EPRI | ELECTRIC POWER RESEARCH INSTITUTE

The Impact of CO_2 Emissions Trading Programs on Wholesale Electricity Prices

In 2005, the European Union (EU) launched the world's largest mandatory CO_2 "cap and trade" program to help its 25 Member States reduce their greenhouse gas (GHG) emissions to levels mandated by the Kyoto Protocol. (See the companion Climate Brief *Key Lessons from Early Experience with the EU Greenhouse Gas Emissions Trading Scheme*, 1012808, for a complete description of the EU-ETS.)

So far, the price of CO_2 emission allowances in the EU has been higher than many analysts predicted and quite volatile, ranging from a low of less than €10 ($12.50) per tonne of CO_2 in early 2005 to a peak of more than €30/tCO_2 ($37.50/$tCO_2$) in early May 2006. At the end of August 2006, the price was €16/tCO_2 ($20/$tCO_2$).

Since the launch of the EU-ETS, natural gas and wholesale electricity prices have risen dramatically across Europe, raising concerns among electric consumers, energy-intensive industries, and government regulators. Some parties have called for dramatic steps to be taken to reduce electricity prices, "claw back" electric company revenues, and re-regulate wholesale EU power markets.

This Climate Brief explores how CO_2 prices theoretically will affect electric prices in competitive markets and compares this with early empirical results from the United Kingdom. Insights are important for competitive markets around the world. In regulated electricity markets, the impact of CO_2 prices on retail electricity prices would depend on the market dynamics described here and on the outcome of the regulatory process.

CO_2 Emissions from Electricity Generation

The combustion of coal or natural gas to produce electricity generates CO_2 emissions, but the amount of CO_2 emitted per MWh generated differs for the two fuels. For example, a typical coal plant may emit 0.97 tCO_2/MWh, more than twice the CO_2 emissions intensity of an efficient natural gas combined cycle plant at 0.38 tCO_2 per MWh.* Nuclear and hydropower units do not emit CO_2.

EU Electric Companies Now Face an Opportunity Cost to Emit CO_2

Today, electric companies and other industries covered by the EU-ETS bear real financial costs to emit CO_2. For example, if the CO_2 price is €20/tCO_2, the estimated CO_2 cost of generating an additional MWh from coal is €19.40, while the corresponding CO_2 cost is €7.60 for natural gas.†

In competitive markets, electric companies bid their short-term marginal cost (MC) of production each hour into the market, where MC is made up of fuel costs, variable O&M, labor, emission allowances as required, and other costs. The market price of power is expected to equal the short-term MC of the power plant that generates the last units of supply to meet market demand.

The Impact of CO_2 Prices on the Dispatch of Generation Units

Figure 1 illustrates a hypothetical dispatch order comprised of four different electric generation technologies – hydropower, nuclear, coal, and natural gas – and the wholesale price for meeting a given level of electricity demand.

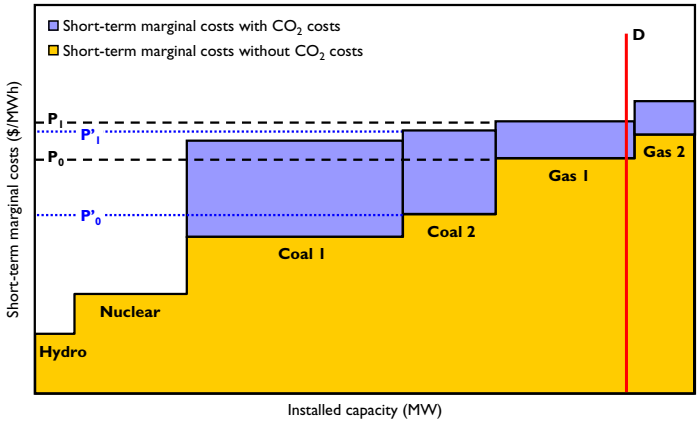

Figure 1. Illustration of the effects of the EU-ETS on electricity generation costs and electricity prices.

Source: NERA Economic Consulting, as adapted by EPRI.

As shown, the Hydro unit has the lowest MC and "Gas 2" is the most expensive plant to run. In this market, the coal plants will operate only after hydro and nuclear generation have been exhausted. The natural gas units will run once all the coal generation has been dispatched. For simplicity, demand (indicated by the vertical line D) is assumed to be fixed in the short run. This implies a

* The CO_2 emissions rates shown here are measured in metric tons CO_2 per MWh.

† 0.97 x 20 = 19.40; 0.38 x 2 0 = 7.60. Also, these simple calculations ignore control costs (e.g., cost-effective costs to increase the efficiency of the units and thereby reduce CO_2 emissions).

market-clearing price of P_0. Each of the generators shown will receive P_0 for each MWh of electricity they generate and sell.

With implementation of the EU-ETS, the short-term MC will increase by the cost associated with abating marginal CO_2 emissions. As shown, the price of electricity can be expected to rise to P_1, where natural gas continues to be the marginal fuel. For a natural gas-fired power plant (Gas 1) that emits 0.38 tonnes CO_2/MWh, the MC will increase by €7.60/MWh (i.e., $P_1 - P_0$) at a CO_2 price of €20/tCO_2. In this case, net revenue[‡] for the marginal natural gas plant (Gas 1) would remain unchanged, since the increase in generation cost would be offset by the higher electricity price.

In contrast, Coal 2 would expect to lose €11.80/MWh in net revenue since its marginal generation cost would increase by €19.40 (i.e., P'_0 to P'_1) while power prices only would increase by €7.60/MWh. In this market, both the nuclear and hydro generators would benefit from the entire €7.60/MWh increase in the power price. These technologies do not emit CO_2, so their marginal generation costs are unaffected by the CO_2 price.

When Coal-Fired Generation is on the "Margin"

In some EU markets and regions of the U.S., coal-fired power plants at times may be the marginal power source. In this situation, CO_2 prices will increase the cost of the marginal coal plant by a much larger amount than a natural gas plant located lower in the dispatch order. For example, a €20/tCO_2 price would increase the marginal cost of electricity generation by €19.40 per MWh using Coal 2. If an efficient gas unit with a lower MC than Coal 2 were in the dispatch order, the MC of the gas-fired unit would only increase by €7.60/MWh. In this case, the net revenue of the marginal coal plant would remain unchanged by the CO_2 price, but the net revenue for the gas plant would increase by €11.80/MWh (i.e., €19.40/MWh – €7.60/MWh).

Early Market Experience in the EU-ETS

Has early market experience in the EU-ETS conformed to this theoretical model? A number of analysts who have reviewed the EU-ETS have concluded that CO_2 prices likely have contributed to increasing electric prices, although it is difficult to say by exactly how much relative to other factors such as higher natural gas prices, renewable energy obligations, and growing energy demand.

Figure 2 illustrates the "spark" spread in the UK electric market during 2005 and compares it with the CO_2 emissions cost for CCGT-based generation. The spark spread represents the wholesale cost of electricity normalized for the cost of natural gas fuel. The two series appear to move together suggesting they may be correlated, but there does not appear to be a simple relationship between CO_2 cost and wholesale electricity prices. Given this, some EU analysts have begun to use a 50% "rule of thumb" to estimate the power price pass-through rate. Using this approach, one might expect a €20/tCO_2 increase in the CO_2 price to push electric prices up €10/MWh on average.

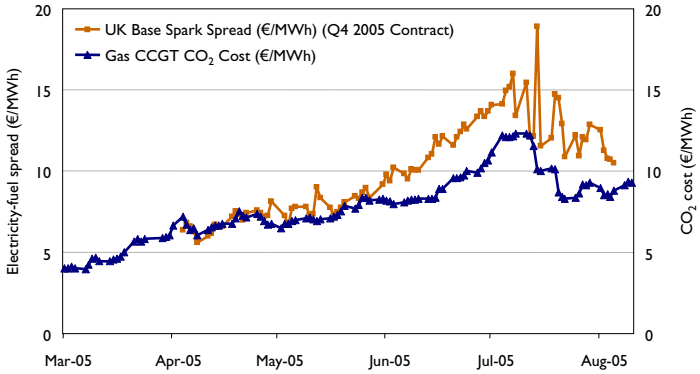

Figure 2. UK spark spread and CO_2 cost of gas-fired generation.

Source: NERA Economic Consulting, as adapted by EPRI.

Increasing Natural Gas Prices

Electricity prices also will respond to higher natural gas prices separately from any potential CO_2-induced price increase. If the rise in natural gas prices is assumed to correspond to the difference between P_0 and P_1 in Figure 1, net revenues for Gas 1 would remain the same as before the price increase. The other power generators – including Hydro, Nuclear, Coal 1, and Coal 2 – also would receive the higher power price P_1, but these generators would not bear higher generation costs due to the higher gas prices.

Implications

The EU-ETS is providing important economic and political insights to market watchers around the World. It is important to understand the evolving situation in the EU, as the EU-ETS establishes important precedents that could impact the evolution of future GHG trading programs elsewhere.

References

1. EPRI, *Effects of the European Union Emissions Trading Scheme on Electricity Prices*, Technical Update, 1011822, 2005.
2. EPRI, *The EU Emissions Trading Scheme: Key Issues and Future Outlook*, Technical Update, 1009924, 2004.

[‡] Net revenue does not equal profit. Net revenues are used to pay back the fixed costs of constructing and operating a plant. To the extent net revenues exceed these amortized fixed costs, they provide a measure of pre-tax profit.

1014478 September 2006

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com