (the main functions) and energy platform functions (the support functions).

5.2. Refineries as Energy Conversion Hubs (Nodes)

Traditionally, the functions of a refinery are simply to import crude oil, refine it into a variety of petroleum products, and then ship them to customers. However, by making use of the energy platform functions with which refineries are equipped, it becomes relatively easy to add to and modify the main functions to make it possible to handle an array of primary and secondary energy sources, provided they are liquid hydrocarbons such as crude oil, LPG, and LNG (Figure 4).

It thus becomes possible to envisage future energy conversion hubs (nodes) that are capable of coping with changes in the energy structure in a flexible manner. Such facilities would have a variety of possibilities within a value network formed from complex and horizontally integrated value chains, as described in the section “Vision of a Total Energy Industry.” By making use of unused space within refineries or the sites of refineries that have been closed, such an approach could be a new source of competitiveness for refineries pursuing a differentiation strategy.
The effectiveness of power generation with residue within refineries has already been proved. In addition, gasification technology should be considered as a new possibility in the context of a differentiation strategy. Gasification (partial oxidation) is a diverse technology in terms of both raw materials and applications. As shown in Figure 5, it has abundant potential for the creation of a more complex value chain in the downstream to oil refining.

The best known application of gasification technology is power generation using the integrated gasification combined cycle (IGCC) method. It is also possible to produce a variety of secondary energy products or chemical raw materials by using synthetic gas as a medium. In addition to gasification of the residue from refineries and petrochemical plants, followed by generation and supply to customers of electricity, steam, hydrogen, or carbon monoxide commonly used industrial gases such as nitrogen and oxygen can be produced as byproducts and then supplied. These products are the most basic energy sources and raw materials utilized by the chemical industry. If it can find a place within an energy and petrochemicals cluster developed in a specific region, it would be possible for a refinery to function as an energy utility supply base within the cluster. This would contribute substantially to the international competitiveness of the cluster in question.
Figure 5: Energy Base Value Chain

Singapore’s Jurong Island provides a real example of such a chemical cluster. This combination of elements is one of the keys to the international competitiveness of Jurong Island.

Figure 6: Formation of Energy Utility Hub on Jurong Island -- Example of Complex Energy Value Chain --

The basic principle of gasification allows flexibility in the selection of raw materials for the process. Any solid, liquid, or gas containing carbon can be utilized. The extremely broad range of possible raw materials includes vacuum residue (asphalt), thermally decomposed residue (petroleum pitch, petroleum coke), Orimulsion, coal, natural gas, waste plastic, discarded tires, and oil sludge.

The gasification process is a fundamentally clean technology that permits recycling of inferior raw materials with low added value into useful materials and energy sources with high added value. Petroleum based raw materials such as vacuum residue (asphalt), as well as thermally decomposed residue in the form of petroleum pitch and petroleum coke, which are difficult to process into conventional fuels due to their high concentrations of sulfur and carbon, can be converted into clean synthetic gas relatively easily. Gasification is thus an extremely effective way of dealing with the traditional “Achilles heel” of the refining process, petroleum residue.

Figure 7 shows some of many possible configurations for a refinery equipped with gasification facilities. A wide variety of applications are possible once the raw material has been converted into general use synthetic gas. Some of the typical applications are as follows:

1. Supply of synthetic gas, hydrogen, and carbon monoxide
2. Integrated gasification combined cycle (IGCC): Supply of electricity or steam
3. Gas to liquid (GTL) synthesis: Methanol, DME, and FT synthetic oil
4. Olefin: Ethylene, propylene
5. Supply of industrial gas: Oxygen, nitrogen, argon, carbon dioxide

![Figure 7: Energy Conversion Hubs (Nodes) and Gasification Processes](image-url)
7. Overseas Policy Trends Related to Gasification

This survey examined the recent policy trends related to gasification at organizations such as the U.S. Department of Energy (DOE) and the International Energy Agency (IEA). In all cases, an orientation toward positive evaluation and support of gasification, including petroleum based IGCC, is observed. Active R&D on gasification are being pursued, chiefly from the standpoint of effective utilization of coal resources. Also, in recent years, the scope of possible raw materials has widened beyond coal, and the DOE has even budgeted funds for R&D on IGCC using fuels other than coal (chiefly petroleum-based fuels). *Gasification: Worldwide Use and Acceptance*, a report issued by the DOE in January 2000, states, “Current pitch and petcoke gasification is a bridge to long-term coal gasification.”

Vision 21, a large-scale R&D program announced by the DOE’s Office of Fossil Energy in 1998, with a target date set 30 years later, aims to promote technological development in a variety of areas. Goals include switching from fossil fuels to alternate energy sources and raw materials, including electricity, in an efficient and environmentally friendly manner, and with a high degree of economic efficiency. Gasification (in particular, fuel-flexible gasification) is identified as a key technology.

Reconciling Disagreements with the EPA over the Environmental Impact of IGCC

On the other hand, since around 1998 the Environmental Protection Agency (EPA) has shown a tendency to increase regulation of gasification plants already operating commercially (principally plants located in refineries or chemical plants) because it viewed two aspects of IGCC as problematic. However, both of these problematic aspects have since been basically solved.

1) Regulations on Synthetic Gas

In June 1998 the EPA announced that synthetic gas produced through gasification would be exempt from the provisions of the Resource Conservation and Recovery Act (RCRA), which regulates toxic materials. This announcement in effect said that IGCC was not to be regulated and that IGCC was not being viewed as a problem. However, the Gasification Technologies Council (GTC) responded to the announcement by emphasizing that rather than being treated as an exception, synthetic gas had in fact never been regulated. The GTC demanded that the EPA interpret the situation this way and act accordingly. As reasons for its viewpoint, the GTC pointed out that synthetic gas is environmentally friendly in terms of emissions characteristics (SOx, NOx, and concentration of particulate matters, etc.) and that synthetic gas is produced not as a final product but rather as an intermediate material, created as part of a larger process. In the end, the GTC ended up taking the EPA to court in an attempt to modify its interpretation of the relevant laws, and as of this writing the two parties still have not reached a settlement.

2) Regulations on IGCC as a Route for Processing Petroleum Waste

Another aspect of gasification technologies such as IGCC is a way of processing petroleum waste at refineries, etc. Generally speaking, the EPA regulates the processing of toxic materials very strictly in accordance with the RCRA. However, in July 1998 the agency announced its view that the provisions of the RCRA would not apply to gasification as a way of processing petroleum waste (oil bearing secondary materials or oil bearing wastes) at oil refineries.
The trash processing and incineration industry, which is in the business of incinerating toxic substances, took issue with this announcement, and as a result, DOE threw its support for gasification by announcing in a technical report dated May 2000 that gasification and incineration have fundamentally different operating process and the former is superior to the latter.

**International Energy Agency (IEA):**

Many of the reports issued by the IEA recently have identified gasification (especially IGCC) as a promising technology for power generation and have singled it out as an important R&D theme that should be positively pursued in the years ahead. *Electric Power Technologies: Opportunities and Challenges of Competition*, a survey report issued in 1999, examines possible changes in the power generation technologies used by the utility companies that may arise due to the liberalization of the power market and increased competition that follows. Gasification is identified as a promising technology that will permit the utilization of low-cost fuel sources.

In particular, the report states that utilization of petroleum-based fuels (especially residue) will be an effective option to lower the generation cost of IGCC to a level competitive with conventional power generation methods. It notes that IGCC method that employs oil residue as fuel is the most active part of the present global IGCC market. The report’s analysis also comes to the conclusion that the practice of making use of IGCC to generate electric power has merits for refineries in terms of changes in the demand structure (increase in gasoline, kerosene, and gas oil and decrease in fuel oil) and environment.

8. **Conclusion**

There are limits to the extent which improvements that each of petroleum, electricity, and or gas sectors can contribute to increasing international competitiveness of the Japanese energy industry. A borderless strategy that goes beyond the conventional boundaries separating these business segments is necessary. An effective approach would aim at forming energy clusters by reconstructing a complex value chain in which collaboration among different business segments produces complementary synergistic effects and allows each player to make the most of its strengths.

For example, industrial complexes could position themselves as energy supply bases by making use of the energy platform functions already possessed by refineries, plus a variety of added energy conversion functions, and electricity companies and gas companies could provide a variety of utility service functions from plants located in industrial complexes. In this way, industrial complexes could be reborn as clusters, creating an environment in which each of the constituent enterprises and industries could concentrate on their fields of core competence. This would help to strengthen the international competitiveness of industries based in Japan.
When envisioning future directions of the energy industry, gasification emerges as a key technology with the potential for a variety of applications to be derived from it. The necessary approach would make use of technologies that have already reached a commercially practical stage while gradually developing new applications in response to technological advances and changes in the demand structure. In particular, building up experience with large-scale gasification processes for IGCC power generation, which converts fuel into electricity, a form of energy already in general use, will make possible a smooth transition to the stage when demand takes off for clean fuels such as methanol, DME, FT synthetic petroleum, and hydrogen.

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