Coal — clean, cleaner, cleanest

Coal has a dirty reputation — dirty to look at, dirty to handle, and dirty to burn. Two researchers at the CSIRO Division of Coal Technology want to change something of that. They envisage the Australian coal industry finding new export markets by offering 'superclean' and 'ultraclean' coal.

These premium value-added coals, low in ash (less than 5% and 1% ash, respectively), could be easily transported and utilised in the form of lumps, powders, pellets, and coal–water or coal–oil mixtures.

Low-ash coals could be used as replacements for fuel oil, as low-polluting fuels for new power stations and industrial boilers, and as feedstock for industrial carbons. In the longer term, ultraclean coal could power gas turbines and slow-speed (marine) diesel engines.

If only 5% of Japan's existing oil-fired industrial boilers changed over to burn low-ash coal, this could create an annual $300million market for Australian coal.

The new coals would compete strongly with petroleum fuels in many fields. Not only would they be appreciably cheaper than heavy fuel oil or natural gas (perhaps $3·50 per gigajoule compared with $8 for their competitors), but, if used to fire power stations in Europe and Japan, they would largely eliminate the acid-rain problems there (Australian coals boast low levels of acid-forming sulfur).

Indeed, the two researchers, Dr Neville Lockhart and Mr Bruce Waugh, see coal processing becoming more a refining operation: just like an oil refinery a coal refinery would have a range of products for sale — different sizes, forms, and ash contents — tailored to specific uses.

The result should be higher coal exports, lower petroleum imports, and better utilisation of our valuable coal resources.

Laboratory studies have demonstrated that a combination of old and new approaches to reducing ash levels looks very promising, and CSIRO has set up a consortium to promote and demonstrate 'AUS-coal' — **A**ustralian **u**ltraclean and **s**uperclean coal.

The consortium comprises CSIRO, the Australian Coal Industry Research Laboratories (ACIRL), and White Industries. In 1989, with additional funds from Elcom (the Electricity Commission of New South Wales), the New South Wales Department of Energy, and NERDDC, it hopes to commission a

Superclean coal mixed in water (courtesy ACIRL Ltd).

demonstration plant producing sufficient AUS-coal for potential users to conduct trials with.

Australia is fortunate in having large reserves of coal that are low in sulfur and low in trace elements (heavy metals, in particular). Sulfur levels are typically 0·2–0·6% — far lower than those in heavy fuel oils and in American and European coals (1–5%).

Not so fortunately, our coals usually contain high quantities of mineral matter (ash-forming material). When mined, Australian black coals typically contain about 20% mineral matter. Here is where the coal washery steps in; its job is to wash out the shaley, low-grade material, leaving a 'clean' coal with 6–10% ash. Upgraded this way, about 60 million tonnes of coking coal are exported each year. We also export some 30 million tonnes of washed steaming coal of 10–18% ash.

The quality of coal, as extracted from the mine, is generally decreasing. At the same time, in a presently over-supplied market, increasingly strict specifications are being imposed on the product. Coal preparation is therefore becoming a more demanding task. Yet in excess of 20% of the total tonneage mined in Australia is discarded as washing waste, and this figure is rising. Some of it is good coal.

If we could more easily separate the coal from its mineral matter, we would recover extra coal, lower costs, and reduce the reject problem. This is quite apart from the prospect of new markets for even cleaner coal.

A new industry has arisen overseas aimed at getting coal to burn more cleanly — engineers are developing sophisticated combustion techniques and adding them to established post-combustion clean-up methods like electrostatic precipitators, fabric filters, and flue-gas scrubbers. But the researchers argue that a better way to achieve the cleanest burn is to clean the coal as much as practicable before it's burnt.

In order to get coal 'cleaner than clean', the first task is to create better opportunities for the coal and mineral matter to go separate ways. That means breaking up the structure that locks the two together. Then effective techniques of separating the liberated coal are needed.

Several years ago Dr Lockhart began working on ways of improving upon the standard liberation techniques. After detailed laboratory experiments, he believes he has identified better procedures for physically liberating coal and separating it from its contaminants.

He is confident that, by allying these methods with conventional coal-cleaning processes, we could easily reduce ash levels to less than 5%, and possibly as low as 2% — in the 'superclean' range.

Mr Waugh's approach differs radically from conventional coal preparation methods: he has developed processes for taking mineral matter out of coal using chemicals (see *Ecos* 45). Mr Waugh, in collaboration with Dr Keith Bowling (recently retired), has found that stewing coal with caustic soda under pressure can produce an 'ultraclean' coal with less than 1% mineral matter.

Carrying out physical and chemical techniques in tandem can create a product with ash yields as low as 0·2%. Such a level is comparable to that of heavy fuel oils. The product would also be suitable as a feedstock for solid industrial carbons, such as those used in electrolytic refining of aluminium.

Even when the ultimate low ash level isn't needed, laboratory studies suggest that a judicious combination of physical and relatively mild chemical methods may often be the cheapest way to reduce ash content to 3% or less.

A major cost determinant is the size of coal pieces to be cleaned. The normal coal-washery technique operates mostly on lumps between 0·5 and 150 mm across and achieves satisfactory separation at a cost of about $5 per tonne.

However, although coal washeries use minimal crushing, the amount of fine coal involved is enough to create problems for them in handling, de-watering, and drying. Sometimes washeries blend it uncleaned into the coarser clean product; another common practice in the past was to simply throw the fine stuff away.

Clearly, grinding the coal to a finer size will create better opportunities for coal and dirt particles to separate, leading to a higher-quality product — but at a high penalty if conventional techniques are employed. With conventional wet separation, it would cost a coal washery more than $10 per tonne to clean coal crushed to less than 0·5 mm. Even with current practices, drying of fine coal, disposing of reject material into tailings ponds, and recycling the water from them, present major headaches.

In this situation, chemical demineralisation has the prime advantage that it can easily remove mineral matter from lumps 2–3 mm in diameter, and even bigger.

Dr Lockhart's studies aimed at finding more effective ways of physically liberating coal and mineral matter should also lead to cost reductions.

These potential markets are vast. If only 5% of Japan's oil-fired industrial boilers switched to low-ash coal, they would require 300 million dollars' worth annually.

Potential markets for premium coal

superclean (1–5% ash) ultraclean (<1% ash)

fuel-oil replacement

- conversion of some existing oil-fired power stations and industrial, commercial, and larger residential steam-raising/heating plants — mainly outside Australia
- chemical feedstock, synfuels
- industrial carbon products — e.g., coke, anode carbon
- engines — gas turbine, slow-speed diesel, perhaps motor vehicles

first choice, clean-burning, fuel

- new power stations (outside Australia), and steam-raising/heating plants, whether additional capacity or replacing older oil or coal stations
- advanced power-generation technologies
- rural and domestic fuels

premium coking coal and other applications

- steel industry; ferro-alloy producers; metal refiners; calciners, kilns, driers; chars/briquettes

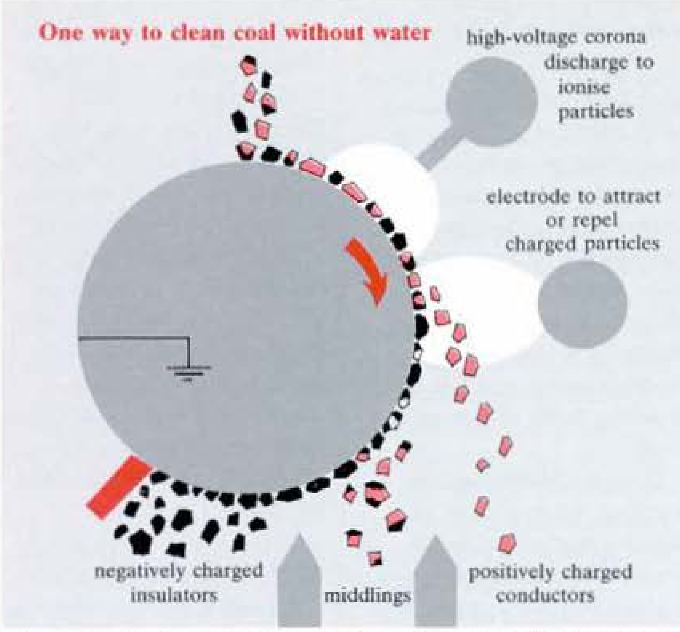
A necessary preliminary has been to study the detailed crushing behaviour and splitting tendencies of different types of coals and their components. Dr Lockhart and his colleagues expect that, by effectively utilising a phenomenon known as selective breakage, they can optimise the amount of coal liberated from impurities while minimising the degree of crushing needed and, where possible, avoiding the need for fine grinding altogether.

Selective agglomeration is a simple technique favoured by the researchers for cleaning and recovering fine coal. Finely ground coal, or the fine fraction resulting from coarser crushing, is mixed with an oil–water suspension. The coal prefers to agglomerate with the oil, while minerals tend to disperse in the water. When the oil and water are allowed to separate, and the fuel fraction is further processed, we end up with a coal–oil mixture suitable for use as a liquid fuel, or with pellets that rate as a premium solid fuel.

Mr Waugh has been working with Dr Lyall Williams of Macquarie University on aspects of oil agglomeration. Flotation of ultrafine coal is another option, which is especially suited to coal–water mixtures. ACIRL has much experience in this area.

Flotation and agglomeration are well suited to dealing with coal-washery tailings — the discarded fine material that may still contain 50–70% coal. With coal at about $50 per tonne, the supply of superclean (or even, with the help of chemical treatment, ultraclean) coal from a normally discarded source need not be an expensive proposition.

Another separation process that will be needed to produce superclean coal makes use of a dense-medium cyclone (a form of large centrifuge). Conventional coal cleaning uses magnetite suspensions of density 1·4–1·6 to separate clean coal of lower density from dirty coal and mineral matter of higher density in a cyclone.



Mineral matter is conducting, while coal is not. So electric fields can separate one from the other, as illustrated. This electrodynamic method avoids using water and the problems that arise from trying to dry fine wet coal.

The CSIRO Division of Mineral and Process Engineering is working with ACIRL in developing an improved cyclone technique based on ultrafine magnetite that allows separation of very clean coal at densities of 1·3 and even 1·25. Dr Lockhart and Mr Waugh hope to test novel dense media other than magnetite that may be better for low-density separations, especially for fine coal.

A drawback with using water in coal-processing is that the coal has then to be dried — quite a problem if the coal is very fine. Although superclean and ultraclean coals will not necessarily be very fine, they will on average be finer than conventional clean coal. Appreciating the attendant difficulty in separating fine coal and water, Dr Lockhart, with sponsorship from the Australian Mineral Industries Research Association, has been working on a technique called electrical de-watering (see *Ecos* 36).

Electrical de-watering is a quick way of drying out a suspension by inserting electrodes and applying an electric field — the particles move in one direction and the liquid in the other. Successful field trials have been completed at a coal washery (where 580 tonnes of tailings were de-watered in 2 weeks) and at a sand washery (where 5000 tonnes of a troublesome clay slime were rapidly concentrated).

Recently a new company, Aquaterre Pty Ltd, has been formed to commercialise this technology. Applications of it may extend to de-watering sewage sludge and wastes generated by paper-making.

Instead of de-watering coal, it may sometimes be better not to use water in the first place, and Dr Lockhart and his colleagues are investigating one promising dry technique involving electrical separation.

One method involves charging fine coal particles — from about 0·04 mm up to 1 or 2 mm — with a high-voltage corona discharge. Because coal is non-conducting and mineral matter conducting, an arrangement for electrodynamically separating the two can be made (see the diagram) and experiments to date show that it works at least as well as conventional wet processes. It can produce superclean as well as conventional clean coal.

An attractive feature of electrodynamic separation is that energy consumption is very low. Dr Lockhart is now collaborating with engineering consultants in a NERDDC-funded technical and economic evaluation of this, and other, dry beneficiation processes.

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More on dry swamps and ducks

The article on page 28 in *Ecos* 55 has generated much interest. The research reported there suggested that wetlands managed for waterfowl-breeding should not be kept permanently flooded. Instead, we should allow these areas to dry out periodically before flooding again. This 'drawdown' leaves a nutrient-rich layer — a result of the death of many organisms with the drying of the swamp — and these nutrients cause an explosion of biological productivity on re-wetting.