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Review of the October 2003 decon report on *Implementing clean coal technologies – need of sustained power plant equipment supply for a secure energy supply* (EP/IV/A/STOA/2002/07/01)

Final report, prepared for STOA, European Parliament

INTRODUCTION

This review has been prepared under the terms of a contract between EASAC and STOA, which provides for EASAC to undertake peer review of the scientific aspects of reports commissioned by STOA from external consultants. The task assigned to EASAC is to give expert, independent comment on the report in question: it is not our role in this instance to draw our own conclusions about the issue under consideration, nor to make policy recommendations.

The report being reviewed is entitled *Implementing clean coal technologies – need of sustained power plant equipment supply for a secure energy supply* (October 2003). It was written, under contract to STOA, by decon (Deutsche Energie-Consult Ingenieurgesellschaft mbG) in consultation with MVV Consultants and Engineers.

The process used by EASAC in undertaking this review was to identify suitable experts through the networks of the member Academies of EASAC, brief them about the task and send them the material, collate their reviews into a single document, review that document and submit it to STOA. Preliminary versions of the report were made available to us earlier, and the final version complete with tables and diagrams was received by EASAC and sent to the reviewers on 26 November. The process of collation is intended to produce as coherent and accessible a document as possible while respecting the sometimes divergent opinions of the reviewers. So far as possible, the reviewers' own words have been used, with a minimum of editing to improve fluency between passages and provide for a connected text. In particular, the aim has been to present the spirit of each set of comments rather than to give an 'average' position. As a result, it may sometimes happen that mutually contradictory statements are juxtaposed.

The four experts whose reviews are collated in this document came from France, Portugal and the UK, and their expertise covered coal science, environmental policy, energy and fuel in general and clean coal in particular. In keeping with normal practice, the names of the individual reviewers remain confidential. Also in keeping with normal EASAC practice, the reviewers were not paid for their reviews.

The review begins with a summary of the decon report. The remaining sections of this document are, essentially, the direct words of the EASAC reviewers.

SUMMARY OF REPORT

The decon report for the European Parliament is intended to highlight interest in, and elicit support for, the development of clean coal technologies. One part of the background is self-sufficiency at EU level: the EU is currently depending for its energy supply more and more on oil and gas, increasingly imported from outside the EU, whereas it is estimated that there are enough coal reserves within the EU to last at least 200 years at the current rate of consumption. A second part of the background is the Kyoto commitment to reducing CO_2 emissions, and all that that implies for levels of energy consumption, efficiency of processes and the need to promote technologies with fewer emissions.

In the context of the greenhouse effect, the report states that the average net efficiency of current thermal power stations is about 32%, whereas with ultrasupercritical pulverised coal 45% is already attainable and 55% should be possible. These technologies would allow Europe to meet 92% of its Kyoto commitments.

The report envisages that global consumption of coal, which grew by 0.9% pa during the 1990s, will grow by 2.1% pa during the current decade and then by 2.5% pa between 2010 and 2030, leading to a doubling of consumption between 2000 and 2030.

Global demand for electricity in 2030 is expected to be 2.3 times that in 2000. The part played by fossil fuels in meeting this demand is said to grow from 60% in 2000 to 70% in 2030, with conventional coal dropping from 36% to 12%, advanced coal technology growing from zero to 33% and gas growing from 16% to 25%.

The ageing of thermal power stations in Europe will, according to the report, start to create a gap in energy supply from 2010, reaching 300 GW towards 2020. At a cost of 800 – 900 €/KW, this implies expenditure of the order of 250 billion Euros.

The major part of the report (chapter 3) outlines a range of different clean coal technologies (CCT) at various stages of development. These include the following.

- Pulverised coal (the main technology for the last 50 years), in a supercritical cycle at 580 °C and 280 bar, at an efficiency of 40% – 45%, with a build cost of €1000/kW. R&D currently under way to achieve an ultrasupercritical cycle of 720 °C and 350 bar holds promise of an efficiency of 50% by about 2015.
- The fluidised bed reactor with circulating atmosphere is an established technology with more than 300 units in operation. It can accommodate a variety of fuels and allows very low emissions of SO and NO. It has an efficiency of 40% and a build cost of €1000/kW.
- Integrated Gasification Combined Cycle (IGCC), with efficiency of 45% possibly improving to 50% and options for CO_2 capture.

The report also describes for reducing pollution from SO, NO, heavy metals, dusts etc.

Later chapters discuss the socio-economic relevance of CCT, the relevance of CCT to climate change and R&D policies in the EU, and development of a demonstration project.

COMMENTS

Does the report take on board the best current thinking about the subject ?

All specialists in this field have similar ideas (with some variants) about the future ways of burning coal for electrical energy production in the context of the growing greenhouse problem. In Europe where the penalty for CO_2 emission is already decided (at €40/tCO_2 from 2005 and €100/tCO_2 from 2008), this thinking is compulsory. In the USA with no commitment about Kyoto, it seems at first that this view is not so compulsory, but the active R&D in progress in that country demonstrates that the same thinking is shared.

This thinking is shared throughout the world, and is seen as a strong obligation for countries having large reserves of coal (USA, China, India) and where coal is a key component of their development (China, India). For these countries, the clean coal technologies are compulsory to keep on with their large use of coal with an acceptable level of pollution. For countries like Europe whose development is not so strongly tied with coal production and having smaller reserves (mainly consisting of lignite in Germany and hard coal in Poland), the thinking may be slightly blended.

If the thinking is roughly shared as concerns the various technologies, some differences appear in respect of the timing: 2050 to reach the target of zero emission seems too far. Some developers have earlier views, in the range of 2010/2020, to be able to maintain a coal line for electricity production in spite of the growing severity of the environmental laws.

The argument that there is likely to be a continuing vigorous growth in energy demand, with strong international pressure on fuel prices and constraints on CO_2, would benefit from greater clarity on the projections and on the constraints. For example, do the demand growth figures take full account of the scope for energy efficiency? The UK expects to meet half its commitment to a 60% reduction in CO_2 over the next 50 years by implementing energy efficiency. Studies for the European Commission have also shown the power of energy efficiency in managing demand.

The CO_2 constraint is well covered, but there are other environmental issues to be taken into account. This section of the report should also include mention of acid rain (SO_2 and NO_x), of release of toxic heavy metals, mercury in particular, to the environment and of health effects of air pollution, particulate matter especially. These other environmental constraints have placed major costs on coal burning power stations and such pressures are unlikely to abate. This has a major bearing on the overall costs of the technology.

The importance of supporting European industry in an increasingly competitive global energy market is covered, but in a distinctly 'pre 9/11' manner. The real issues of competitiveness in fuels will be clouded by concerns about security of supply. This should be given far greater weight in this report. Security of supply is now a major driver in the development of energy policy in the USA and may become so for Europe too if, for example, ocean transport is disrupted.

Peat (p 14) is not considered anymore as a coal category, at least for specialists and in the scope of the International Committee for Coal and Organic Petrology - ICCP. Furthermore, and in modern terms, coal should be classified by the following three main characteristics:

(i) rank: low-rank (lignite and sub-bituminous), and high-rank (bituminous and anthracite);
(ii) petrographic composition; and
(iii) grade, ie the degree of mineral impurities.

These three characteristics should be considered jointly and never separately from each other, although rank remains the most apparent coal characteristic.

On classifying coals we should consider separately:

(i) Classifications: Natural systems mainly for scientific/genetic purposes, as well as for the calculation of resources/reserves in a common basis; in classifications, coal is considered as an organic sedimentary rock *in situ*.

(ii) Codifications: 'Artificial' systems for technical/commercial purposes; in codifications, coal is considered as a commodity for using in different technologies and therefore codifications refer to single coals and/or to beneficiated products (crushed, washed, sized), as well as to coal blends.

Does the report cover the literature sufficiently?

Generally yes, with the minor reservation that it mainly refers to the literature supporting clean coal development, without reference to scenarios where nuclear could play an important role after 2020. As an example, figure 2-6 of page 15, reprinted in the executive summary, dramatizes the future of EU electrical energy in comparing the growing demand up to 2030 with production capacity of the plants younger than 40 years, with the implicit assumption that no replacement of components allowing for life extension nor replacements with new units are decided in between. Such assumptions are not too far from reality up to 2010, but are less and less true between 2010 and 2030: the earlier distortion appears with renewable energies (included in "other"), much new equipment is put in operation as from 2000.

Nowadays, besides national systems, there exist actualized international systems for Classification and Codification implemented by the United Nations, Economic Commission for Europe (Geneva) [UN-ECE]:

(i) Classification: *International classification of in-seam coals*. United Nations, Economic Commission for Europe, Committee on Sustainable Energy. Geneva, 1998. (Document ref. ENERGY/1998/19).

(ii) Codifications: For low-rank coals: *International codification system for low-rank coal utilization*. United Nations, Economic Commission for Europe, Committee on Sustainable Energy. Geneva, 2002. (Document ref. ECE/ENERGY/50). And for high-rank coals: *International codification system for medium and high rank coals*. United Nations, Economic Commission for Europe. New York. 1998. (Document ref. ECE/COAL/115).

This is particularly relevant because the UN-ECE classification/codification systems are on the basis of the European Regulation No. 1407/2002/EC for aids to the European coal industry (see Official Journal of the European Communities, August 2, 2002, particularly Article 2 –Definitions). ISO is currently preparing a standard entitled *Classification of coals* (ISO/CD 11760) which adopted, although with modifications, the UN-ECE general criteria. UN-ECE also published a recent method for calculating resources/reserves of fossil solid fuels (and other solid commodities) in an international common basis. In fact, until now the statistics on fossil fuels provided by different institutions are sometimes rather different. The UN-ECE publication is *United Nations international framework classification for reserves/resources – solid fuels and mineral commodities*. United Nations Economic and Social Council, Economic Commission for Europe, Committee on Sustainable Energy. 1997. (Document ref. ENERGY/WP.1/R.77).

Also, Alpern and Lemos de Sousa recently published an account of the situation in this particular matter in a paper entitled 'Documented international enquiry on solid sedimentary fossil fuels; Coal: definitions, classifications, reserves-resources and energy potential' published in the *International Journal of Coal Geology*, Vol.48, 3-4, p.245-251.

CO_2 capture and sequestration/storage are not the main subject of the report. However, considering that the state-of-the-art of this particular matter is very well described in the report, it will be good to also refer to the different current R&D projects mainly in Europe (see IEA website on CO_2 sequestration: http://www.co2sequestration.info). In my opinion, the only really promising method of sequestration/storage is in abandoned coal mines. In fact, when injecting CO_2 in coal the gas is fixed in the adsorbed state, and only a small amount is able to escape (by diffusion effect, depending on the characteristics of each coal basin) in the long term. In Research Unit of my won responsibility, at the University of Porto, we are specialists in prospecting/exploring Coalbed Methane, with a great experience in coal basins all over the World, and therefore we are also particularly concerned with this matter. In Europe the only R&D project for CO_2 sequestration in coal mines is currently developed in Poland (Silesia), but in the USA there are many current projects in this scope.

Finally, as the European directive regarding CO_2 and other greenhouse gas emissions is already published (Directive 2003/87/CE of 13 October 2003) it should be mentioned in the decon report

Do the report's conclusions follow from the evidence it presents?

For coal-dependent countries and for countries having engineering and industrial competences in coal technologies with high employment in this field, certainly yes, but some shading of the too limited colours of the possible clean coal technologies are detailed below.

I find the chapter on policy options thin. It may be true that there is little to review, but the track record of Europe so far should at least indicate some traps to avoid. For one thing it is clear that an ambiguous environmental policy does not help. So long as Member States do not agree on ambitious carbon and air pollution targets, it is possible for the power companies to limp along with current technology. The authors could make much of the value of good clear ambitious targets to address the real environmental problems Europe faces. This would create a demand for new technology as the European regulators enforce closure on dirty plant.

There also has to be clarity on the incentives that work and those that do not. Again, there is experience of this and there are good sources of advice, for example the OECD.

On the R&D (chapter 6), there is a recommendation to form a large European version of FutureGen. This is not without merit, but needs better substantiation. The FutureGen project is US led. It is also highly protective of US interests and is likely to be built in the US. The US is very keen to bring in partners to show an international dimension, but has shown no interest in sharing the work with European partners. The Commission could pursue a meaningful partnership with the US on this or it could mount an alternative European CCT venture. The demands on resources would, however, be huge. The authors should go into this quite carefully before recommending it. They are right, though, not to rely on a sudden change of heart on nuclear new build.

On the socio-economic analysis (chapter 4), the authors mention employment but do not deal with the major externality, which is health. There is much written on this and a major European Project, ExternE, on the subject. The different health impact of the different technologies should be mentioned, at least as an issue to be addressed in future.

The discussion of sequestration and disposal of CO_2 is welcome and important.

The Conclusions do seem light and could be sharpened considerably. In particular, the policy recommendations are neither clear nor particularly helpful as they are drafted at present. I suggest that the authors think carefully about the different interests of the different DGs in the Commission and make targeted suggestions for each of them, finance, environment, R&D, TREND, for example.

Does the report give a balanced account of the advantages and disadvantages of clean coal technology?

Some technical and economical points should to be scrutinised in more detail.

- The report emphasizes the ultrasupercritical (USC) pulverized coal channel, claiming future efficiencies of 55%, which is a relatively optimistic raw efficiency, leading to 49% or 50 % net efficiency, compared to today's average European efficiency stated as 32%, which looks like an underestimate (European statistics indicate that 8% of power stations have a net efficiency above 40%, 43% have an efficiency between 35% and 40%, 40% have an efficiency between 30% and 35%, and just 9% are below 30% efficient). The efficiency gap between today and future is probably not as large as presented.

- IGCC seems also too much emphasized. It is an expensive way, leading to a range of price of avoided CO_2 of 50/60€/t, compared to about 20€/t for the other ways increasing the efficiency.

- Other solutions are not so emphasized: the atmospheric fluidized circulating bed, of which there are today more than 500 examples world-wide (and not 300 as said in the paper), would exhibit an efficiency similar to pulverised coal for the same USC temperature conditions, with more fuel flexibility and perhaps some significant other advantages compared with pulverised coal (shorter high temperature pipes, cheaper steel materials, etc).

- The expected level of investment cost of the described clean coal technologies (1000 €/kW) seems undervalued, 1300 to 1500 €/kW is given by some other sources.

- From some sources, USC boilers will be able to burn only high quality coals (which can be bought on the international market, but of which there is a shortage in Europe). There is some doubt about the ability of these boilers to be adapted to lignite, which would require additional features to eliminate chlorines and alkalis, as steel corrosion doubles every 10°C in this range of temperature. The report does not give any reference to this problem. If only imported high quality hard coal could be burnt in USC boilers, the energy dependence of Europe would be higher than if lignite can be used with good performances. This point needs clarifying.

- The same remark applies to the mixture of biomass and coal in order to reduce the CO_2 emission (the wood biomass being supposed CO_2 neutral). Can ultrasupercritical boilers accept such mixed fuel? Circulating fluidized bed boilers are probably the best way for this use, as they accept a larger variety of fuels than pulverized coal boilers.

- Admitting wood can be added to coal in the furnace of new USC boilers, it is stated that beyond the 15 to 20% wood tested today with conventional boilers, an increase of the wood percentage up to 50% or more would further lessen the CO_2 emission. OK, but what about the quantity of wood to be supplied to the power stations and the cost and CO_2 emission of its transportation? The report does not present any inquiry about the compatibility of European forest production with electric energy needs.

- The cost of hard coal in Europe is said to be three or four times that elsewhere. Only European lignite is competitive. But the report ignores Polish coal, doesn't quote a price for lignite and seems to ignore the costs of transporting and drying lignite.

The section on candidate technologies and associated costs is, of necessity complex, but I find the layout of this section particularly confusing. On technologies, it is a question of comparing like with like. This is not easily done but means, for example, including the costs of achieving a given environmental performance. I believe that this is essential, otherwise some technologies, for example fluidised bed technologies, appear to be low in cost despite poor environmental performance. In order to do this, there has to be an assessment of the future demand of environmental legislation and it is really for the Commission to specify this. Without this, costs make no sense at all.

The technology costs are only part of the equation. In a study for the United Nations Economic Commission for Europe, the International Energy Agency found that, of the factors affecting the costs of energy, technology ranked about third or fourth, below costs of investment, exchange rates and licence costs. If this is still the case, which I believe it to be, then the authors should consider overall project costs. This is hard to do and has caused considerable difficulty even for the largest assessments, such as those made by EPRI, the US Electric Power Research Institute. The authors have to address these questions, though, as the different technologies have different investment implications.

There is also the question of sunk investment. For all these technologies, costs will come down as more capacity is delivered. The real question is at what stage the costs of CCT can fall below current technology plus after-treatment.

From my viewpoint, the remarks are sometimes too dismissive. For example, I believe that IGCC makes much better sense once environmental controls are taken into account. No one should even consider a power plant without theses controls so why bother to comment that IGCC is costly until they are in place? Similarly, some of the fluidised bed technologies either do not work at a sensible scale or cannot deliver the required environmental performance without after treatment, so why quote them as a low-cost technology?

<u>Does the report give policy makers a clear feel for the subject?</u>

The report expects that world coal production will double from 2000 to 2030 (page 10). This evaluation seems from today very difficult between 2020 and 2030. The production will probably increase by 35 to 40% between 2000 and 2020, but after 2020, the share of coal in the energy mix will depend on some factors that will have changed by that date and are not predictable today:

- The effectiveness of the Kyoto and post-Kyoto international agreements
- The oil price increase at that date where oil production will start to decline
- The natural gas price and its short-term expectation
- The demonstrated technical progress in clean coal technologies and CO_2 capture

- The progress made in the CO_2 storage feasibility and social acceptability
- The progress made in the nuclear wastes storage feasibility and social acceptability

For policy-makers, the viewpoint needs to be enlarged to the merit order of the various possible sources of electricity. The analysis presented here of the potential of clean coal is based mainly on a needs-resources approach which is of value as concerns the energy supply security. Another approach using the comparative merit order of all sources is needed to give the full picture.

- As concerns greenhouse gases emission, the potential of advanced coal, which lowers the percentage of CO_2 emission but does not cancel it, is of course more limited than the potential of the CO_2 free sources as nuclear and renewables. With the assumption that the world park of coal power stations is replaced in 2030 by ultrasupercritical power stations, with net efficiency rising from 32% to 49%, CO_2 emission would be reduced by 35% for the same electric power, but this electric power will be 2.3 times higher in 2030 (page 12), so the total emission would still be increased by 50%. So the development of clean coal technologies is essential for countries whose economy is largely based on coal (USA, China, India). For countries with development not so strongly tied to coal production, but having developed competence and industrial activity in the coal sector, like Europe, consideration of other CO_2-free sources in the energy mix is a duty.

- The lessening of greenhouse gas emissions by means of clean coal technologies is paid by an increased kWh cost, higher than 3 €c/kWh (see page 15) because of the complexity of the technology, exceeding the reference kWh cost of today's other major electrical energies, from natural gas at 3 c€/kWh internal cost + the external cost of CO_2 not yet agreed, or from nuclear at 3 c€/kWh with zero emission. One can not fully agree with the statement page 87: "*In today's outlook, new and highly efficient coal fired power plants meet these requirements best. They offer the greatest potential for closing the forecast shortage of energy supply*". The potential of clean coal technologies would be strongly reinforced if there were a successful and rapid development of CO_2 separation and storage, but as it is said page 78, "*The development of the CO_2 sequestration technology is seen as a very high risk, long term R&D effort*". The two fields of technologies, the one aiming at efficiency increase, the other aiming at CO_2 separation and sequestration, would benefit from being closely associated, with a perspective of first demonstration units in 2010 rather than between 2020 and 2050.

DETAILED POINTS

The impact of this report would be greatly enhanced by a thorough text edit and reorganisation. The English language version is clearly not by a native speaker; it generally lacks clarity and in places is highly ambiguous. The title, for example, leaves the reader unsure whether the reports deals with the need for equipment to secure supply or the need for a supply to ensure that the equipment is available. This matters. In general prepositions are used in an odd way so that the text cannot be clearly understood.

Similarly, the form of the report does not help the reader to focus on the main points, which, I assume, are about the need for Europe to take CCT seriously and to ensure that the climate of investment and incentives encourage its development. It would be far better to make the argument in a single section, perhaps as an extended discussion or an executive summary, and to put the technical material in a series of appendices.

On the technologies themselves, I believe that the summary and the review could be improved simply by structuring it around the technologies the report covers. I believe that there are eight of these: three more or less current and five future. They are:

- Pulverised fuel (conventional power station)
- Fluidised Bed (several different flavours, at atmospheric pressure and pressurised at 10 to 20 atmospheres)
- Integrated Gasification Combined Cycle (IGCC)

then:

- Pressurised Pulverised Fuel
- Integrated gasification with fuel cell
- Direct firing of various kinds
- Magnetohydrodynamics (MHD)
- Liquid fuel from coal (diesel, for example)

This would simplify things considerably.

Among the various channels to open the ways to zero emission, some are inadequately or not at all covered in the report, such as oxycombustion, which needs a cheap source of oxygen, or chemical looping, which has the advantage of avoiding recourse to this expensive oxygen.

The report refers (p 83) to the 'Cleaner Coal R&D Programme/UK'. In this regard, I consulted the indicated DTI site in the Internet and it is interesting to verify that the concept on utilizing the designation 'cleaner (fossil fuels technology)' is about the same when utilizing the designation 'clean (fossil fuels technology)', i.e. the concept 'cleaner' refers to fossil fuels utilization technologies, only. However, among the specialists in fossil fuels, and particularly in coal, the concept of 'clean' technologies and 'cleaner' technologies are quite different: 'Clean coal' refers to the utilization technologies only, and 'cleaner coal' refers to all technologies starting on mining, continuing on preparation/beneficiation, and ending in the utilization. In other words: cleaner refers to the use of clean technologies (i.e. with direct importance on the environment) throughout the coal chain, from mining to utilization. The new wide concept of 'cleaner coal' is the one adopted in USA and in the scope of the World Coal Institute.

Some figures are inaccurate or misleading. For example;

- the average net efficiency of current thermal power stations is more like 37% than 32% as stated;
- the potential efficiency of the ultrasupercritical cycle is quoted as 55% but, for comparability, the net figure of 49% - 50% should be used;
- predictions of energy demand and coal use for the period 2020 – 2030 ignore several factors and should be treated with caution;
- some authorities quote 200GW rather than 300GW for the energy gap arising by 2020 from the ageing of existing thermal power stations;
- the cost of new build is quoted as 800 – 900 €/kW, but this applies to conventional power stations; future clean coal stations are likely to cost 1300 – 1500 €/KW;
- the number of fluidised bed reactors in operation is 500 rather than the 300 quoted on p ;

I would also like to draw attention to the following points.

1. p.1, Table of Contents, item 3.2. I think this should be revised, possibly to 'Early stage of development-coal fired generation technologies' or something equivalent.

2. The references and the numbering system are poor. Two numbering systems are employed – one for footnotes and one for the Bibliography – and this causes confusion, at least to this reader. For example, on p. 54 the legend to Table 3-8 cites ref 46 which is a footnote on that page which then quotes ref 10 in the Bibliography; on the same page ref 3 is given in line 2 of the section 'Power Plant of the Future' but this now refers to ref 3 listed in the Bibliography. I think all the references should be numbered consecutively and that they should be given at the end of the Report and called 'References'. The information currently given in the Bibliography (Section10) are in the main inadequate or inaccurate. Most are incomplete eg 11 and not all the websites cited work (or not for me).

3. p. 74, line 4. Here they quote a figure for the drop in efficiency of 'some 10-12%'. This value needs to have a reference because it could be argued by some that the figure quoted is too low, some say it would be higher if all the steps are included (removal through to actual storage). If it is higher then the economics of sequestration are vastly changed.

4. p. 99, Annex 3. I think more information should be given here about the home pages, since there are considerable gaps. There is no entry in the Table for the activities of the British Coal Corporation at all; in fact they can provide coal preparation/cleaning equipment and should have an entry under 'Services offered/ engineering', or left out entirely. I note that European Gas Turbines is listed but it is now owned by Siemens and the name has changed. RWE Innogy also, I believe, offer services and should be listed.

Annex 3 (b) should include the INETI/Dept. of Energy Engineering and Environmental Control at Estrada do Paço do Lumiar, 22, 1649-038 Lisboa, Portugal (www.ineti.pt). It is a government organisation carrying out projects at Portugese and European level on R&D technologies in the area of combustion technologies applied to fossil fuels, biomass, residues and wastes, aiming to: (i) develop higher combustion efficiency, (ii) produce alternative and substitution fuels with minimum environmental impact, (iii) disseminate new technologies, and (iv) provide technological support to industry.

CONCLUSIONS

The overall opinion of the EASAC reviewers is that the decon report is a useful account of the potential of clean coal technology, but that it contains a number of inaccuracies and, more significantly, misses some of the wider context and thus at times tends to overstate the case for clean coal. Moreover, in places it depends too much on the experience of Germany (where the authors are based), which cannot always be extrapolated to the rest of the EU. For example, the reports says (p 17) that 92% of the European Kyoto commitments could be obtained through the clean coal technologies. This is true for Germany, not for France or for Europe as a whole.

The recommendations of this report do not really cope with the fundamental problems of energy/environment in Europe for the coming decades, but mostly with the need to keep European competence and industrial activity in the coal sector whose business will be more and more an export business.

On the longer term, how could we imagine that the policy-makers could let nuclear power lose about 100 GW, being cut down by more than 80% between 2010 and 2030 in the context of a growing greenhouse problem? It is clear that new nuclear units will have to be progressively put in operation between 2020 and 2030. This figure gives a distorted view of the possible future and lessens the responsible character of the whole paper.

Overall I think that the Report is well written although it could do with another good read through from an editorial point of view. I personally agree with their conclusions. However there are two points that I think I should draw attention to.

1. Coal fired power stations have a poor reputation for being dirty and visually unpleasant with unsightly clouds of condensed steam or particulates from the flue, and I do not think that they have handled these potential criticisms too well. I think the Report should make some brief comment about the future of handling and storage of coal under CCT and perhaps the other aspects as well. There is also the question of how much they mention of the production cycle of the coal. They do refer to coal cleaning under sulphur control but it is part of all methods of coal utilisation.

2. On the other hand – in addition to the advantageous issues that the report has raised – coal-fired power stations do have the very considerable advantage in that it is easy to store the fuel, that they are readily started from cold and they can follow the electricity load (more so than nuclear or renewable energy sources). They mention 'operational flexibility' but only late in the Report, in Table 7-1 on p.84.

The report is a useful summary of the market position and CCT technologies. The major constraints on the electrical supply industry are all covered, including crucially the externalities of employment and environment. In my view, however, there should be an even greater emphasis on the environmental constraints, both on CO_2 emissions and on the emissions of local and regional air pollutants, particulate matter and SO_2 for example. The authors touch on investment and policy issues, but there is much more that can usefully be said about these. I did not find the policy suggestions clear or useful, although I imagine that the authors plan to sharpen these for the final version of the report. The impact of the report could be greatly improved by careful drafting, reorganisation and clear thinking on policies likely to enhance uptake of CCT.

In general terms, the Report represents a very good account of the situation. This statement applies not only in terms of an actualized synthesis, but also regarding the policy options and recommendations which reflect the current real situation and possibilities. Finally, it should be stressed that this report is very realistic regarding the mid- and long-term sustainability of energy supply in Europe.

4 February 2004