



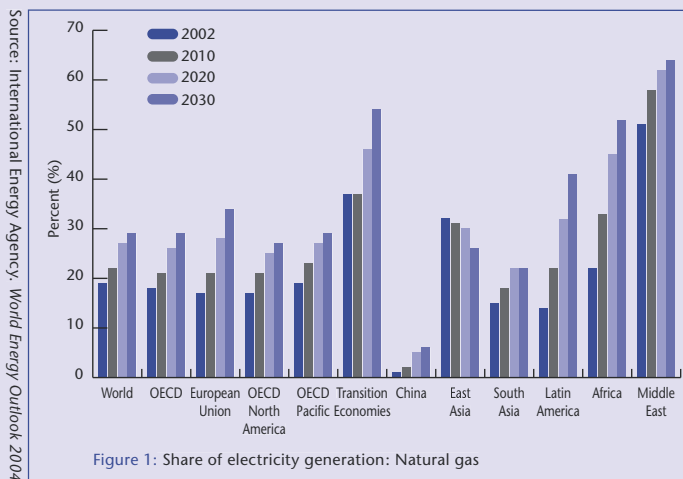
Issue Brief NATURAL GAS

(IN ELECTRICITY GENERATION)

SHARE OF ELECTRICITY GENERATION

The market share of natural gas in worldwide power generation grew from 13% in 1971 to 19% in 2002, and is expected to continue to grow strongly. It is projected to reach 27% by 2020.¹

The share of natural gas in electricity generation is highest in those countries with indigenous supplies, particularly where gas is a by-product of oil production (the Middle East and transition economies). It is projected that the share of generation in China will remain under 10%, with coal continuing to dominate. Yet even in China there will be tremendous growth in the application of natural gas for power generation and other uses. Relatively low shares in 2030 are also projected for India (15%) and Brazil (22%). Conversely, shares of over 50% are projected for Russia, Mexico and many European countries (e.g., the UK and Netherlands).² This raises security of supply concerns for those countries which are net importers of gas, as they become ever more reliant on one imported fuel. One major uncertainty in these projections is the development of gas prices. In many places, they have more than doubled since the year 2000. If they stay at such high levels, this would affect future growth of demand.



The strong growth in gas demand for power generation in the 1980s and 1990s was driven by:

- The five-fold increase in oil prices between 1973 and 1982 and the subsequent oil price volatility;
- Certain countries (e.g., the US and the UK) removing constraints on using natural gas for power generation;
- Gas turbine technology improvements – current combined cycle gas turbine (CCGT) conversion efficiencies of over 55% are unprecedented in the history of using fossil fuels to generate electricity;
- Relatively low capital costs (CCGT typically US\$ 570/kW) and project lead time (CCGT typically 2 years);³
- Development of infrastructure for long distance transport (pipelines and liquefied natural gas (LNG)) – gas transportation has an excellent safety record;
- Significantly lower emissions when compared to oil and coal.

RESOURCE AVAILABILITY

The International Energy Agency (IEA) reports that proven gas reserves were 180 trillion cubic meters (tcm) at the start of 2004.⁴ This is equivalent to 66 years at 2002 production rates, and is higher in energy equivalent terms than proven oil reserves. Russia, Iran and Qatar jointly account for two-thirds of global gas reserves, although significant reserves have now been found in 90 countries. As much as one-third of all reserves are “stranded” (i.e., in locations where production and transport costs are prohibitive with today’s technology). Ultimate reserves (including proven reserves, reserve growth and undiscovered resources) have been estimated at 436 tcm (160 years at 2002 production rates).⁵



North America is currently almost self-sufficient in natural gas (US net imports of 17% of demand in 2005 are largely met by Canada, using pipelines). Trade flows between regions in 2002 were dominated by⁶:

- Pipeline exports from Russia to Western Europe – 112 billion cubic meters (bcm);
- LNG and pipeline exports from Africa to Western Europe – 63 bcm;
- LNG exports to Japan from the Middle East – 29 bcm and East Asia – 59 bcm.

IEA projections to 2030 include:

- Worldwide gas demand will grow by approximately 2.3% per year, nearly doubling total demand.
- Power sector demand is expected to increase (it accounted for 36% of demand in 2002).
- The majority of new demand will be in North America and Western Europe.
- Incremental production will be in those countries best linked to these major markets: transition economies and the Middle East are projected to increase their production strongly, and Asia, Africa and Latin America are also projected to significantly increase their production.

Trade will use pipelines where possible, but extremely large growth in the transportation of natural gas by sea using LNG networks is expected. Total trade is projected to grow by approximately 3 times to over 1,000 bcm per year over the period 2002-2030, driven largely by the demand increases foreseen for Western Europe and North America. Transportation costs are projected to increase markedly as distances between producers and demand increase.

The number of countries that are net exporters of natural gas is likely to decline as indigenous demand growth turns many net exporters into net importers. Supply to date has been reliable, but a declining number of net exporters will concentrate market power in relatively few countries, increasing security of supply and geopolitical concerns.

The strong projections in natural gas growth depend on a major increase in the availability of gas at competitive prices. Massive investments are needed in capital-intensive production facilities, terminals and transportation infrastructure. There are many other uncertainties, including:

- The ultimate costs of production and transport.
- The future price of gas relative to oil, coal and other energy sources – all projections envisage strong increases

in gas prices compared to the relatively low prices experienced during the 1990s.

- Geopolitical factors affecting project risk and which pipelines will be built and their routes.
- Countries' policies on energy security – importing countries may not wish to have too heavy a reliance on natural gas, either for power generation or in the wider economy.
- The pace of liberalization of gas markets.
- The exploitation of "non conventional" gas sources (e.g., coal bed methane, gas from tight sands and oil shale). Such gas already accounts for a quarter of US gas output.⁷
- The exploitation of GTL (gas to liquids, which uses natural gas as a feedstock to make oil products). GTL plants remain largely in the pilot phase, but high oil prices have led many companies to build commercial plants. Such plants could provide a method for bringing natural gas from remote locations to the market.

Various projections show that natural gas demand is likely to peak at some point in the 21st century. If this is the case, natural gas should be seen as a transitional resource. Oil may also peak this century. Transport and distribution infrastructure can later be reused for other forms of gaseous fuels, or see a progressive modification of the composition of the gas (mixing with syngas, hydrogen, etc.).

CURRENT TECHNOLOGIES

Early on, natural gas power was generated in steam cycles using conventional steam boilers, often capable of burning oil or coal as well as natural gas (i.e., "multi-firing"). Electricity generation efficiencies were typically around 35%. More recently, multi-firing applications have been built to take advantage of cheap gas quickly while retaining fuel flexibility. To the extent that climate policy begins to favor less greenhouse gas intensive power generation, these multi-firing units will have another advantage.

The development of the gas turbine and its adaptation for stationary use revolutionized gas-fired power generation. Available since the mid-1980s, gas turbine power generation systems are more efficient, less expensive and quicker to build than their coal-fired counterparts. Combining the gas turbine with the steam turbine in a CCGT is now yielding efficiencies in excess of 50%; capital costs (US\$ 570/kW) and project lead times (2 years)⁸ are lower than for any other large scale generation technology, and are particularly attractive to private sector investors in deregulated markets.

Turbines account for the vast majority of generation from natural gas. Many of the older conventional gas-fired units, including those using multi-firing, tend to be replaced by new CCGT over the medium term. Reciprocating engines and micro-turbine generators are used in niche applications only. In many areas, a very large percentage of new power plants will use natural gas; the use of oil for electricity generation has now practically been eliminated and coal has been displaced in many countries.

Gas-fired power plants can serve all the basic functions of electricity generation, provided the gas is available:

- CCGT and multi-firing operate as base/mid-merit plant.
- Open cycle gas turbines (OCGT) efficiencies are typically 35%, i.e., significantly lower than CCGT; capital costs tend to be approximately 20% lower.⁹ They act in mid-merit/peaking mode, and can be distributed within the medium voltage electricity transmission grid.
- Reciprocating engines and micro-turbine generators are relatively small and serve a significant and growing share of the decentralized load.

All thermal power plants can be used for combined heat and power (CHP). As a practical matter, small gas-fired units close to point of energy use are much more likely to find applications for utilization of waste heat than remotely-sited central units of any type.

Fuel costs dominate gas generation costs, typically accounting for 65-90% of total costs. Decisions to invest in gas are thus dependent on expectations of gas prices, particularly over the next 10-15 years. Gas prices have increased significantly from relatively low levels experienced in the 1990s (e.g., the real price of imports to the US ranged between US\$ 1.6 and 2.3/thousand cubic feet from 1990-99, but had more than doubled to US\$ 5.37 in 2004¹⁰). The volatility of gas prices over the short and medium term, and the potential for rising gas prices in the longer term, are forcing many potential investors to reconsider their options.

IMPACTS

Environmental – Global

Natural gas plants generate the lowest carbon dioxide emissions of any fossil fuel. Natural gas has a lower quantity of carbon per unit of energy produced than other fossil fuels and CCGT plants have a higher energy conversion efficiency than other fossil fuel plants. Life cycle emissions per unit of electricity generation from CCGT are approximately

half those from current coal plants. Nevertheless, CO₂ emissions from gas-fired power generation are significant, and represented 7.8% of total CO₂ emissions from fuel combustion and 20% of all emissions from power generation in 2002.¹¹ Research is ongoing to develop CO₂ capture applied to centralized gas-to-hydrogen plants and large-scale gas turbines, with the intention to go to the carbon capture and storage (CCS) market as soon as they are competitive. CCS technology costs for gas plants are expected to be above that for coal plants.

Environmental – Local

The vast majority of gas fields yield natural gas with negligible sulfur content, resulting in insignificant sulfur dioxide emissions. Tiny quantities of particulates (e.g., PM₁₀) are produced. Only coal plants with the best available emissions reduction technologies can match the NOx emissions per unit of electricity generation from gas. NOx emissions from natural gas are largely due to the oxidization of atmospheric nitrogen. The amount of nitrogen oxidized is a function of the temperature of combustion; higher combustion temperatures are needed to drive the progressively higher efficiencies of CCGT, resulting in increased levels of NOx emissions. Controlling NOx emissions is a key activity in the development of gas turbines.

Social/Community

The safety records of natural gas distribution (including the transportation of LNG) and generation have been excellent. However, some communities have expressed strong opposition to the construction of LNG receiving terminals on their coastlines.

RESEARCH & DEVELOPMENT

The key drivers of R&D are:

- Lower NOx emissions;
- Increased generation efficiency;
- The further development of gas-driven generators capable of serving all parts of the generation spectrum.

Low-NOx burners are already available and their development and improved performance continues. Generation efficiency improvements are being developed for gas technologies of all sizes, with most effort concentrated on improving turbine generation efficiency.

CCGT plants with efficiencies of over 60% are already in the demonstration phase; this efficiency is close to the technical limit. To increase the market share of smaller units, research has targeted a 30% reduction in the capital costs of reciprocating engines and US\$ 650/kW for micro-turbines.

Looking further ahead, research into fuel cells continues. Fuel cells run on hydrogen fuel, which can be produced from natural gas using steam reforming. At high temperatures, this conversion is direct (i.e., it does not require a separate fuel reformer). Research and development efforts for natural gas fuel cells have thus been concentrated within two high temperature types: solid oxide fuel cells (SOFC) and molten carbonate fuel cells (MCFC)¹². MCFC is in the early stages of commercialization while SOFC is just beginning to enter the market with custom-made units, but full commercialization of both options could be a few years away or longer.

The major challenge for fuel cells is to reduce capital costs below today's estimates of the order of US\$ 5,000/kW.¹³ Electricity generation efficiencies could be 10% higher than CCGT, and they could be built in sizes covering the needs of the whole electricity generation spectrum. Fuel cells could therefore be expected to have a major impact on the market, and they could thus be the next large-scale electricity generation technique to use gas. The availability of natural gas distribution networks would be a major advantage in marketing fuel cells.

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- 11 International Energy Agency. *World Energy Outlook 2004*. 2004.
- 12 For a full discussion of fuel cells and hydrogen demand, supply and technologies, see the *Hydrogen Issue Brief*.
- 13 United Technologies Corporation quotes US\$ 1.1 million installed for their commercially available PC-25™ unit. With a rating of 200 kW this equates to US\$ 5,500/kW (see www.utc.com).

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Our **mission** is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

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- **Global Outreach** – contribute to a sustainable future for developing nations and nations in transition.

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