INTERNATIONAL COAL

Coal-fired Power Generation

Compared with other fossil fuels, burning coal produces relatively large amounts of atmospheric pollutants: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and particulates. Therefore over recent decades there has been a decline in the use of coal for power generation. However, as supplies of other easily-accessible fossil fuels dwindle there remain vast deposits of coal, and the International Energy Agency estimates that coal will still be used to generate 38% of the world's electricity in 2020.

Within the European Union, environmental concerns have led to limits on emission of pollutants. A market has been established for trading CO_2 emissions. A generator has to pay for CO_2 emissions at the market rate, so these can be treated as an additional fuel cost. This may be extended to SO_2 sometime in the future, but currently generators are allocated a limit (a 'sulphur bubble') for a year running from October to October (the 'sulphur year').

Flue-gas desulpherisation (FGD) and 'scrubber' technology can reduce emission levels of SO_2 and NO_x respectively from the exhaust gases.

Coals from different regions of the world have different composition, with different calorific values and pollutant content. Combinations of coals are often used so that tradeoffs can be made between costs, energy and the various emissions produced.

Recently, some coal-fired plants have started to 'co-fire', blending coal with biomass. Biomass includes waste products from forestry (e.g. wood chips), from paper production, and from agriculture (e.g. straw and olive cake[1]). In the UK the Department of Trade and Industry (DTI) set targets for the proportion of the UK electricity supply to be generated from renewable sources (e.g. 10% for 2010). To encourage this, generators effectively receive a supplement for each MWh of power generated this way (this is known as the Renewables Obligation Certificate, ROC, supplement). The DTI foresaw the combustion of biomass, both domestic and imported, as being the fastest growing component of the renewable energy.

International Coal

International Coal (IC) operates a large (1,000 MW) coal-fired plant in the UK. They employ a team who purchase different fuels in order to maximise margin (profit) whilst keeping within environmental limits, especially on sulphur. IC has been allocated a sulphur bubble of 30 kilo tonnes for the year (to the end of October). CO_2 emission is taken to be 0.8 tonnes per MWh of electricity produced.

[1] the residue after the extraction of olive oil: skins, pulp and seeds

INTERNATIONAL COAL

Coal is typically bought three or more months ahead of planned burn and stockpiles are kept at the plant. Transport costs are factored into the fuel prices. The plant has a 35% efficiency, i.e. 35% of the calorific energy released in a burn is converted to MWh of electrical power.

Power is sold to the electricity markets, and fuel buying is done on the basis of future prices in these markets. Each month is divided into four price bands: categorised by weekend or weekday, and peak or off-peak. (Peak periods consist of a 12-hour block). Thus there are four future prices for each month. Power is distributed by the National Grid Company which charges IC a transmission rate of 65p per MWh.

The Problem

The fuel-buying team at IC is led by Bob Manchester. The buying decisions have been relatively straightforward, but as the sulphur bubble has become more restrictive, pressure is increasing to show that the best fuels are being used. Bob thinks there must be a systematic way of considering the tradeoffs involved in the decisions being made.

It is now the end of May. To test the feasibility of a modelling approach, Bob wants to investigate power generation to the end of October, considering the stockpile of mixed coals at the plant, three types of coal that can be ordered for burning in September and October, and wood-chip biomass which can be bought with short leadtimes. Fuel is to be paid for now, ignore discounting of any of the cashflows.

Biomass is more difficult to handle than coal, having more variable combustion characteristics (low density, extremes of particle shape, tendency to entangle and demix plus moisture has a large effect has on their behaviour), so may not provide more than 10% of the mix (by calorific value) in any of the generating periods.

Bob has provided fuel characteristics (Table 1) and electricity future price (Table 2) data. The current coal stockpile at the plant (including coals previously ordered and en route) is 600,000 tonnes and there is 30% of the 'sulphur bubble' left this sulphur year. CO_2 emissions are trading at 15 Euros per tonne on the European market, which IC must pay for any CO_2 produced. The ROC is £45 per MWh generated from renewables.

He has also mentioned a couple potential future issues. SO_2 emissions are a major concern for IC. One possibility is to invest in FGD. There is also the possibility that SO_2 emissions may become tradable (and so a direct cost) in the way CO_2 currently is. Either of these is likely to have a major impact on operations at the plant, but Bob is unsure how to start quantifying the potential benefits.

INTERNATIONAL COAL

Data

Fuel	Price *£/tonne*	Calorific value [b] GJoules / tonne	SO_2 *%*[a]
Coal: Stockpile	42.56	25.81	1.38%
Coal: Columbian	43.93	25.12	0.70%
Coal: Russian	43.80	24.50	0.35%
Coal: Scottish	42.00	26.20	1.72%
Wood chips	73.77	18.00	0.01%

[a] a coal with an SO_2 rating of 1% will produce 0.01 tonne of SO_2 for each tonne of the fuel burnt

[b] 0.278 MWh per GJoule

Electricity Market Forward Prices	June	July	August	September	October
Period:	*£ per MWh*	*£ per MWh*	*£ per MWh*	*£ per MWh*	*£ per MWh*
Weekday Peak	36.00	36.35	37.65	38.35	43.70
Weekday Off-peak	27.00	27.00	28.20	28.50	31.70
Weekend Peak	33.50	34.30	35.65	35.80	38.70
Weekend Off-peak	26.20	26.30	27.50	27.65	30.10

Table 2: Future Electricity Prices