Energy Overview;
What is the Role for Coal and can it be Clean?

Andy Brown, Engineering Director, Progressive Energy Ltd.

Introduction – Worldviews and Creation

Let’s have a quick look at world views on sustainability. Firstly, there are two humanistic views. The first one is the anthropocentric view that says the world is here for human use and enjoyment. Sustainability is simply our responsibility to provide enough for fellow humans and for future human generations. I don’t subscribe to that view. The second one is the eco-centric view that sees humans as simply one part of an interdependent biosphere with no greater rights than any other part, so we sustain for the greater good and have as much responsibility for the environment as my brother’s tortoise. I don’t subscribe to that view either. The third one, which I think makes a whole lot more sense, is the theocentric view which sees the world, human and non-human, as deriving its value from being created and sustained by God – now that warms my heart. The other two leave me feeling, frankly, nervous.

Stewardship and the Genesis Mandate

I would like to start with Genesis 1:26 when God says ‘Let us make man in our image according to our likeness and let them rule over the fish of the sea and the birds of the sky and cattle and over all the earth and over every other creeping thing that creeps on the earth.’ So there is a responsibility on us, as human beings, to rule over all the earth. Then look at Genesis 1:28, ‘God blessed them, God said to them: Be fruitful and multiply (we’ve managed that bit) and fill the earth (we’ve managed that bit) and subdue it (we’ve managed that bit) and rule over the fish of the sea and over the birds of the sky and over every living thing that moves on the earth.’ What is interesting, is that word subdue. It is a Hebrew word and it means to bring into shape. It is related to the noun for a pottery or lime kiln, the concept of taking something and making something different, even better out of it.

So, I have to ask myself the question, to whom did God give the responsibility of stewarding this planet on which we live? Us; well, let’s see how we’ve done, because I believe we have abdicated our environmental responsibilities.

Irresponsible ‘Stewardship’

Firstly, I believe we have essentially dug up the earth and thrown it away. 1987 was the first year in which the world used more than one year’s resources in a year. We started to live beyond our ecological means. By 2007 we needed 1.3 planets in order to fuel our consumption and by the end of 2010 we needed more than 1.5 planets worth of resources. This isn’t going up in a linear manner, this is going up exponentially. Obviously, I don’t have the figure for 2011 yet. We are also running out of raw materials at an alarming rate. This really bothers me and it wasn’t until I assembled this talk that I realised just how quickly we
are running out of things and, of course, the quicker we run out of things, the more they are going to cost. So, in 45 years, gold wedding rings are going to be difficult to get hold of. Those of you with grandchildren need to think “What on earth are they going to do?” In 29 years, we’ll have run out of silver, so your silver tea service is going to be worth a lot of money!

Well, not only have we failed to steward the natural resources, but we have damaged the earth’s atmosphere. We’ve got rising levels of CO2, of which everyone is aware, the thinning of the ozone layer and all these other effects. I am starting to feel guilty now. Look at over-population; it’s just growing and growing and growing. The Institution of Mechanical Engineers produced a paper recently that put a lot of the earth’s problems firmly at the feet of over-population. I think it has a lot going for it, but it does suggest that you are able to blame everybody else. And then we’ve got the imbalance of distribution of vital resources. At Redcliffe you had your ‘water-free Wednesday’, which is a good exercise. We should use less water because we use far more than our fair share here.

When you look at drought mortality, you realise that people are actually dying through lack of water. It is all frightening stuff. And then you consider the extinction of species. The more people there are on the planet, the less there is of everything else. So I think the impact of abdicating our environmental responsibilities is significant.

Coal on Trial

So, let’s put coal on trial. It is said that coal is the “Villain of the piece”. I’m not sure whether this presentation should be called “The role for coal”, or “The case for coal”. Let’s see how we get on. What makes coal unclean – apart from the fact that it is black and gets on your shirts and so on? Firstly, it contains mostly carbon and the only way to use coal is to convert the carbon into carbon dioxide. That has an impact. There seems to be quite a good correlation between the concentration of carbon dioxide in the atmosphere and the global temperature.

Looking towards the future, the temperature of the earth’s surface has risen remarkably since the Industrial Revolution, coincident with a rise of CO2 levels. And where we’ll end up at the end of the day depends on which scenario you choose, but the important thing is that we can’t keep going on as we are at the moment, because if we do, the rising temperature leads to rising sea levels, (because water expands when it is heated) and it is not just the ice melting into the water, it is the fact that you have a whole body of water and when it gets warmed it expands. Were we to be living in Bangladesh, instead of at Redcliffe, we would see the impact of sea water rising. It would have to rise a very long way before the lovely gardens outside here became water gardens, but in Bangladesh the problem is a bit more acute.
Secondly, coal contains sulphur, unfortunately particularly in UK coal, and sulphur, when one burns it, produces sulphur dioxide and that leads to acid rain and deforestation. Coal also contains ash and that leads to particulate deposition, fine particles in the atmosphere. I used to be responsible for the coal, ash and dust plant at Didcot Power Station and they have got quite an efficient system there of taking all the particulates out of the coal. But once in a while something would go wrong, the system wouldn’t take the particulates out of the coal and we would end up with complainants at the gatehouse showing their washing covered in little black specks of grit.

Coal contains a lot of other materials as well, arsenic, nickel, lead, mercury, chlorine and uranium. Do you know coal has only got a very small amount of uranium in it, but if you take that small amount of uranium and multiply it by the amount of coal we burn in England, the amount of radiation that coal-fired power stations put into the atmosphere far exceeds what you get from nuclear power stations? Combustion of coal produces nitrogen oxides and nitrogen oxide has 200–300 times the global warming effect of CO2.

Coal; is it the villain of the piece? Yes, guilty as charged! But I am making the case for coal and would plead that it was “not acting on its own”. It is not coal’s fault; it is how we have used it and, if we are going to look to the future, it is sensible to look at how we are going to use coal in the future. So let’s have a look at that. Can we afford to lock up coal for ever, or can coal be ‘bound over to keep the peace’?

A ‘Coal-less’ future?

Let’s think what an energy system without coal would look like. On a typical day, the UK electricity supply system has a demand something like what we coal Load Shape 46. Now somebody may say what does Load Shape 45 look like, or Load Shape 47? I have failed to find an answer to that question, but everybody in the industry calls it Load Shape 46. That starts off with what we call a base load. We are talking generally about energy and we are focusing on how we can create a more sustainable future for ourselves and, as has already been pointed out, in the UK we have a mixture of fuels, a mixture of energy sources and by not putting numbers on the graph, I am hoping that we can avoid the situation where we get coal vs. windmills, vs. nuclear, vs. solar type arguments, because I think we need to look at the whole picture. I don’t want to get into debates about numbers because I could find you numbers that would prove any point that you want to.

So, Load Shape 46; we have this base load and then there is a variable load. The base load is provided by things that don’t shut down, like Tescos, and whereas street lights come on at night, we have other things like computers that come on during the day. There are things like water pumps that pump all the time, so there is what we call a base load. Then there is a variable load which starts about 6am in the morning when people get up and make a cup of tea. Every time you flush the toilet, pumps have got to cut in somewhere and supply more water. Then people get up and have a shower and they have breakfast and then at the end of the day’s work they would come home and do whatever people do in the evening, watch
television or mark books or do some homework. Then, eventually, people go to bed and we settle down to the base load again. Our energy needs have been met, typically in this way. There is a base load of nuclear because nuclear does not like being jolted up and down and so we just let that tick away at the bottom. Then one has the most efficient fuel power stations, and it is the most efficient ones because this is governed by accountants and not engineers, and so the power stations that earn the most money come in next, and finally one gets the less efficient ones doing the odd bits and pieces.

On a day-to-day basis, it is not quite as simple as that; it doesn’t go in nice straight lines. It would be lovely if it did, but it goes up and down. There are very early morning people, there are a lot of people who have breakfast and in the evening there are a lot of people who cook their tea and this is another peak. In between, there would be peaks at lunchtime and in the evenings there might be a peak when ‘Dancing on Ice’ finishes because everyone rushes out to make a cup of coffee and back to flushing the toilet and so on. The actual load of a day goes up and down quite a lot and provides a problem when one comes to planning the amount of energy required and to be distributed. So nuclear is left supplying the base load and the more efficient fossil burning plants, and then in between one has what is called “two-shifting” “three-shifting” and “peaking” plants; one has generating capacity that one brings on and switches off.

When we put wind power into this equation, it exacerbates the situation because, although there is some degree of control over windmills, basically when a windmill is turning it is exporting electricity into the system somewhere and that means that it will take a slice out of the sandwich, so that whatever is at the top end is having to be swung about more and more. As we increase the amount of wind, then for the fossil-burning plants, the scope for running very much of it all the time reduces and there is more and more of it to switch on and off quickly.

If we were to remove fossil-burning from the mix altogether, then it becomes more difficult to maintain the balance. I have taken an extreme situation here just to make the point that we have got nuclear supplying the base load, and we say everything else is supplied by wind, because the wind will blow wherever it wishes, as the Bible says.

I have talked about switching things on and off and swinging things up and down and this will give you an idea about how difficult it is suddenly to bring on more electricity generating plant. The quickest we can get something on is in two different units, which is a bit awkward, so one is in minutes and the other hours. In the case of a coal- or gas-fired power station, if it has only just been shut down, it is possible to bring it back in about an hour or two. If it is nuclear, it will take several hours to start it up again.

The best we can possibly manage to bring on, with a new piece of kit is 30 minutes, and people will do this. So if we have ‘Dancing on Ice’ just about to finish, in the half-an-hour beforehand they will start to bring this generating plant into the system and that is how it
works. We think electricity comes out of a socket in the wall, but behind that there is so much engineering, planning and technology, and in the UK we are blessed to have quite such a stable system.

What happens in the high-wind turbine scenario when we have an anti-cyclone as we had in January for about three days? If we are not going to have windmills generating a significant proportion of electricity, which is the Government’s intention, then we have got to have something in the background to supply that electricity when the anti-cyclones happen.

This is where I think coal can come to the rescue. Many of the conventional power stations we have got at the moment have already had equipment fitted to reduce the sulphur emissions and I have given the example of five power stations. This is interesting because we have taken a power station that is 40 or 50 years old and have made a significant investment on the back end of that to clean up the emissions. The other power stations in the UK will close. In 2007 there was a rule that either one fits this flue-gas desulphurisation equipment on the back end, or that plant will close down, when it has operated for 20,000 hours, or by 31st December 2015. So plants have either opted in and started spending money on flue-gas desulphurisation, or have opted out. After 2015, this will leave the UK with a smaller fleet of plants fitted with such equipment reducing the amount of nitrogen oxides and combustion. It will also leave the UK short of 10,000 megawatts of generating capacity.

I struggle to put 10,000 megawatts of generating capacity into context. I suppose it would be what Manchester would use, so we are losing a significant chunk of electricity supply. We can’t do anything about that, because the European Union has said so, and we always obey their rules.

So you have a conventional type of power station which produces steam and you put this equipment on the back, limestone in the top, (which is not particularly good for the earth’s resources because that means digging up Buxton), and it produces gypsum at the back end, which is good because plaster board can be made out of gypsum. About 20% of the UK’s plaster board comes from flue-gas desulphurisation gypsum. Making gypsum to the right standard for plaster board governs how one operates the power station, because if plaster board cannot be made out of it, it has to go to land fill which is also not environmentally a good idea, but for the accountants it is a bad idea because it costs money. So, Plan A would be to ‘burn it dirty and clean it up’.

‘New Power’

That is the old power station; now let’s look at the new ones. Using what they call supercritical steam conditions, the efficiency rises from about 36% at the moment, which is what we can expect from today’s power station, up to about 45%. 45% is current best practice and that is at a plant in Finland, which benefits by taking its cooling water from the
Arctic at only 2 degrees centigrade. That is an example of a very efficient modern power station. This will give a 20% reduction in the emissions of sulphur oxides, nitrogen oxides and carbon dioxide compared with other power stations, just because it is burning things more efficiently. But with regard to nitrogen oxides which are 200 – 400 times more powerful, as greenhouse gases, than carbon dioxide, this is not enough. More equipment could be bolted on the back to reduce emissions further but, this reduces efficiency, makes it more expensive and gives the accountants a headache.

We in the UK are amongst those piloting the post-combustion capture of carbon dioxide; there is a scheme and the tax payer is paying for it. Plan B is to burn it and clean it at the same time. This is another technology and there is a power station of this sort on the Slough Trading Estate, but it has not taken off in the UK. Limestone is added to the coal in a chamber at the bottom and air is bubbled up through it allowing simultaneous combustion and desulphurisation.

The reason it hasn’t taken off in the UK is the ash from that has been designated as Special Waste, so it is a bit difficult to get rid of. But in other countries it has taken off, such as in the United States and China, because what they call carbon neutralisation is quite good. If you have got difficult coals, like the woody coals that are burned in Germany, it is good for that and, particularly good for biomass, and I think that is where it has got a niche. But the flue-gas isn’t suitable for carbon dioxide capture without a lot of treatment, which means a lot of kit and that upsets the accountants. So I don’t think Plan B is going to work.

Plan C is to ‘clean it and then burn it’ and this is something which rejoices in the name of Integrated Gasification Combined Cycle. What we do is firstly turn a coal into a gas, similar to the days of town gasworks. I say similar to because when I mention town gasworks, people think of this pungent odour that surrounded it, coal-tar soap and people leaving on their bicycles in the evening with filthy faces.

Now, of course, we have got the legacy of the land it contaminated. Technology has moved on a bit since then and we can take the gases out of coal without any of that stuff at all. The gas it turns it into is mostly carbon monoxide and hydrogen, and then it is cleaned of mercury, sulphur and carbon dioxide. So one ends up with a gas that is mostly hydrogen and that is helpful. Because of its chemical processing, we can add to it and we can clean it of more stuff, if we discover that there is more stuff we need to clean it of, or we can clean it better of the stuff we are cleaning it from at the moment, so you have got some flexibility there. There are plants operating successfully in Spain, the Netherlands, Poland, Japan and the United States and there are at least two projects planned in the UK.

We start by taking fresh air and we separate that into oxygen and nitrogen; that is common technology. Then the oxygen is put into a reaction vessel under pressure with coal or coke or biomass and, because it is there with oxygen, it will react very quickly. We put steam in there to keep the reaction temperature down to about 1,600 degrees centigrade. At that
temperature, all sorts of things happen. There isn’t enough oxygen for carbon dioxide to be formed so the first reaction is between the carbon and the oxygen and that produces carbon monoxide. Carbon monoxide isn’t a very nice gas, it replaces oxygen in the blood to form carboxy haemoglobin instead of haemoglobin and this can lead to death.

I mentioned steam is added to keep the temperature down to 1,600 degrees centigrade. At that sort of temperature water just falls apart and that releases hydrogen molecules and some oxygen molecules. The oxygen molecules quickly get sucked up by the carbon molecules to produce carbon monoxide, which leaves a lot of hydrogen gas. Coal contains sulphur, as we have noted previously, and the sulphur reacts with the hydrogen to form H2S which is poisonous. We then take the carbon monoxide and add it to water, shuffle the molecules about and make it produce hydrogen and carbon dioxide. At that point you have got a gas that is about 50% hydrogen and 50% carbon dioxide and this is ideal for chemical processing. The carbon dioxide and H2S is washed out, leaving a gas that is mostly hydrogen. Hydrogen can be burned in a gas turbine and generate electricity, where the emissions are mostly water vapour. So we have taken coal and we have produced an emission which is mostly water vapour, and that has got to be good news.

There is the carbon dioxide to deal with, but before we do that, consider the sulphur. The same process that washes out the carbon dioxide will wash out the H2S and then we can react that with oxygen and produce elemental sulphur. That is saleable into the fertilizer industry, for instance, so that is good. And the sulphur it replaces is the sulphur that is mined, particularly in Germany. This is good; we are digging up coal, we are using it responsibly and we are minimising an extractive industry.

So, what about the carbon dioxide? The UK is uniquely blessed in that we have got a lot of carbon dioxide storage capacity. What I didn’t bring with me today is my piece of Bunter Sandstone which is sitting on the window sill in the study. You may have seen a lot of pictures of carbon dioxide being stored underground. What they normally have is a bit of sea, then sand, then rocks and then a black dome and that is where the carbon dioxide is stored and you have other rocks and things underneath. That leaves you with the impression that underneath the sea there are huge caves full of absolutely nothing where the carbon dioxide can be pumped. It is not like that. The carbon dioxide is stored in sandstone and, if I passed it round, it would be similar to Cotswold stone but just a bit grainier. The trick is to take a glass of water, pour it into the rock and the rock absorbs it! That is the mechanism by which our carbon dioxide is stored. What is in this rock at the moment? We can find natural gas in a rock, and you can find oil in there, held within the rock.

Some of these formations have got salt water in: they are called saline aquifers. Some of them have got fresh water in and we drink that stuff; a lot of our water comes from aquifers. The carbon dioxide is pumped down, typically two or three kilometres, and displaces some of the salt water in the aquifer, where the carbon dioxide stays. You can also put it into wells where you have taken out the natural gas and you can put it into wells where you have taken
out the oil. The nice thing about the last one is that, when it goes into the rock where the oil was, it pushes more oil out, so that makes the accountants happy. You can argue that it doesn’t make the environmentalists so happy because they would rather the oil stayed in the ground, but as we will see in a minute, we need something to keep us going whilst we do other things.

Clean Coal

So we have taken a piece of coal, where we have acknowledged it has got problems and I have introduced to you a technology today whereby we can deal with the carbon dioxide problem, we can deal with the sulphur problem and we can deal with the nitrogen oxide problem by burning it in modern gas turbines. This is the technology that will enable coal to be used cleanly. It will not smell like a gas works; it is remarkably clean and if you were buying the technology from me I would circulate to you now a little lunch box that is filled with yellow sulphur that is produced in the plant, just to show that it really does produce real sulphur.

If we can say that we can make coal clean, how clean is clean? We have power stations like Didcot which are unabated (the ones that are going to close after 20,000 hours or on 31st December 2015). Then we have other power stations where they have fitted kit on the back, and finally you have the ‘state of the art’ modern power station.

By introducing modern technology we can deal with nitrogen oxides. With carbon dioxide emissions, when we put the kit on the back it reduces the efficiency of the power station. Even with the newest power stations it is not zero carbon dioxide emissions; you reduce it by 85% which is a step in the right direction. How much will it all cost? The impact of some of the emissions trading coming in at the moment has given the right signals to the market to do something about it.

Conclusion

In conclusion, I think that continued use of coal with yesterday’s technology is not environmentally responsible. I think that in the future emissions from coal-based electricity production can be much lower, and it can provide the flexibility needed to balance the variable or inflexible low CO2 alternatives. We need something to bridge the gap and I think today’s technology offers a role for coal in the future, as a bridge towards sustainability. I would not pretend that coal is a sustainable solution but I think we need something that is a lot better than what we have got at the moment to put in place until what is emerging and developing can come in and take its place. I would like you to consider that coal has a role in the future, provided that it is used responsibly using modern technology.

I rest my case.
Please Note: The views expressed in this article are those of the author and do not necessarily reflect the position of Redcliffe College (or any organisation they are associated with).

This and other articles can be downloaded from the Encounters website (www.redcliffe.org/encounters).