

Scope for Future CO₂ Emission Reductions from Electricity Generation through the Deployment of Carbon Capture and Storage Technologies

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In: Avoiding Dangerous Climate Change 2006 Ed H.J. Schellnhuber. Cambridge University Press. 379-384
<http://www.defra.gov.uk/environment/climatechange/internat/pdf/avoid-dangercc.pdf>

Abstract

Ongoing work on the potential for carbon dioxide capture and storage (CCS) from fossil fuel power stations in the UK suggests that this technology may be capable of supplying significant amounts of low-emission electricity within one or two decades. Renewable generation is also planned to increase over similar time scales and there is the additional possibility of nuclear replacements being built. If the political justification for significant UK CO₂ emission reductions emerges from global post-Kyoto negotiations, it is therefore possible that large (~45%) reductions in CO₂ emissions from UK electricity generation could be achieved by as early as 2020. Both the technical and the political aspects are, however, changing rapidly, with perhaps the conclusion of the post-Kyoto negotiations in 2007 as the first clear pointer for the future. CCS technologies also have considerable potential for future emission reductions world wide, especially in regions where large numbers of new fossil fuel power plants are being built within ~500km of sedimentary basins.

1. Introduction

In recent years emissions of carbon dioxide from the UK electricity generation sector have stayed constant or increased slightly. Values predicted in recent DTI Updated Energy Projections (UEP) [1] show a decrease over the next two decades, but at a reduced rate compared to the 1990's.

FIGURE 1 INSERTED HERE

It should be noted, however, that the observed and assumed values in Figure 1 all represent electricity supplies with no (historically) or low (UEP projections) UK CO₂ reduction targets. As Figure 1 shows, if overall UK energy use were to match DTI UEP predictions for 2020, the UK would not achieve the reduction path for CO₂ emissions recommended by the Royal Commission on Environmental Pollution [2], and subsequently endorsed by the Energy White Paper [3], exceeding the target by about 30 MtC/year. If required, however, a reduction in CO₂ emissions of 15 MtC/year in the electricity generation sector by 2020 is probably technically feasible, through combinations of increased fuel switching, greater renewable generation, new nuclear and carbon capture and storage. However, the 'commercially viability' of some or all of these measures for deployment in 2020 depends entirely on final UK carbon emission targets and the ability of alternative options to deliver at a lower price. Additional costs for the 'decarbonised electricity' options are probably in the range of 1-3 p/kWh.

2. Carbon capture and storage in the UK generation sector

With negotiations on post-Kyoto emission targets only just beginning, it is not possible to provide meaningful predictions for electricity CO₂ emissions for the latter part of the next decade and subsequent decades. It is evident, however, that achieving large CO₂ emission reductions in the UK requires significant reductions in electricity sector CO₂ emissions (e.g. as shown in UK

MARKAL scenarios [4]), which will be challenging. UEP electricity generation mix figures for 2000-2020 and some illustrative alternative scenarios for 2020 are shown in Table 1.

TABLE 1 INSERTED HERE

The UK power generation sector contains opportunities for the commercial deployment of a wide range of CCS technologies. The scenarios shown in Table 1 include an option in which significant coal generation capability is retained. This would probably involve some existing power plants being upgraded from sub-critical to supercritical steam conditions and having post-combustion CO₂ 'scrubbers' added. It is also likely, however, that some new Integrated Gasifier Combined Cycle (IGCC) plants, with the carbon monoxide in the gas shifted to hydrogen and carbon dioxide for capture, would also be built – several such schemes are already being planned. In the longer term, further existing coal power plants may be upgraded to oxyfuel operation or be repowered with gasifiers.

Natural gas combined cycle (NGCC) plant may also have CO₂ capture fitted. In the first instance this would probably be post-combustion capture technology. This is likely to offer relatively low-cost CO₂ capture so long as gas prices remain low, particularly for new NGCC plant that is designed for capture from the outset. The last column in Table 1 shows this option - the amount of NGCC plant capacity with capture corresponds approximately to new plant that would need to be built between now and 2020 to meet demand in a high-gas scenario. In any case it is important that all new UK power plant is built to be 'capture ready', even if capture equipment is not installed when it is built. Depending on future natural gas supply conditions, some existing NGCC plant may be modified to operate on gas from new coal gasifiers – these would also need to be suitable for CO₂ capture, either when built or subsequently.

The UK has significant CO₂ storage opportunities offshore, with probably the greatest absolute capacity of any European country after Norway and the best combination of CO₂ sources relatively close to potential CO₂ sinks. Storage capacity for UK oil fields as a result of enhanced oil recovery has been estimated at approximately 700 Mt CO₂ [5]. Storage capacity in saline aquifers may be significantly larger (possibly orders of magnitude larger) than this but estimates are more difficult due to the uncertainties surrounding poorly characterised aquifers. To develop this potential, however, needs a higher value to be given to CO₂ by emissions trading, or by UK government fiscal policy – as well as public and legal acceptance. Deployment of such a strategy is viewed as best value bridging technology towards much more drastic CO₂ reductions between about 2020 and 2050

The abundance of CCS options in the UK also brings challenges. A range of stakeholders need to participate in developing effective strategies and there is a risk of excessive diversification and dissipation of effort. As a result, new integrated research projects have been proposed to study the issues involved in getting the best value for the UK out of CCS applications and to make sure that maximum benefits are achieved through international collaboration on technology development. The DTI CAT (Carbon Abatement Strategy) and the Research Councils' TSEC (Towards a Sustainable Energy Economy) initiative are both planned to address CCS issues in depth, and to place them in an integrated UK energy system context and to consider the social, environmental, economic, technological and other aspects. Environmental and health and safety issues surrounding CCS on a range of temporal and spatial scales require a focused and coordinated research activity. In the longer term, it is hoped that a UK Carbon Dioxide Capture and Storage Authority will be established by the UK Government to take overall responsibility for the

regulation of this new industry, and eventually to provide long term stewardship for the CO₂ stored underground.

3. Global applications for carbon capture and storage technologies

The UK energy economy has the potential to develop and demonstrate CCS technologies that could find applications in many other countries. The UK has the opportunity to make a leading contribution in this field, because of:

- its industrial expertise in a number of key areas,
- the need for new UK power plant capacity over the next two decades,
- a window of opportunity in the next decade for enhanced oil recovery in the North Sea,
- national CO₂ emission targets that could justify the deep reductions that CCS technologies can give.,
- a fortuitous combination of geological endowment with subsurface engineering

CCS is likely also to see early use in other countries over the next two decades and, even where immediate deployment is not justified, it is important to ensure that new power plants are designed and built to be 'capture ready'. This can generally be done at minimal cost, for conventional pulverised coal and NGCC plants as well as new IGCC stations. It would then be possible to add CO₂ capture rapidly and at relatively low cost whenever political and economic conditions develop to justify it. The capability to achieve rapid and cost-effective deployment of CCS technology, as part of a portfolio of demand and supply side options to manage carbon emissions, is also likely to encourage a positive approach to atmospheric CO₂ concentration stabilisation.

Making new power plants at least capture ready, if not actually built to capture CO₂ from the outset, is particularly important in economies where large numbers of new power plants are being built. China is currently the prime example of this. As Figure 2 shows, new coal plant planned to be built in China up to 2020 offers scope for significant reductions in CO₂ emissions if capture technology can be added in the future. Carbon dioxide emissions from just these new plants are likely to exceed total current UK emissions (black bar) by at least a factor of two without any abatement measures. The Clean Development mechanism (CDM) or similar future mechanism may offer a ready-made route to finance and incentivise such capture retrofits. However, large amounts of new power plant capacity will also be required in Europe and the USA relatively soon, to replace ageing generation capacity built in the latter half of the last century. Carbon capture and storage, and the initial requirement for capture ready new power plant as a standard, are likely to be needed eventually in all major economies to contribute to avoiding dangerous climate change.

FIGURE 2 HERE

References

[1] UEP, (2004) *Updated UK Energy Predictions*, DTI Working Paper, May 2004.

(<http://www.dti.gov.uk/energy/sepn/uep.pdf>)

[2] Royal Commission on Environmental Pollution (2000) *Energy - The Changing Climate*, June 2000. (<http://www.rcep.org.uk/energy.htm>)

[3] DTI (2003) *Our Energy Future - Creating A Low Carbon Economy*, White Paper, HMSO, Feb 2003.

[4] DTI (2004) *Options for a low carbon future*, DTI Economics Paper No. 4, June 2003.

(http://www.dti.gov.uk/economics/opt_lowcarbonfut_rep41.pdf)

[5] Goodfield, M. & Woods, C. (2002) Potential CO₂ retention capacity from IOR projects. DTI Improved Oil Recovery Research Dissemination Seminar, June 2002.

[6] Guo Yuan and Zhou Dadi (2004) *Low emission options in China's electric power generation sector*,

ZETS Conference, Brisbane, Feb 2004.

Table 1 UEP electricity generation mix [1] and illustrative alternative scenarios for 2020

Fuel	ORIGINAL UEP VALUES					2020 SCENARIOS		
	Electricity Generation, TWh/yr					No coal, 20% renew- ables	9 GW CCS, 2GW new nuclear	Less coal, 13GW gas CCS
	2000	2005	2010	2015	2020			
Coal	111.9	113	106	89	57	0	7	20
Coal + CCS						0	50	0
Oil	2.1	2	2	2	2	2	2	2
Gas	127	116	132	159	225	264	174	144
Gas + CCS						0	17	100
Nuclear	78.3	84	61	41	27	27	43	27
Renewables	10.1	15	39	58	58	76	76	76
Imports	14.3	9	10	10	10	10	10	10
Pumped storage	2.6	3	3	3	3	3	3	3
TOTAL	346.3	344	353	362	382	382	382	382
MtC/yr	41.9	40.1	37.9	36.6	34.6	24.0	19.4	19.7
kgCO ₂ /kWh generated	0.444	0.427	0.394	0.370	0.332	0.231	0.187	0.189
Mt CO ₂ to storage						0	54	31
Low emission power	30%	32%	32%	31%	26%	30%	52%	57%
% gas	37%	34%	37%	44%	59%	69%	50%	64%

Assumptions:

	Coal	Oil	Gas
2020 plant kg CO ₂ /kWh generated	0.903*	0.660	0.329
..... with CCS		0.108	0.054
Fraction of CO ₂ captured		90%	- 85%
Additional fuel for CCS plant	20%	-	10%

* UEP value – pessimistic for new or upgraded coal plant with CCS

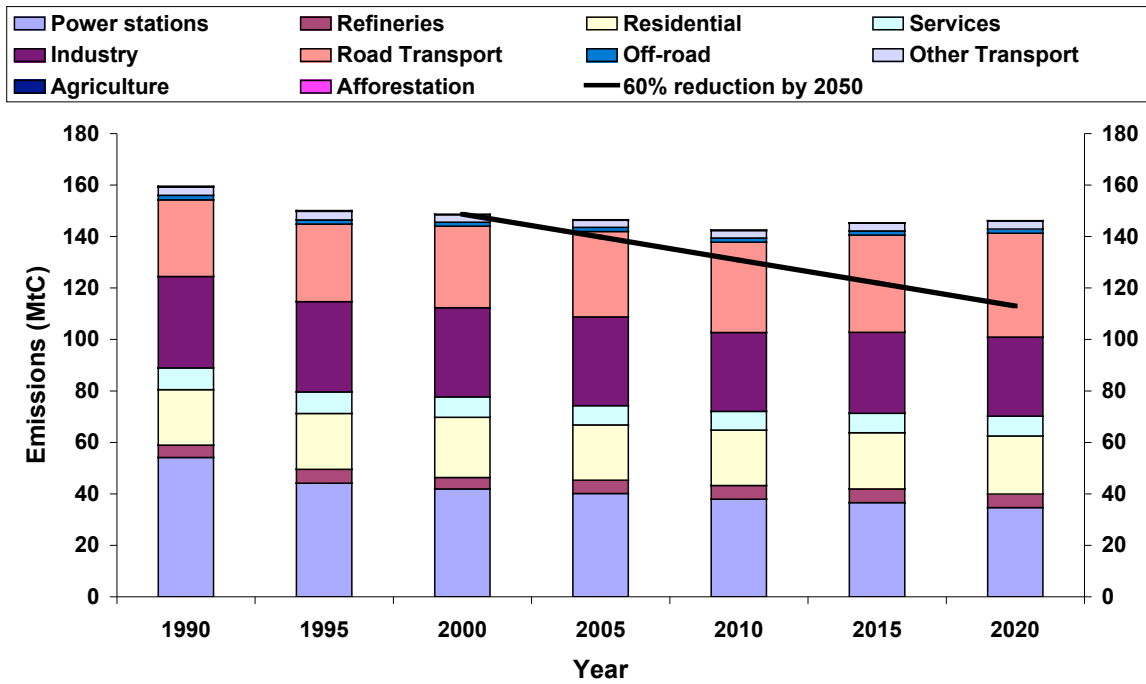


Figure 1 UK carbon emissions by sector from *Updated UK Energy Predictions* [1]

The line corresponds to a linear path to the 60% reduction target for 2050 recommended by the Royal Commission on Environmental Pollution [2],

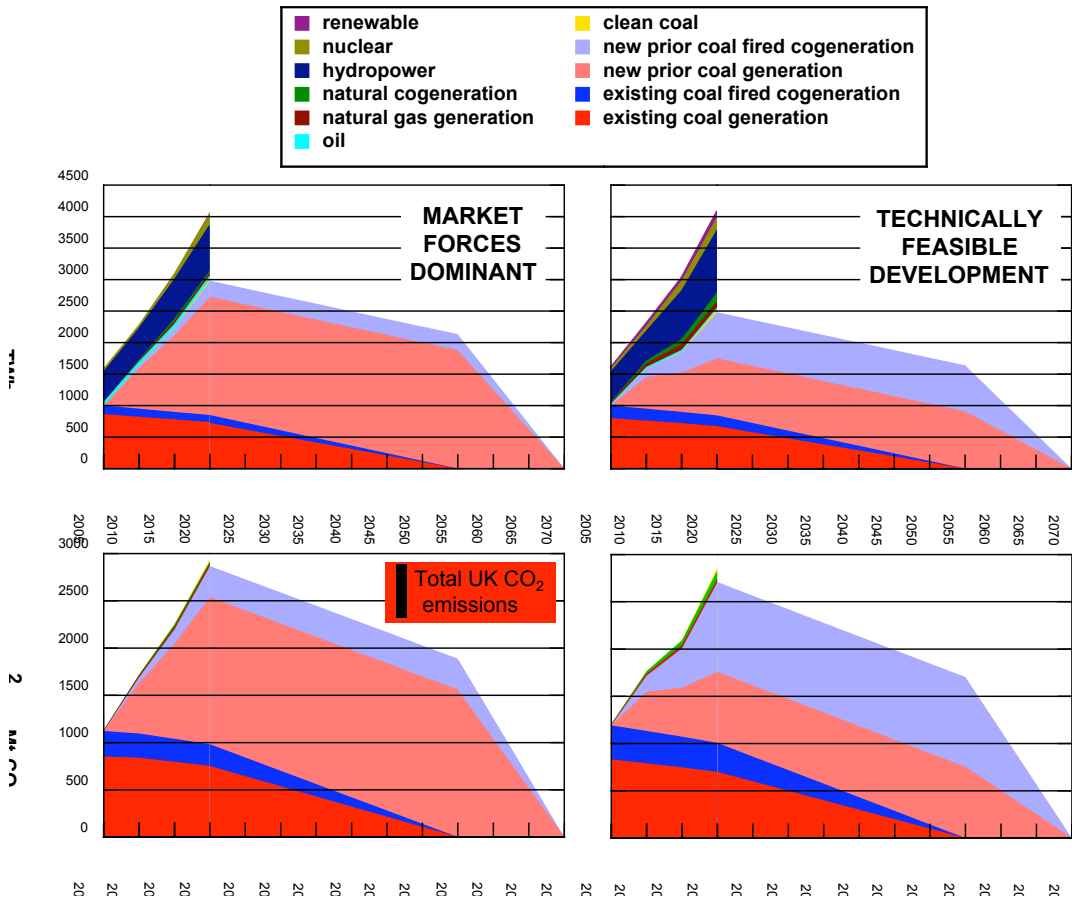


Figure 2 Estimates for future Chinese electricity generation and associated CO₂ emissions (based on Guo and Zhou [6]). Note the black bar whose length corresponds to total current UK CO₂ emissions at the same scale - these are potentially dwarfed by emissions from just the new coal plants that are planned to be built in China up to 2020.