

# **The Advantages of Combined Cycle Plants: A 'New Generation' Technology**

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Electricity industries worldwide are undergoing a period of profound upheaval. The way electricity is generated, who generates it, who finances its generation, how it is delivered, and how prices for it are determined are all changing. And as electricity technology changes, the role of governments, electricity producers, consumers and citizens in electricity development and decision making are also changing.

Technological advances now make it possible to generate electricity on a small scale at the same, or lower, cost than that produced from the very large, centrally managed power stations built over the last fifty years. Of particular interest are the advances in cogeneration -- the process of simultaneously producing useful heat and electricity from the same fuel source -- which increases the efficiency of fuel burning, from 30 percent up to 90 percent, thereby reducing damage to the environment while increasing economic output through more efficient use of resources.

Cogeneration systems, especially those using gas combined cycle units, are proving so successful in industrialized countries that some industry analysts predict they will render the model of centralized generating stations obsolete within the next decade. Already, superefficient combined cycle plants using cheap natural gas are displacing state-subsidized, environmentally destructive power plants (i.e., large-scale coal, hydro, and nuclear).

The global electricity supply industry recognizes the combined cycle plant as the generating technology of choice for private investors because of its outstanding efficiency and performance. In parts of Europe and North America, its demonstrated environmental advantages have led environmentalists, rural communities, and other citizens' groups to advocate reforms that promote the use of combined cycle plants as well as other clean, decentralized generating technologies. For those concerned about building sustainable electricity systems in developing countries, this report outlines both the economic and environmental advantages of combined cycle plants and provides examples of their successful application around the world.

## Fuel Efficiency

Combined cycle plants include a gas-fired turbine and a steam-driven turbine that generate electricity. They are superior to conventional thermal power plants because of their high fuel conversion efficiency. In conventional power plants, turbines have a fuel conversion efficiency of about 33 percent -- which means that two-thirds of the fuel burned to drive the turbine is given off to the atmosphere as waste heat. With such inefficiency, it made economic sense in the past to use the cheapest fuel possible in the process, usually coal. The turbines in combined cycle units, on the other hand, have a fuel conversion efficiency of 50 percent or more, which means they burn about half the amount of fuel as a conventional plant to generate the same amount of electricity. Heat given off by the first gas-driven turbine is used to produce steam for the generation of additional electricity by a second steam-driven turbine. All remaining waste heat can then be used for industrial applications in which case the fuel conversion efficiency can be as high as 90 percent.

The waste heat can be used in the form of steam or hot water in applications such as food processing, production of building materials (cement, kiln-dried lumber) and of petrochemicals, and heating and cooling systems. Combined cycle plants that cogenerate (produce electricity and steam) are also ideal for replacing conventional boilers (hot water heaters) that typically have a fuel conversion efficiency of just 30 percent.

Efficiency ratings are extremely important in economic terms because over a 20-year project life, 70 percent of the operating cost for a combined cycle plant of any size is the cost of fuel. Therefore, efficiency improvements can represent significant fuel cost savings to the plant owner and lower electricity rates for the power consumer. Greater efficiency in terms of fuel resource consumption also means that more electricity can be generated with less damage to the environment. According to Siemens, a leading German supplier of combined cycle plants, an increase in efficiency of just one percent at a 100-megawatt (MW) plant represents electricity savings equivalent to the electricity needs of 1,000 Germans.

In the last decade, private industry has steadily improved the fuel efficiency of combined cycle plants. In 1993, the Swiss multinational Asea Brown Boveri (ABB) developed the world's most efficient combined cycle plant in Korea with over 50 percent efficiency. Two years later, General Electric developed a turbine that broke the 60 percent efficiency barrier.

## Low Capital Costs

The capital cost of building a combined cycle unit are about two-thirds the capital cost of a comparable coal plant. Depending on model and size, the capital cost can range from US\$400 to US\$900 per kilowatt (kW). Plants under 115 MW, for example, can cost between US\$600 and US\$850 per kW. (A large hydrodam can cost US\$2500 per kW or more to build.)

Based on operating experience, the payback period for combined cycle plants is significantly shorter than conventional power plants. In general, the payback period for a combined cycle plant is around 7 to 11 years compared with 15 to 23 years for a large dam after it is completed, which usually takes 7 to 10 years. In the Philippines, the Hong Kong-based infrastructure developer, Hopewell, secured commercial financing and built a 210-MW combined cycle plant for US\$41 million in less than a year. By comparison, a hydrodam in Lao PDR, with the same installed generating capacity, is expected to take 7 years to build at a cost of US\$280 million. As far as the payback period, the dam's Nordic developers are hoping they will break even after 10 years of operation (weather permitting). Unlike Hopewell's plant, the hydrodam in Laos has taken almost a decade of planning and was able to attract commercial financing only after the Norwegian government provided more than US\$12 million in grants and the Asian Development Bank provided a US\$60-million interest-free loan to lower the capital costs, as well as other grants to shift responsibility for the project's social and environmental costs away from commercial investors.

While costs associated with conventional power plants continue to escalate (due to land expropriation conflicts and demands for compensation, tougher emission controls, environmental mitigation measures, thorough environmental assessments, and public consultation), the capital cost of combined cycle units has actually dropped over the last few years by as much as 40 percent. Even the smaller units ranging from 1 MW to 20 MW in size, which cost roughly 30 percent more per MW than the larger units, are still cheaper than conventional thermal plants.

Because of their low cost, some private power producers in the United States anticipate that electricity can be profitably delivered to U.S. markets from combined cycle units for as little as 2.0 to 2.5 US cents per kilowatt-hour (kWh). In Canada, combined cycle plants are currently supplying electricity to customers for less than 5 US cents per kWh. In Thailand, the first private power producers to install large combined cycle plants have agreed to sell their electricity to the central utility for an average 5 US cents per kWh.

## Commercial Availability

Combined cycle units are commercially available from suppliers anywhere in the world. They are easily manufactured, shipped, transported and plugged into new or existing transmission systems that deliver electricity to towns or even to a single unit, such as a factory, commercial building, or college campus. In developing countries, the commercial viability of combined cycle technology makes rapid upgrading and expansion of electricity systems possible without government subsidies or guarantees, which have typically been required for investments in electricity supply expansion.

In the last decade, the world's leading manufacturers of conventional power equipment, such as Black & Veatch and General Electric of the U.S. and ABB of Switzerland, have diversified into the design and manufacture of combined cycle systems. In Austria, a leading hydropower turbine manufacturer, ELIN, promotes its combined cycle plants as "the power plant of the future." General Electric is gearing up for expanded sales of high-efficiency gas turbines (used in combined cycle units) in developing countries, where demand for new power plants and electricity supply is growing more rapidly than in many industrialized countries.

To reduce installation time and costs, manufacturers and equipment suppliers, such as Japan's Kawasaki, have worked to simplify design and installation through the use of pre-engineered, standardized packages that include both equipment (turbines, heat recovery boilers, electric generators), plant services and, in some cases, local distribution systems. On average, the installation time for a combined cycle plant of 150 MW to 200 MW is about one year or less. Recently in Argentina, Black & Veatch installed a General Electric combined cycle unit (128 MW) for a local company in just nine months.

## High Performance Standards

Private purchasers of combined cycle units are demanding higher performance standards of their suppliers than state-owned utilities did, leading to better industry-wide standards. Typically, performance and obligations are specified and enforceable by commercial contracts signed by both the purchaser and supplier. In India, for example, the Punjab Alkalies and Chemicals company invited bids from power companies to install a 50-MW combined cycle plant to provide electricity and steam to its industrial complex. Successful bidders were required to have installed a similar plant elsewhere and were asked to provide evidence of its successful performance for a period of at least two years.

## **Abundant Fuel Sources**

The turbines used in combined cycle plants are commonly fuelled with natural gas, which is found in abundant reserves on every continent. Natural gas is becoming the fuel of choice for private investors and consumers because it is more versatile than coal or oil and can be used in 90 percent of energy applications. To meet demand, the gas industry is rapidly expanding production in most countries, including those that have not previously tapped their reserves, such as Mexico, Malaysia, Brazil, and Vietnam. Japan is one of the few countries in the world without its own reserves but it imports liquefied natural gas from its gas-rich neighbours, Indonesia and Malaysia, and its electric utilities have rapidly expanded their use of combined cycle plants. Chile, which once depended on hydropower for 70 percent of its electricity supply, is now boosting its gas supplies to reduce reliance on its drought-afflicted hydrodams. Similarly, China is tapping its gas reserves to reduce reliance on coal, which is currently burned to generate about 80 percent of the country's electricity supply.

Where the extension of a gas pipeline is impractical or cannot be economically justified, electricity needs in remote areas can be met with small-scale combined cycle plants, using renewable fuels. Instead of natural gas, combined cycle plants can be fuelled with biogas derived from agricultural and forestry waste, which is often readily available in rural areas.

## **Reduced Emissions and Fuel Consumption**

Combined cycle plants use less fuel per kWh and produce fewer emissions than conventional thermal plants, thereby reducing the environmental damage caused by electricity production. Because of this, suppliers such as Siemens of Germany advertise their combined cycle plants as the technology for the environment, offering "ideal solutions to environmental problems because of their outstanding performance and efficiency."

Compared with a coal-fired plant installed with the latest clean coal technology, the burning of natural gas in combined cycle plants is much cleaner. Combined cycle plants produce no sulphur and virtually no particulate matter; they reduce nitrous oxide emissions by up to 90 percent and carbon dioxide by 60 percent. In Britain, installation of gas combined cycle plants in the last decade has displaced the burning of about 30 million tonnes of coal annually, which is equivalent to roughly 40 percent of the country's total coal mine output in 1992.

As electricity investment decisions become increasingly influenced by public objections to air

pollution, and as the demand for tougher emission standards and environmental regulation of power producers increases worldwide, the combined cycle plant is expected to replace conventional thermal power plants.

### **Reduced Need for Long-Distance Electricity Transmission**

Combined cycle plants can be installed near industry or other demand centres, thereby reducing the need for transmission of electricity over long distances, lowering the overall cost of electricity to consumers, and eliminating the rationale for building environmentally destructive power projects in sparsely populated areas to serve distant markets. Instead of moving energy through electric wires, it is more efficient to move gas through pipelines and avoid the losses experienced in electricity transmission systems, which can range anywhere from 30 percent to 70 percent. And because natural gas is methane, it is relatively easy to process compared with oil and less expensive to transport via pipeline than coal by rail.

Regions that do not already have access to a central transmission system or grid can avoid massive subsidization and overexpansion of long-distance transmission systems, as experienced in many developing countries, by promoting private investment in combined cycle plants and local distribution wires.

### **Decentralized and Flexible Electricity Supply**

The average size of combined cycle plants is declining worldwide, indicating a trend to more decentralized, flexible generation after decades of highly centralized generating systems. The first wave of combined cycle plants built in the mid-80s were large -- in the 600-MW range -- compared with an average of 100 MW by 1992. In terms of plant and fuel efficiency, some private power companies report that the optimal size of plant is 50 MW or less.

Unlike conventional power plants, combined cycle plants are well suited to operating for peak or intermittent demand because they can be quickly switched on and off as needed. Whereas conventional power plants are often designed to run continuously to feed a central grid, independent of local demand, combined cycle plants are designed to respond to the varying demands of their customers. With the combined cycle units, the plant operator has the choice of running both turbines for greater electricity output or running just the gas turbine to produce electricity while utilizing the waste heat for other purposes.

Combined cycle plants can be profitably operated in a wide range of sizes suited to local needs (i.e., industrial estates, factories, university and college campuses, commercial buildings, municipal offices, and rural cooperatives). In developing countries, the first wave of beneficiaries of this technology have been the large, industrial power consumers that typically consume at least half the country's electricity supply and require vast amounts of electricity and steam. By installing and operating their own combined cycle plants, large power consumers expect to lower their production costs and also boost the efficiency of their operations.

In Thailand, for example, a semi-conductor producing company, Alphatech Electronics, recently set up its own power generating company and installed a 210-MW combined cycle plant that supplies electricity and steam on-site and to housing and commercial facilities in the vicinity. By generating its own electricity, Alphatech expects to save approximately US\$40 million a year on its electricity bill. The plant also includes a gas-fired cooling system to produce chilled bottle water as a byproduct. (Alpha Power is 20 percent owned by the U.S.-based power company Sight, and it bought the plant technology from GEC Alstrom of France, Mitsubishi of Japan, and Electrowatt of Switzerland.)

Apart from the industrial sector, a 100-MW plant is capable of supplying a large university with all its electricity, hot water, heating, and steam for air-conditioning and chilled water systems. A 5-MW plant could supply a hospital. And a 10-kW unit can supply a small business, such as a coin-operated laundry, with electricity and steam, saving hundreds of dollars monthly in electricity, heating, and cooling bills.

### **Trends and Potential Applications in Developing Countries**

The potential for reducing environmental damage and making rapid improvements to power generating systems, using combined cycle units, is greatest in countries such as China or India where power consumers are heavily reliant on coal, where electricity, steam, or heat are currently used extremely inefficiently, and where millions of rural people have no access to electricity.

In China, for example, power cuts and black-outs currently affect 40 percent of industry in some parts of the country and some inland provinces experience chronic shortages of electricity. To expand electricity supply, without increasing reliance on coal, the government has accelerated gas exploration and production and is constructing gas pipelines to prepare for a boom in combined cycle gas plants in the next 10 years. (The environmental benefits of cogeneration have already been proven in Jingzhou province where the state utility built a cogeneration plant in 1986. This

eliminated the need for 115 small coal-fired boilers and reduced sulphur dioxide and particulate concentrations in the area by 32 percent and 48 percent respectively.)

The largest immediate potential for new combined cycle plants, or retrofitting old power plants, is with industry that requires electricity and heat or steam. In the paper industry, for example, 8 out of 14 processes require steam. Pharmaceutical industries also have a steady demand for steam. China's textile industry alone could save an estimated one million tonnes of coal annually through cogeneration. Sugar refining mills in China have already installed nearly 500 MW of cogeneration capacity. The chemical fertilizer industry also has a large potential, and in rural areas, where forest and agricultural waste is readily available as a low-cost source of fuel, cogeneration is a commercially viable option.

In Africa and Latin America, where state utilities are overly dependent on large-scale hydrodams, where drought has crippled electricity output, industrial power consumers have begun to invest in small combined cycle plants to meet their needs. In Ghana, for example, Westinghouse recently installed combined cycle units on easy-to-move barges along the coast to supply electricity to the country's energy-intensive mining industry.

In Colombia, more than three-quarters of the country's electricity supply has traditionally come from hydrodams whose output today is crippled by frequent drought. To avoid production losses due to power shortages, the country's largest private industrial and financial group, Sindicato Antioqueno, plans to invest in a 160-MW power plant in Barrancabermeja. The project cost is US\$ 80 million, and it is expected to start commercial operation in December 1997. Sindicato Antioqueno's international partners include: the Wing Group, which is a subsidiary of Western Resources, an energy company that is developing other combined cycle plant projects in China and Southeast Asia; and Conoco Global Power Inc., an international power project development company, which is a subsidiary of the Houston-based Conoco Inc., and its parent company, Dupont.

In Cambodia, where the state-owned electricity system is bankrupt and decrepit after years of war and political upheaval, private companies are prepared to invest in combined cycle plants while the government's plans for massive-scale hydrodams have failed to attract private investors. A U.S. power company, Beacon Hill, for example, has raised financing for a 60-MW combined cycle plant to supply electricity to the capital of Phnom Penh. Similarly, in newly opening Vietnam, the government is having difficulty finding investors for its planned massive-scale hydrodams meanwhile private companies are moving ahead with combined cycle plants. The new

Amata Power Company, for example, is backed by local and international investors to install a 214-MW combined cycle plant to supply electricity and steam to the Amata City Bienhai Industrial Estate, near the southern capital Ho Chi Minh.

Elsewhere in Asia, combined cycle plants are becoming a popular alternative to dependence on state utilities, which are often incapable of providing reliable supplies of electricity to their customers. In Pakistan and Indonesia, the U.S.-based El Paso Energy Corporation recently invested in several combined cycle plants, ranging from 130 MW to 150 MW. In Indonesia, the Asia Pulp and Paper mill in Tangerang installed a 10-MW combined cycle unit to power its own mill and provide steam for paper making.

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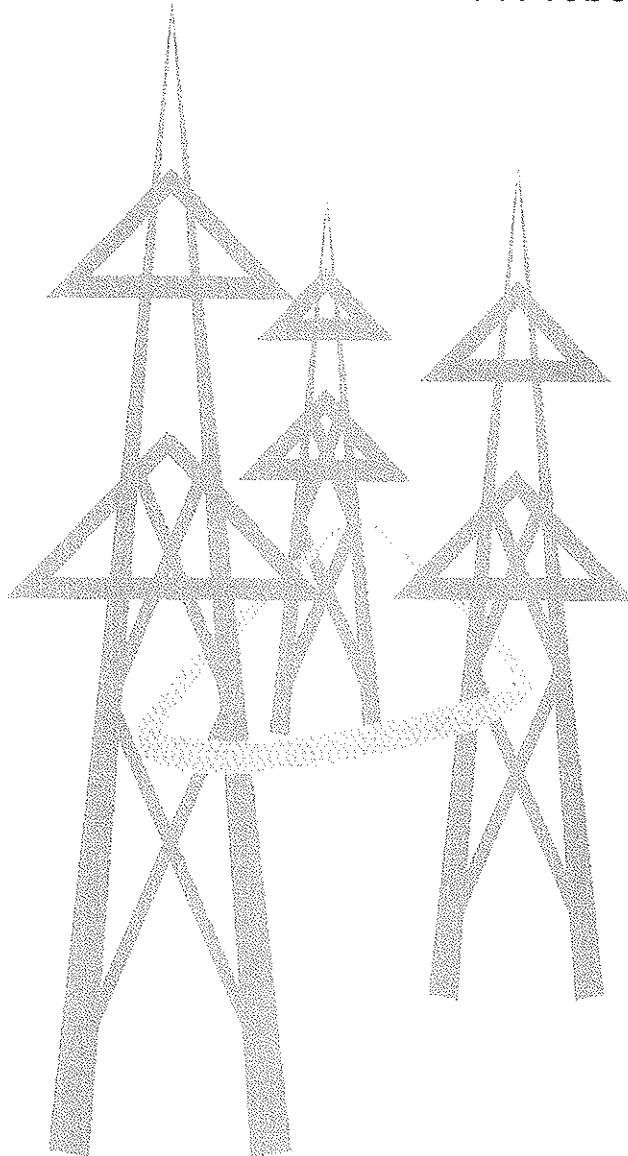
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The Advantages of Combined Cycle Plants:  
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