Is coal the new oil?

Dave Willmott and Steve Haywood, Otto Simon Ltd, UK, ask whether clean coal solutions provide a viable alternative to oil and gas in securing global energy supplies.

An over reliance on oil and gas has the potential to create significant problems in the future. One answer is to develop clean solutions using coal. This article explores the issues and the options for using coal as a remedy and explains that proven technologies already exist for the cleaning and treatment of syngas from coal and other fuel sources.

Typical large capacity syngas scrubbing vessel for removal of hydrogen sulphide, ammonia and BTX.

The problem

"In 2015, someone in the UK will flick a switch and nothing will happen. Eight years from now, the country will have only a fraction of the power it needs. Towns and cities blank out as the National Grid fizzles and dies. Pensioners die of cold, then putrefy in unchilled mortuaries. The only light comes from families burning their furniture. Streets after dark belong to armed gangs operating black markets in everything from clean water to butchered pets. Shop staff flee as customers brawl in the aisles over torch batteries and out-of-date Pot Noodles. The prime minister declares a national state of emergency but nobody hears him."

This dramatic augury appeared in the London-based *Sunday Times* newspaper in October 2007, giving a stark warning to Governments and policy makers to get their act together before the forecasted energy crisis became a reality.

At the time it was written, oil had not reached US$ 100/bbl, and some analysts and experts were predicting that it would reach US$ 150/bbl in 2008, whilst others believed that US$ 100/bbl was sustainable. Well the US$ 150/bbl team received the Oscar® for best prognosis as 2008 saw the prices exceed US$ 140/bbl. Once again the analysts debated the issue when prices started to fall in July, some even asking whether prices would reach US$ 200 – 250/bbl? Or, once again those magic words: is the position sustainable?

There have been previous oil shocks, of course, in 1973 – 1974, 1980, and 1990 – 1991. However, these stemmed from specific interruptions of energy supplies from the Middle East due to events such as the Arab-Israeli war, the Iranian revolution and Iraq's invasion of Kuwait. Once peace was restored, a post-revolutionary order established or the invader expelled, vital Middle Eastern energy supplies returned to normal. The 2008 oil shock however, belonged to a different category altogether.

On the one hand, there were the fiscal axioms, such as the sub-prime mortgage crisis in the US, which drastically affected the property market leading investment fund managers and speculators to direct their cash into commodities such as gold and oil, thereby driving up the prices. The situation was intensified by the weakening US dollar, the denomination used in oil trading. Speculation also sharpened as investors used oil as a hedge against the depreciating currency.

On the other hand, there is the strategic view: North Sea oil has reached the decline phase of the product life cycle; Russia has moderated exports due to attempts to re-nationalise the industry; Canada struggles with its infrastructure and labour shortages; and Mexico, a key exporter to the US, is predicted to be a zero net exporter by 2010. In this context, as the US Republicans and Democrats argue about re-establishing oil exploration off the Californian coast or increasing taxes, OPEC is left in a stronger position to reduce output and control prices.

Whichever point-of-view one subscribes to for higher prices and

View of gas cleaning facility in Asia.

availability, one fact remains: demand is outstripping supply, and this will continue unless something is done. The current position has been revised somewhat as the IEA has adjusted down the world oil demand by 2.56 million bbls/day, and inventories are high, with an estimated 150 million bbls stored at sea – but these were bought in Q4 2008 and Q1 2009 when the price had fallen to around US$ 40/bbl, not the current US$ 63/bbl. The last 6 months have seen an increase in price despite the falling demand, rising supply period, which probably resulted from oil trading following the major market indexes after the October crash. It is now once again trading inversely to the dollar, but high production costs, creating a difficult marginal cost, have led the secretary general of the IEA to predict prices in excess of US$ 200/bbl in the next 4 – 5 years as world demand recovers.

The decline in retrievable oil reserves has highlighted the need for substantial investment in the industry, which some have quoted as US$ 2400 billion on upstream facilities and US$ 455 billion on refinery processes. This might potentially be good news for those sectors involved in investment projects, but the oil situation is bad news for people at the pumps and for industries, such as the chemical industry, which saw energy bills rise by 42% in Q1 2008.

The world is facing ever-increasing energy bills, a decline in available energy resources and insecurity of supplies following the dash for gas and the resulting reliance on imports from unstable sources. A nuclear option is years away. The renewables sector can only supply a small percentage of the required energy, and it is growing slower than anticipated. In this context what else can be done to achieve security, reliability, diversity and affordability of energy?

One solution

One answer to this question is coal. In the context of securing energy supply in a world where constraints on CO_2 emissions are rapidly being adopted, this might appear to be a hard sell. However, new technology can play a significant part in maintaining coal's position as a viable player in the future global energy mix.

Dr Ernest J. Moniz, professor of physics and engineering systems, Massachusetts Institute of Technology, US, said: "There are many opportunities for enhancing the performance of coal plants in a carbon constrained world – higher-efficiency generation, perhaps through new materials; novel approaches to gasification, CO_2 capture and oxygen separation."

Forecasters predict depleted oil reserves within the next 40 to 60 years. In comparison, coal reserves exceed 100 years. The world demand for coal is stronger, up 4.5% in 2007 due to developing economies, such as China, reducing exports as domestic use increased. China also controlled movements in the lead up to the Beijing Olympics. This had a knock on effect on coke price and availability, lifting prices to almost US$ 600/t for 12.5% ash coke and kick starting a resurgence in coke making.

The upturn and renewed interest in coal was seen in the market place as Mittal increased its stake in Australian MacArthur Coal and the US Mid Vol Coal Group, Posco, increased its Macarthur stake and BHP Billiton launched a takeover bid of Rio Tinto. An IEA report, written before the extent of the world economic crisis became evident, predicted an increase in the demand for coal of up to 0.6% in OECD countries and between 1% and 4.1% in non-OECD countries for the years 2006 – 2030.

Clean coal is not an oxymoron: it is the future for coal as part of an energy portfolio. But what does technology have to offer to bring coal back into the energy melting pot?

Clean coal technologies

Clean coal technologies include CCS. The Ospar agreement has now been changed to allow the storage of CO_2 under the North Sea. At the oil summit in Jeddah, British prime minister, Gordon Brown, announced that the UK would work with Saudi Arabia on perfecting the technology for carbon capture. The US and Australia are already committed to advance this technology with public funds. The Obama administration's US$ 800 billion stimulus package includes US$ 1 billion for clean coal research. Research into storage is also underway in Germany's Potsdam project.

Collection of the CO_2 can be post-combustion, via amine scrubbing chemical absorption or oxy-fuel combustion, where oxygen is separated from the air and mixed with recycled CO_2 for injection into the boiler, or by pre-combustion by capture gasification.

Gasification converts coal into CO and H_2, by reacting the raw material at high temperatures with a controlled amount of O_2 and/or steam to produce syngas, which is itself a fuel. Pyrolysis devolatilises the coal to produce char. The volatile products and some of the char react with O_2 to form CO_2 and CO, which provides heat for the subsequent gasification reactions. The

gasification process occurs as the char reacts with CO_2 and steam to produce CO and H_2. The gasification process can be enhanced by other technologies; examples of which are IGCC power plants, which use syngas to power a gas turbine generator, the waste heat of which is passed to a steam turbine system. This system has already been described as 'capture ready', meaning that it has the potential to capture and store CO_2.

The US FutureGen project is an example of developing these technologies further. This US$ 1.5 billion investment programme is designed to use coal in a gasification plant. Following removal of the water and sulphur, the CO_2 is separated and stored while the hydrogen is removed and used as a transportation fuel. The remaining syngas is used to produce electricity through a combined cycle generating system. Other projects include the Polish ZAK/PKE consortium's plan to build the first zero emission power plant and chemical complex, which is part of the Polish Flagship Programme of Clean Coal Technologies, (PFPCCT). This will include IGCC and CCS. Also, in England's coal heartland, Powerfuel, in partnership with KRU, one of Russia's largest coal producers, also intends to produce power at the Hatfield Colliery site using IGCC and CCS technologies. However, only one company, the Swedish utility Vattenfall, currently has a functioning pilot plant, a mini 30 MW facility at Schwarze Pumpe in the Lausitz region of eastern Germany.

The next phase to enhance the potential of coal gasification is underground coal gasification (UCG). Very simplistically, O_2 and steam are pumped down one shaft into a coal seam, which is ignited and the syngas extracted via another shaft. Like any technological alternative, this method has its advantages and risks, its supporters and its critics. However, if coal is to be a serious option then it must be worthy of investment and further research. A UCG plant was operational in Uzbekistan before financial pressures forced Russia into using an alternative energy source. In the UK, research was conducted in the 1970s and again in the 1990s through a Department of Trade and Industry programme.

There could by synergies for UCG and CCS. As Professor Colin Snape, director of Energies Technologies Research Institute, School of Chemical and Environmental Engineering, University of Nottingham, points out, CCS on a UCG plant could have the advantage of bringing about mineralisation. This enables the CO_2 to be stored as a solid or even enhanced CBM production, producing more fuel. Together with CCS underground, UCG must have real potential to bring clean coal a step closer as a future energy source.

One final example of the congruency of coal within a future energy supply amalgamation is the hybrid energy system (HES).

It has been known for over 100 years that coal can be used to produce hydrocarbon fuels. The process of distilling oil from coal in the absence of oxygen is called 'destructive distillation' or 'low-temperature carbonisation.' Useful byproducts formed from the pyrolysis of coal are nitrogenous and sulphurous materials, which are useful for the production of materials such as sulphuric acid, elemental sulphur, ammonia, ammonia salts and fertilisers.

In the HES, this destructive distillation process converts 25% to 30% of the total energy of the feed coal to hydrocarbon fuel. The remaining energy source, in the form of a char residue, is recovered and employed as a fuel source for a conventional power plant. An operation consuming 2 million tpa of low-grade coal could produce 2 million bbls/year of oil (based on an expected oil yield of 1.0 bbls/t of coal). The coal char residue and gas from 2 million tpa of coal would provide sufficient fuel for a 200 MW power plant.

This process has been pilot plant tested in Utah, extracting oil from shale rock. The World Energy Council estimates that there are over 2.6 trillion bbls of recoverable oil in the Green River formation area in Utah, Colorado and Wyoming. Oil shale reserves also occur in many other countries, including: Canada, Sweden, Estonia, Scotland, Spain, Italy, China, Russia, South Africa, Australia, Zaire, Brazil, Jordan, India, Israel and France.

Proven technology for syngas treatment

This article has covered new technologies dealing with the production of dirty gas or syngas. These technologies require suitable processes for treating the syngas and in some cases recovering valuable components. Fortunately syngas gas treatment is extremely well proven in the conventional cokemaking process. Otto Simon Ltd has a proven track record of coke oven syngas treatment with 100 years' experience in the production of coke from coal and, more specifically, the various techniques and processes that are used for gas treatment and byproduct recovery.

Cokemaking is carbonisation and essentially involves the conversion of an organic substance into a carbon-containing residue through pyrolysis or destructive distillation, i.e. the cokemaking process. The gas produced is highly contaminated and various unit processes are required to cool and transport the gas and remove the various components, which include tar, naphthalene, BTX (benzene, toluene, xylene), ammonia and sulphur. In fact over the years various processes, which have been used, include the following:

- Tar removal, dewatering and distillation.
- Ammonia removal to produce anhydrous ammonia and ammonium sulphate as useful products; ammonia combustion or ammonia destruction to produce a weak CV gas, which can be added back to the syngas.
- Desulphurisation by a variety of methods. However, the main technologies used today normally use either ammonia (already present in the syngas) or sodium bicarbonate to react with the H_2S, followed by stripping and then production of molten sulphur or sulphuric acid.
- Removal of naphthalene and BTX to either produce a crude product for sale or refine the BTX into individual components.
- Liquor treatment, which typically includes ammonia stripping and

Overview of coke making facility and gas cleaning plant, Germany.

biological treatment but may also include phenol removal.

Some of the technologies described above are used in other industries. However, the contaminants found in coal gasification/pyrolysis processes create unique problems. Over the years, many capable engineering companies have tried to transfer proven processes used in various aspects of oil refining, for example, only to find that the processes do not work successfully on coal syngas.

Not everyone appreciates that the right expertise exists, but several clients have recognised the expertise within Otto Simon. The technologies and expertise are not only being applied to coal gasification and char production processes, but also to thermal treatment processes involving the production of gas, heat and electrical power from renewables, including municipal waste, sludge and wood. In fact, this expertise and practical experience is being used not only to ensure that the right technologies are being applied to thermal treatment projects, but also to ensure that projects are being successfully developed, designed, built and commissioned.

The future

Global demand for energy is outstripping available supply. Alarmingly, there is no short-term prospect that supply will match demand. In the hydrocarbon family, coal is the least efficient energy source, providing only half as much energy as oil, while producing twice as much CO_2, but coal has the longest history of supplying energy to modern societies, and as the twenty-first century began, it was still one of the leading fuels for power plants worldwide.

Global energy supply is facing many challenges. In the context of population growth, the economic development of non-OECD countries and turbulent economies, the system will require more energy but less CO_2. Addressing the key drivers of supply and demand and environmental effects – which are influenced by price, technology, politics and social choices, within a perplexing energy framework of antithetical conditions, such as prosperity vs poverty, globalisation vs security, and growth vs environmental impact – will need clear thinkers, huge investment and effective leadership.

A secure energy supply is in the hands of the policy makers, but it is also in the hands of the scientists, technologists and the radical thinkers who are not afraid to challenge traditional ideas, explore new technologies, and use and enhance traditional resources in the contemporary context of reduced CO_2 emissions – and then turn these into practical realities. Some of the technologies may be relatively new but it is important to appreciate that proven technologies exist for the treatment of syngas and liquor streams for the gasification of coal and other energy sources. WC