Predominance Diagrams for the Generation of Electricity from Natural Gas in Relation to Nuclear Energy or Wind Power in North America

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Abstract

Natural gas-based combined–cycle technology (NGCC) is favoured at present for the generation of electricity in North America and in many other countries around the world mainly because of its low unit investment cost, high efficiency of fuel conversion, low environmental impact, and the more convenient increments in production possible when installing new or expanding existing facilities. Nevertheless, it is possible to define an equivalent price of natural gas above which other technologies, for example nuclear and wind generation or some mix of the two, would be less costly. In the absence of more detailed information, this equivalent price is assumed here to be $US 6.00 per million Btu in terms of trading on the New York market for gas.

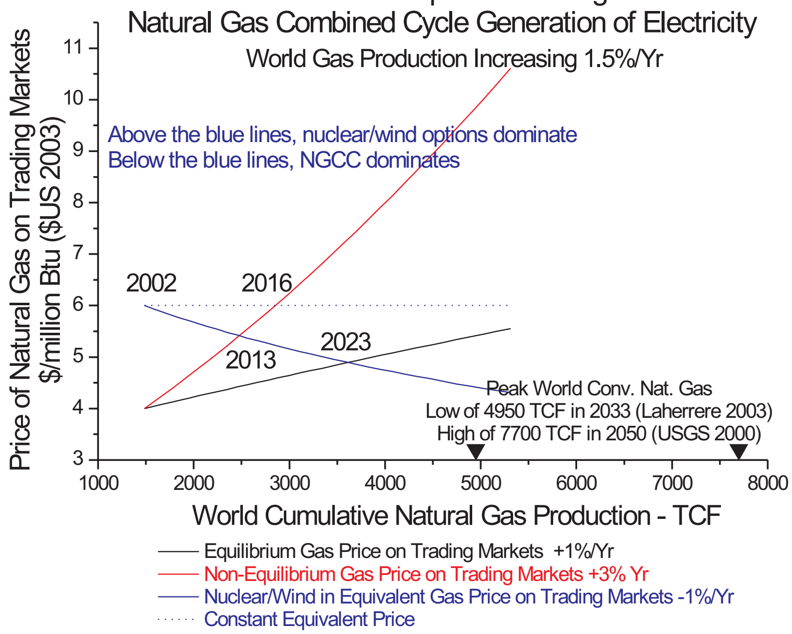
The equivalent price is then examined in the context of two current developments in the natural gas market in North America. First, the market is integrating among the three major nations of the Continent under the influence of the North American Free Trade Agreement (NAFTA). This means that one trading price may approximate the state of the market throughout the Continent through arbitrage. Second, excluding the more expensive Arctic gas, the North American production of conventional natural gas will likely peak by 2010, if not earlier. Once the peak is past, given an integrated market, the price should be set by that of the next least costly alternative assumed here to be liquefied natural gas (LNG) delivered from gas surplus countries by cryogenic tanker. The competitive market–clearing price for LNG should then set the minimum price for all gas offered to the market which, in the equilibrium case (all demands met from competitive sources), is assumed to be $US 4.00 per million Btu. This supply price is assumed to increase at a real one percent per year over time under the influence of slow but steady depletion around the world. A non-equilibrium case is also selected where the price of gas increases at a real three per cent a year as might be the case when the delivered supply of LNG cannot fill all markets at equilibrium prices.

Two illustrative predominance diagrams were prepared which show the relationships between a steady real equivalence price and one set to decrease at one per cent real per year to reflect possible advances in nuclear and wind technologies relative to the NGCC process. In essence, the plots compare the importance of achieving lower equivalent prices on the one hand to increasing gas prices on the other plotted in terms of world cumulative natural gas production to permit ready co-relation with resource potential studies.

The market for natural gas in the three main countries of North America is steadily becoming more integrated as additional long-distance pipeline facilities are built. This growing interconnection implies that in time a single price such as emerges from trading on the New York Mercantile Market may be used as a proxy for natural gas prices throughout the Continent. This trading price is based on transactions at the Henry Pipeline Hub in Louisiana, but is related to those at other trading hubs, including the two Canadian hubs, in a coherent way by arbitrage.

When the production of conventional natural gas has passed its peak in North America - an event which is expected by 2010 at the latest – the price of all gas in an open market, whether derived from conventional or non-conventional sources, will be set in the equilibrium case by the price of the least costly next substantive alternative. This alternative is currently expected to come from some mix of two non-conventional options: Coal Bed Methane (CBM) and Liquefied Natural Gas (LNG), the latter produced from conventional supplies in gas surplus countries but delivered in cryogenic tankers.

Figure 1
Nuclear and Wind Equivalence Diagram with
Natural Gas Combined Cycle Generation of Electricity



Though the locations of these two supply options are very different in North America – inland regions versus along the sea coast - the supply prices are close to each other although CBM may be somewhat cheaper at least initially. Nevertheless, the quantity of LNG potentially available is much greater suggesting it will be price controlling in the longer run. The equilibrium price for LNG – that is, the price at which markets will clear given sufficient supply - is estimated here at $US 4.00 per million Btu on the New York Trading Market. Pipelines intended to bring gas from conventional sources in the northern or far offshore regions must therefore compete with this price.

When the peak in conventional gas production is passed in North America, it is far from clear that anything approaching an equilibrium situation will result. This is because it may not prove possible to site and build receiving ports for LNG or the necessary cryogenic tankers fast enough to meet market demand, especially if conventional production falls sharply or Arctic pipelines are delayed. In this situation, the price may well be much higher. (If the price of gas is too high, there is another possibility. Because the peak in North American gas production will occur before the world peak in production of conventional oil which is expected about 2020 and well before the peak in production of world conventional gas is reached perhaps as late as 2050, it is possible oil products will prove cheaper for many applications for some years, with liquid distillates substituting for gas in the generation of electricity in gas turbines. The need to meet NOX emission standards is a complication.)

The leading option at margin for the generation of electricity in North America is the Natural Gas Combined Cycle (NGCC) in which gas is burned in the combustion chamber of a gas turbine with the hot exhaust gases used to raise steam for further generation after expansion. This technique has advantages in terms of low unit capital cost, high efficiency of fuel conversion, good environmental characteristics, short construction times, and conveniently small increments of production all of which characteristics reduce the risk to those installing the process. Nevertheless, above a certain price for gas, this process would not be employed. This upper boundary is believed to be in the $US 6 per million Btu range at the present time. When natural gas is above this price, other options, such as nuclear and wind generation, would be preferred on economic grounds. Coal-based generation equipped for the capture and sequestering of carbon dioxide

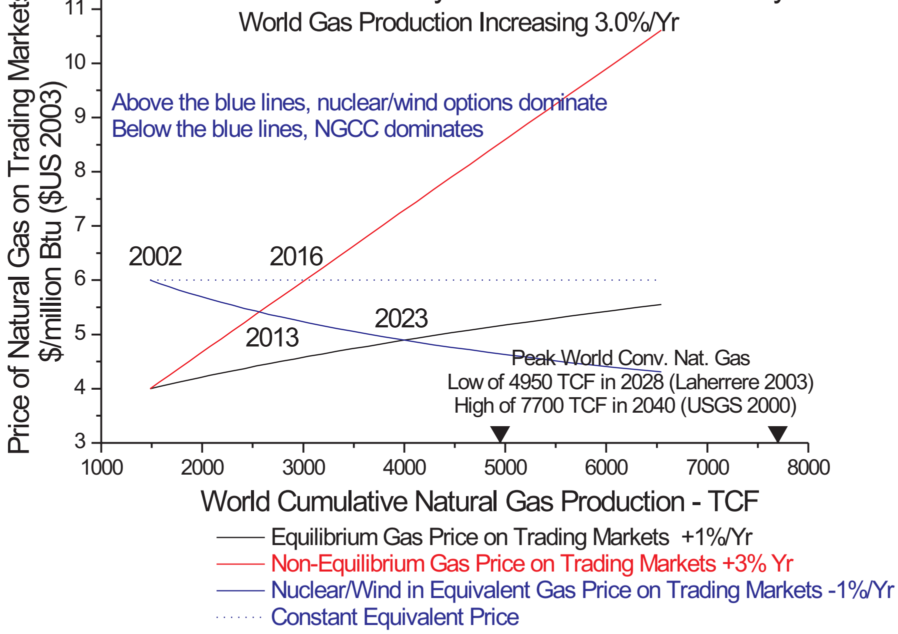


Figure 2
Nuclear and Wind Equivalence Diagram with
Natural Gas Combined Cycle Generation of Electricity

might be in the same range at most locations. Liquid distillates would have to be available for less than about $35 per barrel for the oil option to become important though some NGCC facilities are likely to be equipped to store and burn liquids for emergency standby reasons. It is now important to know as precisely as possible where this price boundary is: no doubt the determination of this price equivalence point has been the subject of proprietary studies.

Details of Assumptions

World Cumulative Natural Gas Production

The world cumulative production of natural gas was chosen for the abscissa in the two figures to make it convenient to relate the price data directly to resource potential studies. Cumulative production was taken as 1483 trillion cubic feet (Tcf) to the end of 2002. Though a number of statistical sources were consulted, this value must be considered somewhat uncertain and subject to refinement as better information becomes available from the many reports and papers now being prepared because of the increasing attention being paid to this fuel. Two projections were chosen to serve as boundary conditions for the future as the market grows for gas. In Figure 1, the world production was assumed to increase at 1.5% per year as the low end of the range (world gas production increased 1.4% in 1992 over 1991). In Figure 2, world production was assumed to increase 3% per year as the high value, an estimate that has been used in some publications of the International Energy Agency.

Supply Price for Liquefied Natural Gas (LNG)

In the equilibrium case – the price at which demands are met and markets clear - the supply price for LNG determines the price of all gas once the peak in conventional production has passed. This value was assumed as the equivalent of $US 4.00 per million Btu on the New York Trading Market at the end of 2002. Below this price without long-term contracts, the LNG would not be imported because it would be unprofitable. The equilibrium price is assumed to increase a minimum of one per cent real per year over a long period of time. The justification for this choice is by analogy with coal. Coal is distributed widely around the world and may be purchased from many suppliers. Most long-term studies, including those of the National Energy Board, use a real increase of one per cent a year in this competitive supply situation. Natural gas is not so widely distributed as coal and there are fewer suppliers nearly all of which operate on a contractual basis. In this situation, before a mature trading market for LNG emerges on the world scene, a one per cent per year real rate of increase should be considered a lower long-term limit.

There is a major problem in estimating the long-term non-equilibrium supply case. This price will likely be very volatile depending upon weather and other such factors that influence short-term demand. For the high case, the rate of price increase is assumed here not to exceed a real value of three per cent per year over the longer-term. Other such scenarios might be formulated according to preferences. Both the low and high cases appear in the illustrative Figures 1 and 2.

Nuclear and Wind Equivalence Price

Generation from both nuclear facilities and wind turbines are assumed to be approximately equivalent to natural gas at $US 6 per million Btu at the end of 2002. The delivered price will be higher depending upon location. Two cases are assumed over time. The horizontal dotted blue line in the two figures indicates that this value stays constant in real terms for the next decades. The solid blue line assumes this equivalent price will fall at one per cent per year in real terms over time. This latter assumption is justified on the ground that the NGCC process is already quite efficient in terms of capital investment and fuel conversion efficiency so there is more opportunity to improve these factors in nuclear and wind technology. In essence, there is a race to improve the performance of all the generation technologies with faster advances in the nuclear and wind options than in the NGCC case. The price of natural gas must therefore fall for NGCC technology to remain competitive in electrical generation. The difference between the rate of advance in the competitive technologies is not likely to be large and hence the modest assumption of a one per cent fall in the natural gas equivalent price each year. The plots in the two figures show the fall in equivalent price related to the high and low increases expected in the natural gas price.

Peak in World Production of Conventional Natural Gas

The peak in the world production of conventional natural gas was assumed to occur at the midpoint of the ultimate size of the recoverable resource. The low value of 9900 Tcf was taken from Laherrere (2003: Web: www.oilcrisis.com/Laherrere) and the high value of 15400 Tcf from the U.S. Geological Survey (2000). The half-way points of 4950 Tcf and 7700 Tcf are shown plotted in Figures 1 and 2. The corresponding dates to reach the peak for the +1.5%/year case in Figure 1 were 2033 and 2050, and for the +3.0%/year in Figure 2 case were 2028 and 2040. The true peak will likely occur between these two sets of values. No new installations of NGCC technology are expected after the world peak as much higher prices are anticipated at that time.

Summary of Results

In Figures 1 and 2, the dates for generation predominance remain the same because the changes in the equivalent natural gas price and the high and low supply prices for gas are calculated on a yearly basis independent of cumulative gas production. With a constant real equivalent price over time, the crossover point is not reached until 2016 in the case of the high rate of price increase for gas (3 % per year) and much later for the low price increase case (1% per year). When the equivalent price falls one per cent per year, the crossover point is reached earlier in the high gas price increase case in 2013 but as late as 2023 in the low price increase case.

The main conclusion of this note is that it is important to increase the rate of fall in the natural gas equivalent price as much as possible. Even small increases in relative efficiency will prove important in shortening the time to the crossover point.

Plotting these results with world cumulative natural gas production as the abscissa allows this improvement to be gauged against the increase in worldwide production of conventional natural gas (including Liquefied Natural Gas but excluding Coal Bed Methane). Faster rates of production are much more likely to be associated with higher rates of increase in real price of gas. The main advantage of plotting the data relative to the world endowment of conventional natural gas is that it is possible to illustrate the evolution of the main factors as the peak in production is approached. There are now many studies underway of this important and controversial question and much more reliable information will be forthcoming soon. With the best information available at present, this peak may occur as late as 2050.

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