Clean energy special: A greener goal for coal

By Bennett Daviss

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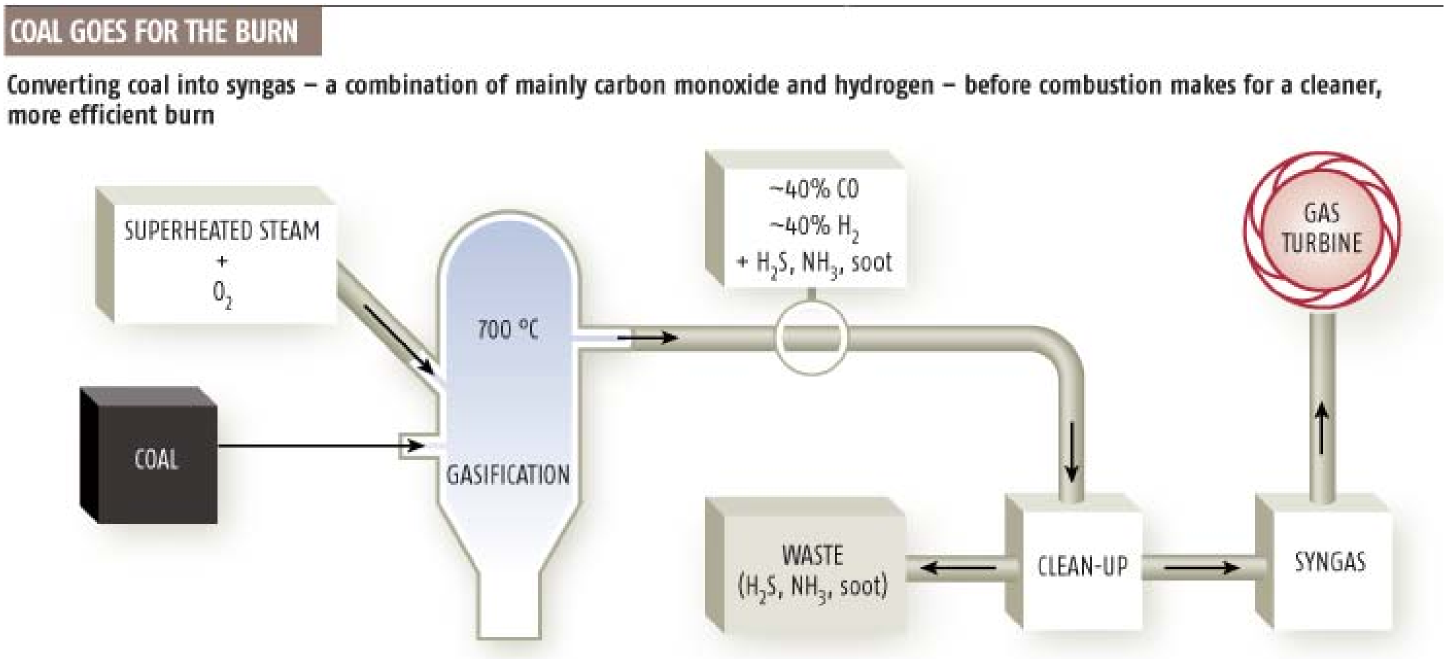

Coal goes for the burn

WHETHER or not the member nations of the Asia-Pacific Partnership are truly united in their commitment to combat global warming, there is something they definitely have in common. All six are addicted to coal.

Coal provides nearly 50 per cent of Australia's energy, making it the biggest single source of electric power down under. Australia has so much coal that the nation is the world's fourth-largest exporter of the stuff - one reason why nearby Japan and South Korea are the world's largest and second largest coal importers respectively. China is another coal junkie: it is both the biggest consumer and the biggest exporter in the world. In India, coal accounts for close to 60 per cent of the energy supply and 70 per cent of the fuel used in power plants. Even the oil-addicted US cannot resist coal's allure. Coal represents about 90 per cent of the country's remaining indigenous energy resources, and according to the government's Energy Information Administration, by 2025 the US is likely to burn almost 40 per cent more coal than it does now. China and India also have big expansion plans for coal, with China alone planning to almost treble the capacity of its coal-fired power stations by 2020.

If these six nations are serious about simultaneously growing their economies and shrinking their greenhouse gas emissions, they are clearly going to have to take a long, hard look at their use of coal.

At present, that use is highly profligate. The vast majority of their coal-fired power plants operate by burning coal to produce steam, which is then put through a steam turbine. This process is inefficient, converting only around 30 per cent of the energy in the coal into electricity. By contrast, some gas-fired plants run at an efficiency of up to 60 per cent.

Low efficiency is one reason why coal is so bad for the environment. "The ultimate fate of every carbon atom that burns is to become carbon dioxide," points out Rod Judkins, director of the fossil energy programme at the Oak Ridge National Laboratory in Tennessee. "The way to lower CO2 emissions is to improve efficiency - either burn the same amount of carbon and get more energy, or get the same amount of energy while burning less carbon. Those are your choices."

Another problem for the environment is that coal is an inherently dirty fuel in terms of greenhouse gas emissions, producing almost twice the amount of carbon dioxide as natural gas for the same amount of energy, and about 30 per cent more than fuel oil.

But an energy future that is heavily reliant on coal might not be quite as bleak as it seems. For one thing, carbon sequestration could take a deep bite out of future carbon dioxide emissions from coal-fired plants (see "Going underground"). And more immediately, "clean coal" technology is gradually nudging the efficiency of coal-fired plants upwards. It's a painstaking process of adding a percentage point here and there. But it's worth it, says Tom Sarkus of the US National Energy Technology Laboratory in Pittsburgh, Pennsylvania. "An improvement of even a half of 1 per cent is a big success. When you calculate the amount of coal used worldwide to produce electricity, even small gains like that can become meaningful."

There are two main ways to achieve such gains. The first is known as pulverised coal or PC, a brute-force technique nearly a century old. PC is already used in most coal-fired plants but is being continuously improved. Modern PC plants run at about 33 per cent efficiency, which is a significant advance on the 30 or so per cent that older ones deliver. And many researchers believe that pushing PC up to 40 per cent or higher is a realistic goal.

In a PC system the coal is powdered, with most granules smaller than 300 micrometres across. This means more coal surface is exposed to the flame, so a larger proportion of the energy in the fuel is extracted as heat. Recent improvements in steel alloys also allow turbine components to endure much higher temperatures and pressures, which means that the coal can be incinerated at ever-higher temperatures, raising efficiency even further. Coupling that small but crucial breakthrough with steady, incremental improvements to control systems and other components means that, according to the most optimistic estimates, a spanking new PC plant could reach up to 47 per cent efficiency.

The second and perhaps most promising clean-coal concept is a new twist on a 40-year-old idea: gasification. This is where you first partially burn the coal to create a gas which can then be burned in a gas turbine. Gasification has long been used in petrochemical plants to convert coal into more valuable chemicals. But it is increasingly used in power generation too, in what is known as an "integrated gasification combined cycle" (IGCC).

The principle benefit of IGCC is that it allows you to run two types of turbine, not just one - exactly the reason that gas-fired plants generally outperform coal ones. First, a pressurised stream of air or oxygen plus water vapour or hydrogen is drawn through smouldering coal, much like sucking on the end of a lit cigarette. The air and steam react with the hydrocarbons in the coal to produce "syngas", a mixture of mainly carbon monoxide and hydrogen. The syngas is then cleaned up and burnt in a gas turbine to produce electricity directly (see Graphic). Meanwhile, the heat from this process is used to make steam, which runs a steam turbine as normal. The energy from burning coal therefore does two kinds of work, not just one.

There are four commercial IGCC power plants in the world - two in the US, one in the Netherlands, and one in Spain - all built between 1994 and 1997. They average just below 40 per cent efficiency, though future plants could capitalise on tougher alloys, better control systems and other improvements to pass the 50 per cent mark.

A more radical solution could be underground coal gasification, a process in which entire coal seams are reacted with oxygen and steam in situ. The mix of methane and hydrogen this generates can be pumped out of the ground and burnt in generators. A recent UK government study suggests the technology could be cheaper than other coal gasification methods and simplify carbon capture. The Australian government research organisation CSIRO has just completed a major study, and the country has one underground gasification project close to commercialisation. China has five major trials under way and more planned.

Future technology is expected to take efficiency higher still. One especially ambitious plan is FutureGen, a $1 billion, 10-year US government project to build an ultra-clean coal-fired power plant that can produce electricity with virtually no environmentally adverse waste. FutureGen's plant aims to extract at least 70 per cent of the energy from coal, yield only half as much CO_2 (which will all be sequestered), and do it all at a unit energy cost roughly the same as today's best clean-coal systems.

It's a tall order, but there are various ideas about how to achieve it. In one concept advanced by the ZECA Corporation, a consortium of companies and public bodies from the US and Canada that is independent of FutureGen, coal would be gasified and the syngas mixed with steam and passed over a bed of calcium oxide. The calcium oxide reacts with carbon and water to form calcium carbonate, in the process doubling the proportion of hydrogen in the remaining gas. A portion of that hydrogen would be drawn away to gasify more coal; the rest would be fed to a fuel cell where it would react with oxygen to produce water and an electric current. The fuel cell's waste heat would be recycled to convert the newly made calcium carbonate back into calcium oxide, and the resulting CO_2 would be sequestered.

Admittedly this scheme is dependent on technologies that do not yet exist, not least fuel cells able to cope with impurities such as hydrogen sulphide and ammonia in syngas. But a demonstration FutureGen plant could be producing power within a decade, says Hans Ziock, a clean coal researcher at Los Alamos National Laboratory in New Mexico. And FutureGen isn't the only project of its type, either in the US or elsewhere. Researchers expect that over the next 10 to 15 years a variety of clean-coal demonstration projects will begin strutting their stuff, with commercial plants up and running by about 2025.

Realistically, however, there is no prospect of FutureGen-style plants becoming the norm in the near future. "This concept is so radically different that it couldn't be retrofitted to existing plants," says Ziock. "It would have to be a new facility built entirely from scratch." In other words, all of today's plants, plus the vast majority of the ones on the drawing board, will belch CO2 throughout their working lives.

And that makes it even more important to continue chipping away at those efficiency figures, squeezing every last fraction of a percentage point out of the coal. "The technologies are here, now, to begin to make significant improvements in coal's greenhouse footprint," says Frank van Schagen, head of the Cooperative Research Centre for Coal and Sustainable Development in Brisbane, Australia. "Per unit of energy, we're slowly and surely reducing the amount of CO2 we emit."