Enterprise, Innovation and Networks Committee

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The background to clean coal technology is highly complex and associated with general energy policy, climate change and the behaviour of many large industrialised countries post 2012 when hopefully a successor to the Kyoto protocol can be agreed.

It is useful here to put ‘Clean Coal Technology’ in the context of the history of coal utilisation for power generation and see what it can teach us for the future. This is inexorably associated with the generation of steam.

This history extends back for nearly 300 years with the initial development of the first Newcomen steam engines for pumping water from mines, 1712. Subsequent improvements by James Watt, 1884 lead to improved efficiency and specific power output. By the start of the 19th century substantial experiments on steam locomotion were undertaken, with the work of Trevithick and others. This culminated in Stephensons Rocket railway locomotive engine in the early 1830s, the rapid global expansion of railways and the dominance of the coal/steam combination for railway locomotives until superseded in the 1950s with more efficient diesel and electric power systems.

This is paralleled with marine technology when in the early 20th century, Parsons in Newcastle developed the steam turbine. This rapidly superseded reciprocating steam engines and dominated the industry until the 1960s when large diesel engines and now gas turbines took over as the prime movers for maritime propulsion.

The steam turbine was rapidly adopted for electrical power generation some 80 years ago or more and initially in the USA became coupled with very large scale pulverised coal furnaces for generation of steam for the turbine. This technology is still dominant today with essentially much higher pressure and temperature steam being used, giving overall power generation efficiencies up to 45%, compared to ~38% for systems completed 30-40 years ago (& 10% for a steam locomotive). The enormous change over this period with this technology is associated with substantial reduction in emissions of substances such as NOx, SOx, CO, particulates, unburned hydrocarbons..

The common theme over the last 300 years has been:

- Reduced use of fuel via higher efficiency
- Higher power outputs from a given size of system
- Substantially reduced emissions

- Reduced capital and running costs per MW of power generated

Now with concerns about Global warming attention is particularly focussing on CO_2 emissions, especially those from coal fired units. There are two complimentary methodologies here, improvement in efficiency and sequestration of the separated CO_2 from the exhaust gases underground. Before returning to these points it is useful to examine other technological developments which are alternative to conventional large scale coal furnace and steam turbine systems.

The development of the gas turbine for aerospace application has lead to the development of power turbines, primarily for natural gas of capacity up to 200MW(e). When coupled with special designs of steam boiler and turbine to form a combined cycle efficiencies of up to 60% can be achieved on natural gas: enormous numbers of these systems have been ordered and become operational as global supplies of relatively cheap natural gas have expanded. For clean coal projects it is possible to substitute natural gas by so called 'syn gas', an artificial product formed by reacting coal (or biomass/coal or biomass) in a vessel (gasifier) with meagre supplies of oxygen such that far less than complete combustion occurs and the solid fuel is turned primarily into fuel gas. There are numerous designs of gasifiers globally developed by different organisations, with different characteristics and ways of obtaining oxygen, such as air, pure oxygen, steam etc. These have been coupled to combined cycle gas turbine power generation systems (IGCC), but with limited success despite the claims of many organisations trying to promote these systems. The following table thus generically compares the present state of the art of conventional developed 'clean coal technology ' and 'clean coal IGCC, without sequestration of CO_2.

The reasons for the lack of application of IGCC is clear

.	**Conventional Advanced Coal Fired Systems**	**IGCC**
Thermal efficiency	Up to 45%	Slightly lower
Capital costs	.	Generally higher than conventional
Emissions	Low by now need extensive and expensive flue gas treatment for SOx, NOx, particulates	Very low indeed
Physical size	Very Large	Compact
Financial and technological risk to Utilities	Low, proven technology in China	Still uncertainties, more risk than conventional

It is now necessary to move onto the subject of sequestration and how it will affect the use and application of ‘clean coal technology’. One scenario from the recent UK energy white paper indicates that by 2020 power generation will have a large component of renewables, up to 20%, with a little residual nuclear, coupled with combined cycle natural gas systems and unspecified (technologically) clean coal units. Other scenarios indicate some new nuclear build via construction by Utilites, at the expense of natural gas and coal systems. Post 2020 (possibly earlier now) it is anticipated that all new coal build will have to incorporate provision for CO2 sequestration.

The increasing pace of this is illustrated by EONs proposal to replace Kingsnorth power station in Kent with a high efficiency conventional coal fired power station with a supercritical steam boiler, also incorporating provision for CO2 sequestration in the North sea. Such pilot scale work will mirror work in Norway on CO2 sequestration and in North Africa by Oil Companies, also others in other parts of the world.

However despite the euphoric nature of much that is written about sequestration there are many major problems to be overcome before it can become universally accepted as a safe disposal route for CO2.

These include:

- For existing oil or gas fields, each geological structure is different, has been deformed, hydrofractured by the very act of removing oil or natural gas. For instance the north sea bed has dropped by up to 2 metres in the area of the forties oil field. For CO2 sequestration each individual geological field will need to be modelled and assessed and decision as to suitability made
- This is attractive to governments like the UK as there is some enhanced oil recovery if CO2 sequestration is carried out at the appropriate life stage of the field. It may also be initially attractive to governments like the UK to sell CO2 storage space in regions like the north sea to others
- Saline acquifiers are potentially attractive, but again there are problems of sufficient availability
- Even a leakage rate of 0.1% means that the reservoir will become depleted of CO2 in ~ 1000 years, really too short a time frame.
- It will probably take up to 50 years or more to realistically evaluate CO2 leakage rates from sequestration-if there is leakage offset methods will have to be developed (i.e. maybe more CO2 sequestration elsewhere to compensate)
- How will containment be validated and any leakage monitored?
- Who will be responsible and pay the costs? Long term that can only be governments and the taxpayer?
- China, from its 1 billion tons /year coal production, produces of order 3 billion tonnes/year of CO2 : note the 3:1 ratio of CO2 produced to coal burnt
- Total world coal production is ~ 4 billion tonnes per year with an associated 12 billion tonnes of CO2/year
- If the Climate crisis is as severe as predicted by some, vast effort on sequestration will be needed using every available storage facility, even just to deal with the CO2 production from existing Coal fired systems, noting the 3:1 ratio of CO2 produced to coal burnt
- The concept of sequestration makes an interesting contrast to storage problems for the waste from nuclear power stations where relatively small quantities of highly dangerous waste have to be stored for very long periods geologically.

What should we be doing in Wales with respect to Clean Coal technology in the light of the above and following

- Existing Plant such as Aberthaw are coming to the end of their life and will need to be replaced by what technology?
- There have been proposals for new medium sized coal fired plants using IGCC and related cycles by a number of different organisations both in Wales and the rest of the UK. None have yet been built
- Undoubtedly any new coal fired system will need to be designed to allow capture of CO2, probably at a later date, this possibly tilts the technology towards IGCC for medium sized systems, as most of the components can be factory built and assembled on site. For large 1000MW(e) type systems probably updated and upgraded conventional designs will be used, because of the 'low risk': a good example of this is the Kingsnorth proposal in Kent from EoN
- Firing of Coal/Biomass blends in large power stations. This has been developed in the UK via the use of ROCs. Long term this is very uncertain taking into account the competition for biomass which is likely to arise with the increasing emphasis on the production of biofuels (25% substitution by biofuels in transportation fuels for the EU by 2030, similarly globally), chemicals and other products. With sequestration of CO2 maybe it will be better to burn 100% coal in large power stations and use the valuable biomass elsewhere. Indeed as much is already imported competition for supplies could be intense

In the light of the above what actions should we be carrying out in Wales that will maintain and possibly our position with respect to this very important fuel and associated technologies?

I would postulate a number of areas where actions are needed:

- Surveys of possible sites for CO2 sequestration, both in Wales itself (Saline Aquifers) and especially offshore including the North Wales Coast where there are well known underground reservoirs of gas
- Energy crops; although there is likely to be demand for biomass for co-firing in coal fired power stations for at least 10 to 15 years, there could be more added value for Wales in growing other crops (i.e. for biofuels, chemicals etc). Here more work is needed on suitable higher added value crops (with low energy inputs) and high technology, efficient, conversion processes, especially for lingo-cellulose materials (IGER, Universities etc?)
- Conversion, utilisation technologies/improvement of existing coal technologies. Here the work of Welsh Universities is important. Ongoing relevant industrial work, which needs long term support, includes:
    - The new large scale gas turbine combustion facilities at ECM^2. This is a unique world class facility and will enable Wales to be at the forefront of gas turbine technologies aimed at utilising gasified coal, coal/biomass mixtures for use in gas turbines, with subsequent CO2 separation and sequestration. This centre could well form the focus for inward investment and the creation of new start up Companies. Efforts are needed to globally market this facility and use it as base for developing new ideas and concepts and associated Industrial involvement.
    - Underground gasification of coal. A WERC study contract in this area has recently been awarded t evaluate the potential. Here coal is gasified underground with oxygen, and the resulting fuel gases extracted and used in a gas turbine. The burning characteristics of

    these fuel gases can be realistically modelled at gas turbine operating conditions in the rig at ECM^2
  - Studies of slagging and fouling problems in conventional power stations when firing coal/biomass blends using advanced modelling techniques. This arises from European Union research programmes lead by Cardiff University
  - Clean up of waste minewater using a range of chemical techniques and biological techniques such as reed beds.
- The steel industry. Hopefully Corus will not enter a stable state with the recent management changes and takeover. Continuing support will be necessary here as significant quantities of coal/coal related products such as coke are used. Possibly there may be scope for advanced coal related technology in a number of areas
- The cement industry. Again despite the use of a wide range of substitute fuels in both Welsh Plants at Aberthaw and Padeswood, very significant quantities of coal are still used and likely to be used for the future. In many ways Cement plants could be a highly significant target for sequestration of CO2 due to the relatively high amounts of CO2 produced due to the decomposition of dolomite as well as coal combustion. Imposition of sequestration even in the longer term could lead to the migration of these industries to regions of the world with different, more benign regulations. This needs to be monitored long term, although prospects are in the medium term good with the development of the new cement plant at Padeswood by Castle Cement
- There is little point in CO2 sequestration if we merely displace much of the CO2 production to regions where there are much laxer CO2 regimes. Some estimates for the UK indicate that if we take importation of manufactured goods into account substantial increases of CO2 emissions have occurred. There is thus a need for political, maybe pan European actions to monitor this and maybe long term to develop a CO2 tax on manufactured items to reflect the CO2 liability. This could be of considerable benefit to Wales in reducing the migration of industries to more CO2 benign countries, as well as encouraging inward investment to develop more CO2 benign products and industries

by Professor Nicholas Syred, March 2007