# Alleviating environmental impact by networking natural gas-fuelled co-generation systems

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Fossil fuels are expected to remain a vital energy source, at least, in the first half of the 21st century. Among the fossil fuels, natural gas has been reputed to be the most environment-friendly fuel, because its combustion products are much cleaner and contain less $CO_2$. Technological advancement and economies of scale have brought down the cost of natural gas production and transportation and, therefore, have improved the competitive edge of natural gas in the energy market. The discovery of new natural gas reserves has been extending the life of this resource (reserves by production ratio: R/P) year by year. The current R/P of natural gas world-wide exceeds 60 years and reserves are more widely distributed in terms of geography, which means better security of supply than oil. Thus, the 21st century is called the "age of natural gas".

In Japan's Basic Energy Plan published in October 2003, the shift of Japan’s energy supply to natural gas and the acceleration of this shift is clearly recognised as one of the principal energy policy agendas of the government, because of the need both to ensure the security of energy supply and to take the environment into account. The Basic Energy Plan also mentions promotion of energy saving and levelling the peak load of electricity as measures to contain energy demand. A distributed energy system such as co-generation is referred to in the Plan as an important example that can contribute to efficient use of energy and at the same time can reduce the peak summer demand for electricity. Subsequently, "Outlook for Energy Supply and Demand in 2030", a long-term quantitative scenario published in June 2004 by the Energy Supply and Demand Subcommittee of METI's Advisory Committee for Natural Resources and Energy, shows great potential for further introduction of natural gas and the distributed energy system into the Japanese energy supply and demand structure.

This paper first introduces the current status of distributed energy systems and the use of natural gas in Japan. Then, we will discuss and examine efforts by Japanese city gas utilities and the government to advance distributed energy systems based on gas-fuelled co-generation systems and networks based on them as a means for achieving energy efficiency and protection of the environment. We will also identify a number of challenges lying ahead in order to achieve the networking of co-generation systems. Once Japan has successfully constructed co-generation-based distributed energy networks, it will share its experience and expertise in energy efficiency with countries and regions where energy demand is increasing significantly and, thus contribute to international efforts to prevent global warming.

## 2. Distributed Energy Systems

### (1) Advantages of Distributed Energy Systems (vis-à-vis a centralised system)

Since a distributed energy system produces heat and power on the spot, or adjacent to the location of energy demand, it can make the best use of exhaust heat that would have been discarded by a remote large-scale power station. Proximity to the centre of demand will remarkably reduce transmission losses, as well. As a result, a distributed system has the potential to attain a higher level of energy savings and thus to mitigate the impact of energy use to the environment. An appropriate combination of efficient distributed systems with a centralised grid system can produce greater energy savings and environment friendliness.

Secondly, compared with large-scale thermal power stations or nuclear stations, a relatively small distributed energy system can enjoy a shorter lead time for construction, smaller investment and easier adjustment of capacity to fit the actual demand. This means that distributed generation is less risky and, hence, a favourable option as a power supply for investors to commit to, when growth in power demand is difficult to predict due to economic conditions and increasing competition resulting from the liberalisation of energy markets.

Customers benefit from having an additional power supply on top of grid electricity, thereby minimising the probability of power failures and other risks inherent to a centralised grid system. A distributed system will give customers the option of selecting energy sources according to their specific circumstances with respect to the availability of energy, which can be renewable energy rather than conventional energy, for example oil products.

Thirdly, distributed energy systems will open opportunities for a variety of related new businesses. It is easier for non-utility companies to join a new business than to join a full-scale utility. Hence, the number of new businesses will increase and the competition among them will enhance energy efficiency and service for customers.

Competition will not be limited to distributed systems but will also include competition with centralised systems, which will bring about further efficiency for both types of system. Distributed systems will benefit customers as well as stimulate the economy itself.

### (2) Categories and Types

Although there is no established definition of a distributed energy system, such systems always contain any form of generator other than large thermal, nuclear or hydro power stations operated by a traditional electric utility for the grid. The term 'distributed' is used to express a system in contrast to the grid system, which has large-scale power stations outside the local community. Examples of distributed power supplies and their primary energy sources are shown in the table below.

Examples of distributed power supplies

- Private power generation
- IPP (Independent Power Producer -- supplying electricity to a power company on a wholesale basis)
- PPS (Power Producer and Supplier -- supplying electricity to liberalised markets, etc.)
- Co-generation
  - Industrial (factories)
  - Commercial (hotels, office buildings, etc.)
  - Residential (engines, fuel cells)
- Renewables (supplying electricity to a power company )

Type of fuel

- Oil Products
- LPG
- Natural gas
- Coal (inc. gasification)
- Hydrogen
- Solar
- Wind
- Biomass

### (3) Natural gas for distributed energy systems

Although the quality of natural gas is already well known, it is useful to elaborate on the merit of natural gas as a fuel for a distributed energy system:

- Preservation of the environment

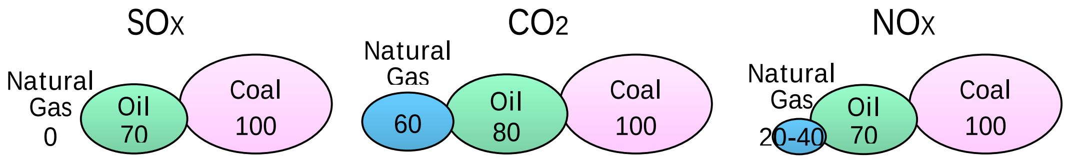
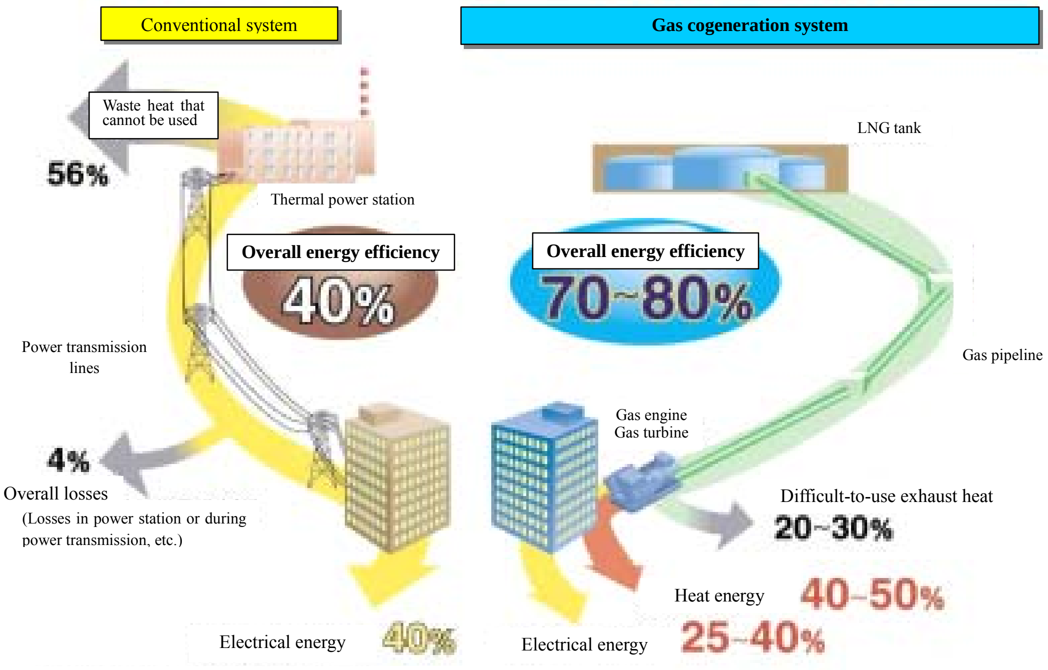


Figure 1. Comparison of combustion products

Natural gas burns without producing soot or sulphur oxides. There is an arsenal of technologies readily available to minimise the formation of nitrogen oxides (NOx) or to remove NOx from flue gas. Natural gas will provide a 60% to 80% reduction in emissions of $CO_2$ when compared with oil products and coal. It is regarded as the most environment-friendly fossil fuel.

- <u>Energy savings</u>



(Power generation efficiency is calculated on the basis of FY 2000 records)

(LHV standard)

**Figure 2. Energy efficiency of co-generation**

Because natural gas co-generation systems produce heat and power at the location where these two forms of energy are required, there is no loss associated with power transmission or other forms of energy transportation. While conventional centralised power stations scarcely use their exhaust heat, in the case of natural gas co-generation, the exhaust heat can be recovered to generate steam, to provide hot water or to drive absorption chillers for air conditioning. In this way, the overall efficiency of primary energy utilisation of co-generation can be between 70% and 80%, as shown in Figure 2.

In Japan, a generator is driven mainly by a gas turbine or a gas engine, whose generation efficiency in the past may have been inferior to that of large-scale thermal power stations connected to an electricity grid. However, the efficiency of gas engines has recently made remarkable progress thanks to new technologies. The latest gas engines available on the market are quite comparable to large-scale power stations in terms of thermal efficiency. Improvement of gas engines and development of fuel cells will continue and is expected to result in higher efficiency of power generation for distributed systems, which keeps pace with, if not exceeds, that of large-scale stations.

So long as the generating efficiency of the distributed system is comparable with that of grid electricity, the focus for energy saving will be on the efficient use of heat. The model shown in Figure 3 illustrates a typical comparison between a distributed system and a centralised system. To obtain the same amount of heat and power, the input of primary energy for co-generation is reduced by as much as 15% compared with that of the centralised system.

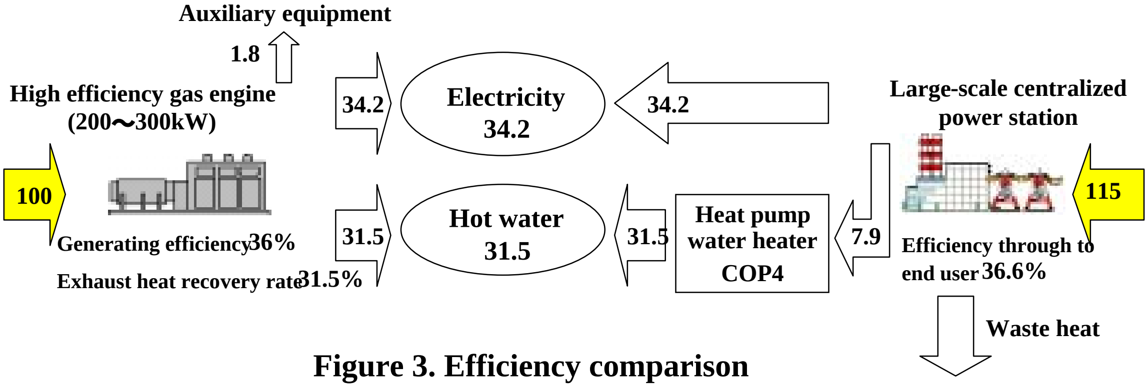
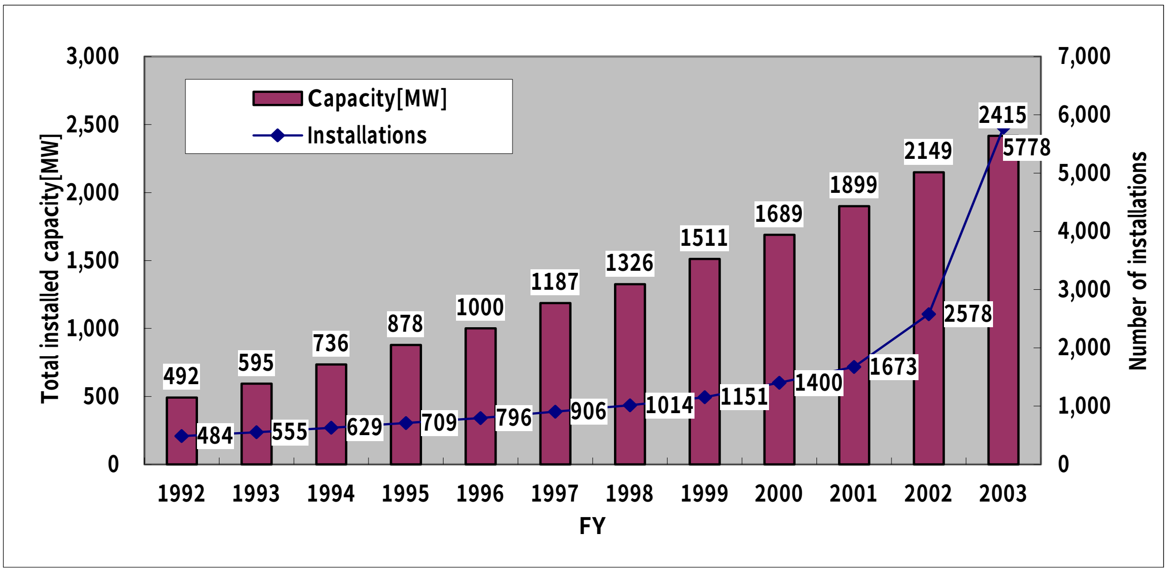


**Figure 3. Efficiency comparison**

## 3. Market penetration of co-generation

Although both the number of installations and the installed capacity of co-generation systems in Japan, as is shown in Figure 4, are steadily and gradually growing, the total generating capacity of gas engines and gas turbines at the end of FY2003 was a mere 2.42 GW, or less than 1.0% of the total generating capacity in Japan. In contrast, as is shown in Table 1, the corresponding figures in European countries are 28% in the Netherlands, 18% in Denmark, 9% in Germany and so on, all of which are much higher than Japan. There are a number of reasons for the difference in the degree of market penetration between Japan and Europe, but one decisive factor appears to be the extent to which each of these countries has institutional measures (see Table 2) to provide support for co-generation.



Source: Japan Gas Association

**Figure 4. Natural gas co-generation installed in Japan**

## Table 1. Penetration of co-generation in U.S. & Europe

| | U.S. | U.K. | France | Germany | Italy | Nether-lands | Denmark | Japan |
|---|---|---|---|---|---|---|---|---|
| Natural gas co-generation (GW) | 18.96 | 3.21 | 0.67 | 10.31 | 3.48 | 5.93 | 2.14 | 2.42 |
| Total generation (GW) | 863.91 | 78.33 | 115.16 | 120.86 | 70.39 | 21.05 | 11.82 | 266.13 |
| Proportion (%) | 2.2 | 4.1 | 0.6 | 8.5 | 4.9 | 28.2 | 18.1 | 0.9 |

Source: Figures for total generating capacity are taken from Electric Power Industry in Japan 2003/2004

## Table 2. Incentives to use co-generation systems in various countries

| | Category | Incentive system | Outline of system |
|---|---|---|---|
| UK | Tax concessions (fuel, etc.) | Climate Change Levy exemption for co-generation | Co-generation systems that meet or exceed efficiency standards are exempt from Climate Change Levy taxation. |
| | Additional capital allowance | Enhanced Capital Allowance | 100% amortization in the year of introduction is permitted for co-generation systems that meet or exceed efficiency standards. |
| | Enterprise tax exemption | A level playing field for Good Quality CHP within Business Rating | Co-generation systems that meet or exceed efficiency standards are exempt from business rating (enterprise tax). |
| | Subsidies for introduction of equipment (investment subsidies) | The Community Energy Programme | Subsidies are available for introduction or upgrading of district heating and cooling equipment. |
| | | Value added tax exemptions for 'Warm Front Team' and CHP facilities installed under the same system | Equipment investment subsidies and added value tax exemptions for systems introduced for low-income groups where there are older people or children |
| | Subsidies for technological development | Energy Efficiency Best Practice Programme (EEBPP) | Program for general technology development relating to energy-saving technology etc. Includes education for promoting uptake as well as technological development. |
| France | Tax concessions | Exemption from TIPP (natural gas consumption tax) and TICGN (oil products tax) | Natural gas co-generation and oil-fired co-generation systems meeting certain standards are exempted from natural gas tax and oil products tax. |
| | Subsidies for amount of power generated (purchase obligation) | The Electricity Law of 10 February 2000 the Order of 31 July 2001 the Order of 3 July 2001 | Electricity purchase obligation system |
| | Subsidies for technological development | 5th Research and Development Programme - Energy, Environment and Sustainable Development (EESD) | General technical development program concerning energy and environment issues, run by the EU |

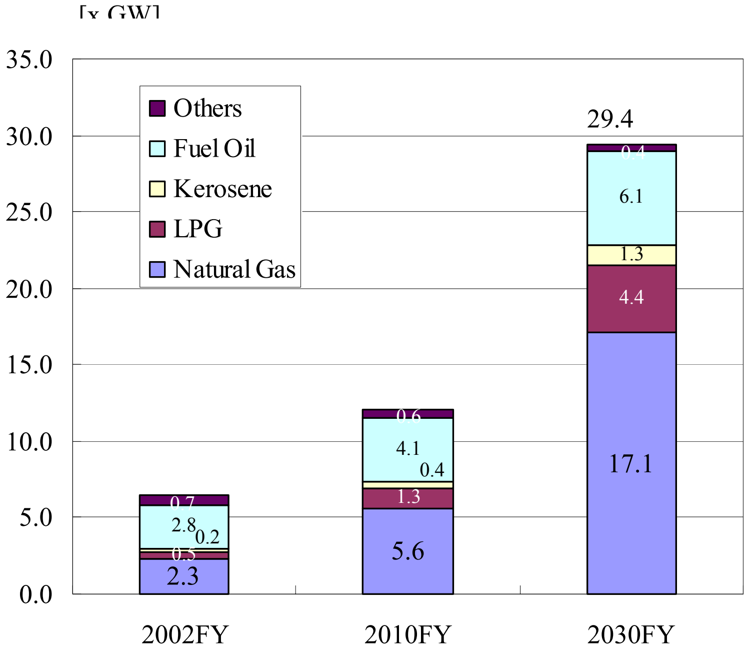
| | | | |
|---|---|---|---|
| Germany | Subsidies for amount of power generated | CHP Modernisation Law (Modernisierungs Gesetz Kraft-Waerme Kopplung) | Subsidies are made available with the aim of protecting the economic aspects of CHP systems. |
| | Tax concessions | Ecological Tax Reform and the Law on Continuing the Ecological Tax Reform | Co-generation systems that meet or exceed efficiency standards are exempt from environment taxation on mineral oils. |
| | Subsidies for technological development | 4th Energy Research Programme - Reduction of Energy Use Program | General program aiming for technological development to enhance energy efficiency. The scope of the system includes co-generation. |
| Netherlands | Subsidies for introduction of equipment (Tax concessions) | Energy Investment Relief + Regulatory Energy Tax (EID) | Enterprise tax deductions from corporate profits for investment in energy-saving equipment |
| | Tax concessions | Exemption from environment tax | Tax exemptions for natural gas used for co-generation |
| | Subsides for introduction of equipment (investment subsidies) | Program for $CO_2$ reduction ($CO_2$ reductieplan) | Investment subsidy system for programs with $CO_2$ mitigation |
| | | Program for energy conservation through technical innovations (energiesparing door innovatie) | For technology with energy conservation effects: Subsidies for surveys of corporate adoption, R&D projects, market introduction projects, and knowledge transfer projects |
| | Subsidies for introduction of equipment (special amortization) | Accelerated Depreciation of Environmental Investments (VAMIL) | Environmental and energy-saving investments can be depreciated as desired. |
| | Subsidies for amount of power generated (purchase obligation ) | Electric power law | Electricity purchase obligation system |
| | Subsidies for technological development | Economy-Ecology-Technology (EET) Program | Program providing support for fields such as development of environmentally-friendly products, transportation technology, renewable energy, sustainable industry and production technologies, etc. |
| | | New Energy Conversion Technologies (NECT) | Technology development program for energy conversion technologies utilizing natural gas as the fuel |
| | | Dutch Fuel Cell Corporation (BCN BV) | Program for technological development of fuel cells |

Source: Japan Gas Association

# 4. Potential for distributed energy systems

## (1) Prospects for introduction by 2030

According to the "Outlook for Energy Supply and Demand in 2030", published in June 2004 by METI, up to five times the capacity of current distributed energy systems, or 20% of the total generating capacity in Japan, will be achieved, if the costs of a distributed system become competitive thanks to technological progress and economies of scale. Fuel cells, in particular, are expected to be one of the prime catalysts in this scenario, and both the industry and government are putting great efforts into the development of fuel cells. Eventually, the capacity of natural gas-fuelled distributed energy systems is expected to grow to 17 GW. The contribution to the reduction of $CO_2$ emission in this scenario is calculated to be 24 million tons.



Source: "Outlook for Energy Supply and Demand in 2030", the Energy Supply and Demand Subcommittee of METI's Advisory Committee for Natural Resources and Energy (June 2004).

**Figure 5. Prospects for distributed energy systems**

## (2) Potential demand

According to the “Outlook 2030” document in the previous paragraph, the capacity of natural gas-fired distributed energy systems is estimated to be 17 GW in 2030, assuming certain progress in technologies and market conditions. Table 3 below, which is based on a METI report from 2000, shows the size of the potential market for natural gas-fuelled distributed energy systems in Japan, estimated sector by sector, and the corresponding reduction of $CO_2$, provided that each market sector is fully converted to distributed systems. The total generating capacity to be installed will reach 56 GW, as shown in the table. The Japan Gas Association estimates that the corresponding reduction of $CO_2$ achieved by the switch to the distributed system can be as much as 73 million t-$CO_2$, equivalent to 6.2% of Japan's 1990 greenhouse gas emissions, which is more than the target for Japan under the Kyoto Protocol.

**Table 3. Potential for natural gas market and the reduction of $CO_2$ emissions**

| Sector | Consumer/ residential | Consumer/ commercial | Industrial | Total |
|---|---|---|---|---|
| Installation potential* (GW) | 14 | 27 | 15 | 56 |
| Estimated $CO_2$ mitigation**(10^6t-$CO_2$) | 9 | 29 | 35 | 73*** |

* Installation potential figures are taken from "New Energy Potential and Economy", documentation from the New Energy Subcommittee of METI's Advisory Committee for Natural Resources and Energy (January 2000).

** $CO_2$ mitigation figures represent the amounts of mitigation compared to conventional systems, estimated on the basis of figures for thermal power stations.

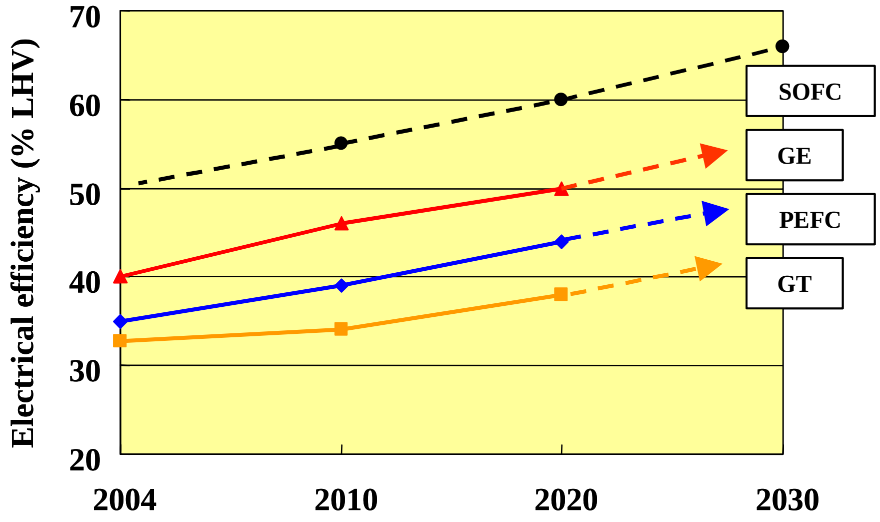
*** 73 million t-$CO_2$ is equivalent to 6.2% of Japan's 1990 greenhouse gas emissions of 1,187 million tons ($CO_2$ equivalent).

## 5. R&D for the future

One of the most important issues with respect to technology for distributed energy systems is to further improve the thermal efficiency of gas generators such as turbines and engines. Thanks to continual hard work by manufacturers, efficiency has been rising in each type of generator and is expected to improve in the years to come, as shown in Figure 6. In order to expand the co-generation market, improvement in efficiency must be fulfilled for a wide range of capacity, from small generators to large ones. Recently, after considerable development, a new co-generation product, which replaces a conventional water heater and supplies a part of the electricity required for a household using up to 1kW, has been launched for the residential market and has been received favourably by customers.

Efforts are not limited to rotational machines. Efforts to develop polymer electrolyte fuel cells (PEFCs) and to commercialise co-generation systems using PEFCs are under way. The target is to introduce the fuel cell co-generation system, whose generating capacity is 1 kW, into the residential market as early as 2005. The government fully supports development of fuel cell technologies, not only PEFCs but also solid oxide fuel cells (SOFCs), which are a different type of fuel operating at higher temperatures and, therefore, greater efficiency, and practical applications of fuel cells with high electrical efficiency are expected to come to market in the foreseeable future. Further ventures and efforts will continue to cut costs and increase the durability of fuel cells.

Improvements in the efficiency of each generator are important both for stand-alone application of co-generation and for distributed energy systems, because they will increase opportunities for using co-generation and improve the economics of the system.



Note: SOFC: solid oxide fuel cells, PEFC: polymer electrolyte fuel cells,
GE: gas engines, GT: gas turbines

**Figure 6. Projection of efficiency improvements**

## 6. Local area energy networks

Even when individual co-generation systems have come to attain maximum energy efficiency, there appears to be more room for further improvement in efficiency when the community as a whole is taken into consideration. The proportion of heat and power required varies from customer to customer, as well as the proportion of one single customer also varies from time to time. Therefore, if the optimisation of energy efficiency is viewed from a different angle, i.e. not individually but collectively as a local community, solutions for optimisation may take a different form. To achieve this community level optimisation, what is required is a local area energy network for heat and power. If energy users in distributed energy systems are connected to a local network and can pool heat and power, it will be possible to accomplish additional energy savings. Instead of installing separate distributed energy systems at individual locations, using shared co-generation and other distributed energy systems to pool heat and electricity among customers via an area network can further increase energy efficiency and reduce $CO_2$ emissions.

Figure 7 shows local energy pooling of various forms of energy in the future. In a local community, several energy consumers and producers such as houses, offices, and factories exchange energy via a variety of local networks. They will use the Internet to exchange information for balancing and controlling energy demand and supply in the area. Of course, the local energy pool will operate in close co-ordination with the power grid and pipeline networks of natural gas, a preferred fuel for distributed energy systems. Each participant within the local pool will actively play its own role in improving energy efficiency, in mitigating the impact on the environment and, ultimately, in obtaining the maximum value from the pool. During this process, new businesses may emerge and, in due course, new forms of energy such as renewables and hydrogen will be incorporated into the system as local energy sources or even centralised sources.

Figure 7 also implies that local networks will encourage the development of new technologies such as fuel cells and hydrogen, and that society as a whole will gradually shift towards less energy-intensive and carbon-intensive systems.

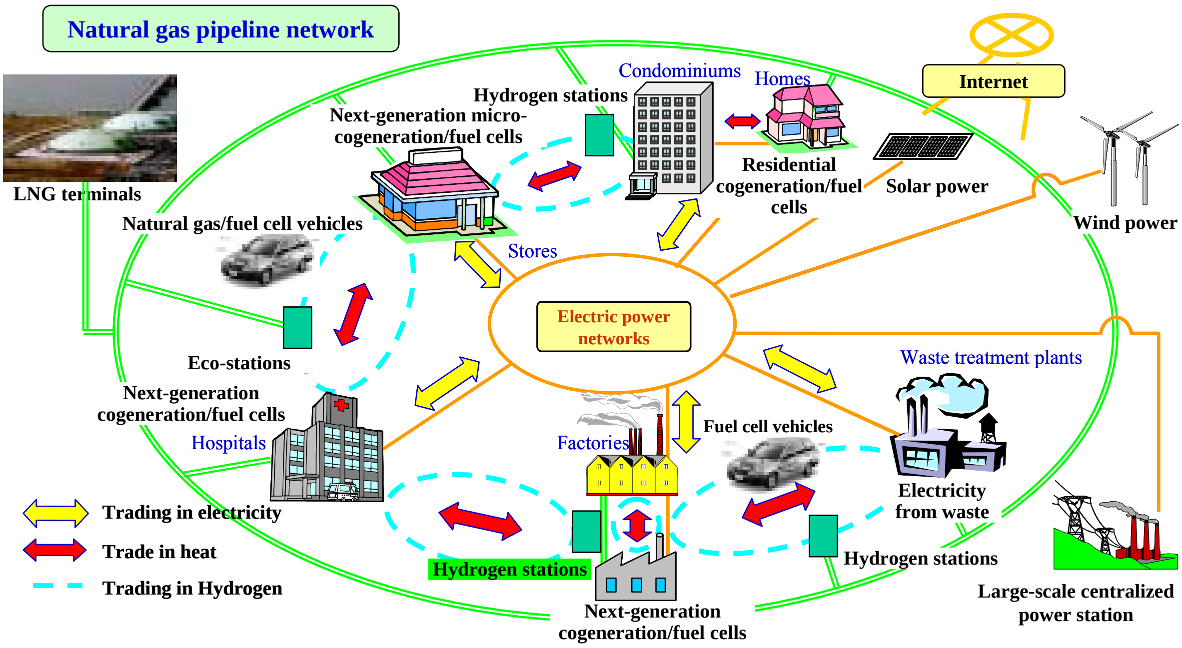


**Figure 7. Local area energy networks**

- Roppongi Hills

As an example of a distributed energy system, Figure 8 shows the Roppongi Hills Development Project which provides energy for eight buildings with a total floor area of 755,000 m2. All the electricity and heat required within the area is provided by one company, Roppongi Energy Service Co., Ltd. The total capacity of gas turbines is 38 MW and their heat is used either directly for users as steam, or through absorption chillers to supply chilled water. The proportion of heat and electricity produced by the turbines is adjustable to handle fluctuations in power and heat loads within the area.

This system is designed to achieve 20% primary energy savings and 27% $CO_2$ reduction. An additional advantage of the system is that it reduces construction costs because individual buildings do not need space and equipment to generate heat or receive electricity.

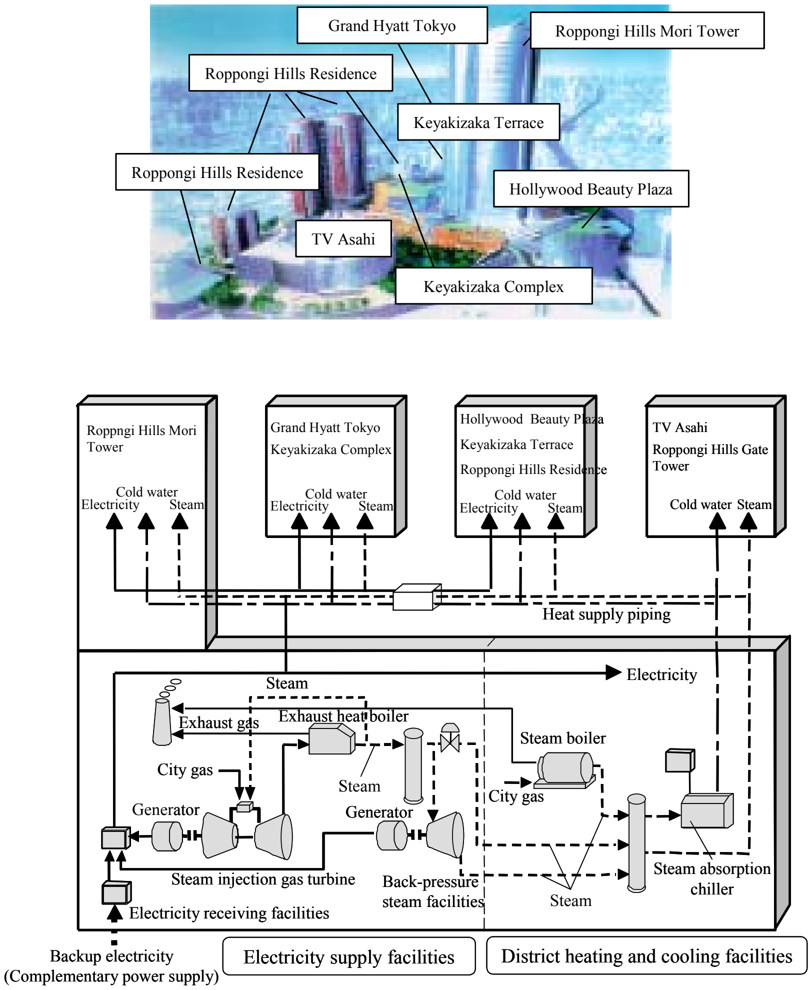


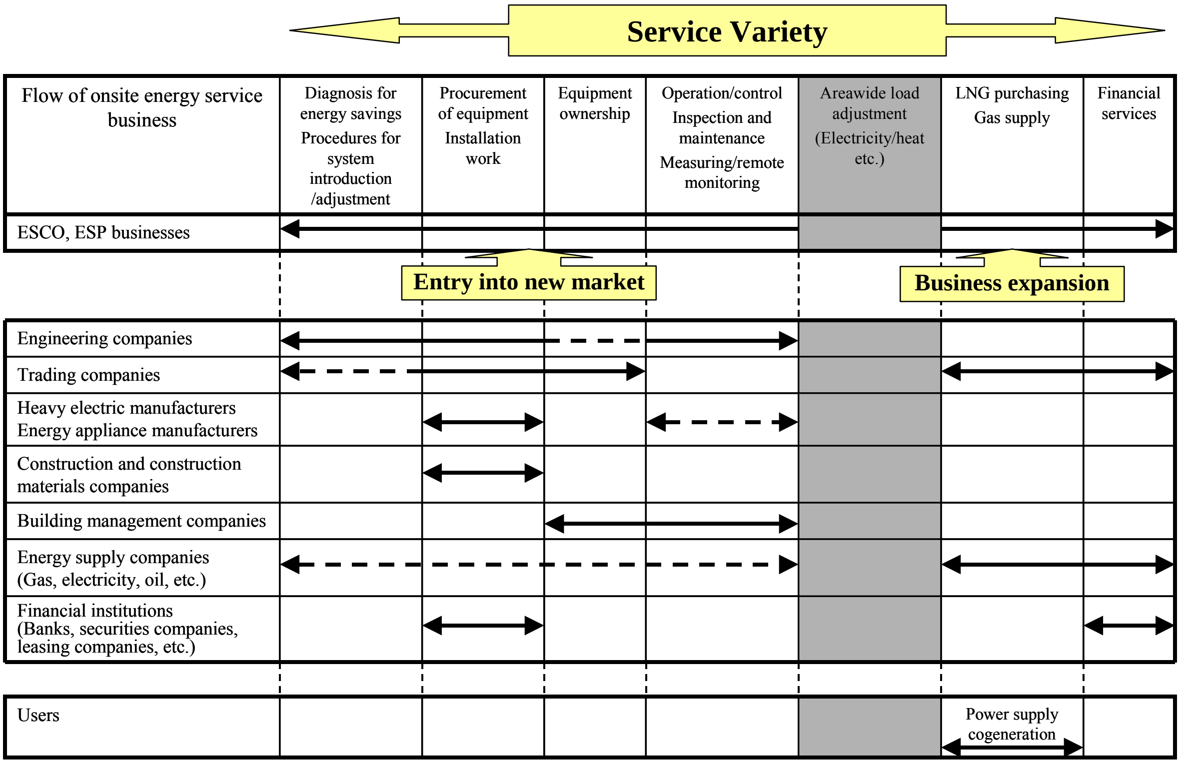
**Figure 8. Roppongi Hills Project**

## 7. New business opportunities

An additional advantage of a distributed energy system is that it gives an opportunity to various entities to be involved in a distributed energy business. Unlike centralised power stations, there are a wide variety of stakeholders in distributed energy projects.

So-called energy service companies (ESCOs) or energy service providers (ESPs) will have an important role to play in the promotion of distributed energy systems. They have in-house specialists, know-how and financial strength to provide a variety of services such as diagnosis for energy saving, equipment ownership, control of operation, fuel provision, and financial services. They can propose attractive distributed energy projects to customers and mobilise the necessary resources for projects, which need not be confined to Japanese.

New industry players coming into the market as ESCOs, ESPs or other companies will include engineering companies, trading companies, heavy electric equipment manufacturers, and financial institutions, as well as utilities that supply energy in the form of gas or electricity. Those utilities that are ready and willing to expand their businesses can make contributions to distributed energy system projects beyond their traditional role as energy suppliers. Throughout the course of project development, from design and construction of distributed energy systems to operation, maintenance and financial services, utilities can become one of the key players in the project.



*Solid lines mark core business areas

**Figure 9. New businesses & players**

The new players will compete and co-operate to make the system more economical and reliable and environment-friendly. In addition, possible competition and co-operation with large-scale centralised power supplies will work as a motivation for achieving greater energy efficiency, and will bring substantial benefits to customers.

## 8. Challenges for distributed energy systems

There are many potential sites (more than 1,000) in Japan where pooling of electricity and heat is considered possible within the local area, provided an energy network existed. In practice, however, it is difficult to develop an area energy pooling scheme only through the efforts of the private sector because the co-ordination of various interests in the area to form a operationally and financially sound venture is a lengthy and painstaking process. In order to form local energy networks, therefore, it must be given an appropriate place in the national energy policy as a necessary social infrastructure, having such institutional and financial privileges as access to public funds, tax-exemption and subsidies.

For example, in the case of development or redevelopment of a property in an urban area, the developer is required to undertake an energy study. The study is to determine, with support from the local authorities, whether it is feasible to install a local area energy network for pooling energy with the surrounding buildings. Preferably, the study will include the feasibility of local renewable energy resources such as solar, wind and waste into the energy network.

There are also some technical problems. One is the problem of how to facilitate access to the power grid, which must be sorted out in order to form a local power pool. New technology may be needed to ensure a safe, reliable and cost effective connection to the grid. Easy access is vital in order to add a small-scale generator to the pool.

## 9. Conclusions

There is still great potential in Japan for further use of natural gas. Use of natural gas will intrinsically contribute to energy savings and reduction in $CO_2$ emissions, but an important factor in maximising the benefits of gas is the formation of distributed energy systems, or, to be more specific, local area energy networks, which connect co-generation systems to pool heat and power in the area. Distributed energy systems will provide both great benefits for energy consumers and many opportunities for new players in the market, and thus will vitalise the economy.

Competition and co-operation to gain customers by offering better services and prices will take place among ESCOs and ESPs as well as between distributed and centralised systems. This competition will produce a motivation to seek greater energy efficiency in energy systems, which will bring substantial benefits to customers and society in general.

Japan's experience in distributed energy systems will be transferred to other Asian countries such as China and India, where the appetite for energy is expected to grow rapidly. From a global perspective, working on energy efficiency and environmental conservation in these countries is of vital importance. Japanese ESCOs and ESPs can expand their business base overseas by taking advantage of the transfer of technology. Since energy use and available technologies differ from country to country, systems will have to be adjusted to fit regional requirements.

Japan's city gas utilities will continue to do their utmost to improve the efficiency and economics of co-generation systems. They would also like to solicit appropriate institutional encouragement from central and local governments to install co-generation systems and relevant infrastructure. Gas utilities believe that co-generation systems connected to local area energy networks will bring about an energy-efficient and environment-friendly future. Success in Japan will also pave the way to sustainable growth for other countries, and will be the key to achieving energy savings and reductions in $CO_2$ emissions on an international basis.

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