To the Committee on Climate Change

Thursday 2 December 2010

Review of report ED56369 Issue Number 1 dated 10 November 2010 by AEA Technology PLC to the Committee on Climate Change on opportunities for greenhouse gas abatement in major emitting industry sectors in the UK.

Context

AEA Technology PLC were commissioned to write this report between August and November 2010 and have attempted to provide a quantitative assessment of abatement opportunities in UK energy intensive industries by 2030, with their results summarised in a series of marginal abatement cost curves.

I have been asked by Alex Kazaglis who works for the Committee to write an end of project peer review of this document and in particular “to evaluate the scope of the work in terms of whether it achieves the objective of quantifying industrial abatement potential”. I have not been paid for this work and have no commercial interest in the outcome.

Methodology

The assignment in the contract placed with AEA Technology PLC is extremely difficult: there are only a few real experts in each energy intensive sector world-wide, we are short of reliable data on true patterns of energy use, and most information on abatement opportunities is commercially skewed.

The lack of dependable data on the sources of emissions is a major problem for any attempt to advise policy makers on future abatement strategies. We are critically short of audited numbers on emissions: the Carbon Disclosure Project is voluntary, and its definition of “scope 3” emissions allows extraordinary manipulation by companies wanting to transfer responsibility up or down their supply chains; the European Emissions Trading Scheme as yet provides too little detail to analyse behaviour at process level. As a result the only significant data sets come from industry partners directly, or more frequently through associations – such as the World Steel Association. While considerable effort is put into gathering these numbers, they are viewed as
commercially sensitive – both within the sector and in comparison with potential rival sectors – so there is a significant danger that the data may be positively slanted.

The methodology used by AEA to develop their abatement curves is not made clear within the report – section 2.5 suggests that information on both the available opportunities and their valuation arise from “academic, industry and consultant experts” – but sources have not been provided, so these cannot be verified. This lack of an evidence trail is extremely important to policy development – there is a suspicion in many discussions around climate change that aspects of the subject are misrepresented through self-interest – so detailed declaration of the basis on which numbers are reported is essential in building trust.

Some references are used within the report, although the key documents on this topic – chapter 7 of the 2007 IPCC report (WGIII) on mitigation opportunities in industry1 and the annual reports of the IEA Energy Technology Perspectives series have not been referenced at all. This is unhelpful: while it may be tempting to believe that numbers gathered close to home are more accurate, the difficulty of gathering and validating credible abatement estimates is so great that the outputs of IPCC and IEA which have been subject to intense effort should be taken seriously.

**Treatment of uncertainty in reporting numbers**

Predictions about future abatement potential and costs are subject to very great uncertainty. The report aims to analyse abatement opportunities 20 years ahead of now and presents a set of marginal abatement curves which show a set of additive options for potential abatement plotted against the marginal cost of their implementation. Each abatement option is accorded a single number giving its potential emissions mitigation, and a single cost value. However, both numbers are subject to tremendous uncertainty: in the past four years, the price of new low-grade steel sections has varied between £400/tonne and £750/tonne, while the price of equivalent steel scrap has varied between £50/tonne and £300/tonne. Similarly, some of the abatement options discussed require change in the delivery of up to 50% of total output of key sectors in the UK. It is impossible to reflect this implementation challenge in a single number specifying cost per tonne. Thus both the prediction of abatement potential and its cost are subject to great numerical uncertainty, and all numbers in the report should be read as estimates with an uncertainty of up to ±100%. Section 3.10 discusses uncertainties very briefly, and suggests that they are reflected in capital cost variations of ±20%, but this is too narrow. Despite section 3.10, the summary of abatement potential in appendix 3 is given to four significant figures, which gives a misleading impression of accuracy.

**Uncertainty related to technical risk**

Further to the numerical uncertainty discussed above, there is also considerable technical uncertainty in the options being discussed. The executive summary of the report states that “the majority of long-term technical abatement potential lies in carbon capture and storage (CCS) technology” and figures 10 and 11 show approximately half of the opportunities in the report are due to CCS. However, CCS has yet to be applied to any industrial plant (although some trials are planned.) The first major application of CCS to electricity generation at Schwarze in Germany opened in 2008 operated by Vattenfall, on a small experimental 30MW plant, but to date although the carbon has been sequestered, it has not been stored but re-released into the atmosphere. CCS has become the current favourite silver bullet of “business as usual” responses to climate change – following on from exaggerated expectations about wind turbines, the

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hydrogen economy and biofuels. However, it carries very substantial technical uncertainty, the true costs are not known, the time required for widespread deployment of the necessary infrastructure is unknown, and the true risks of long-term storage can only be assessed by models whose predictions depend on their assumptions. None of this means that pursuit of CCS is wrong, nor that it won’t eventually work at some scale. However, it should be clear that there is a substantial vested interest – by the energy companies, the energy intensive industries, and by politicians – to invest more hope than appropriate in a technology that apparently allows growth in energy demand to grow unchecked.

**Detailed examination of the numbers**

The *qualitative* description of abatement opportunities given in the report seems to be a fair summary of current understanding, but the *quantitative* predictions of both abatement potential and cost are subject to tremendous uncertainty and it would be unfortunate if policy was developed on the assumption that these numbers were dependable.

To illustrate this concern, one of the three largest abatement opportunities recorded in the report is increased recycling of steel, which is reported to have a negative cost of -£20/tonne CO₂ saved, to have a technical potential of abating ~5 tonnes CO₂/year and a “realistic” potential of ~1.1 tonne CO₂/year (figures 4, 5, and 6).

The basis for this prediction of abatement potential is described in sections 3.3.1 and 4.1.2 with reference to two papers derived from Roland Geyer’s PhD thesis at Surrey – Geyer et al. (2007) referenced on page 21, and Davis et al. (2007) referenced on page 39. These papers make an estimate of the flow of iron and steel through the UK based on 2001 data, and predict scrap arisings of around 11.5Mt ferrous scrap per year (Davis et al. figure 5) based on historical figures for iron and steel entering use in the UK (Davis et al. figure 4) and modelled lifetimes for different product types. They estimate that 30% of scrap arisings are lost based on comparison of this 11.5Mt figure with an estimate of 8Mt of ‘actual recycled iron and steel’ based on 2001 data from the British Metals Recycling association and the Iron and Steel Statistics Bureau.

However, since 2001, landfill regulation in the UK has changed significantly, leading to a considerable increase in recovery rates. The British Metals Recycling association website today reports 2005 data showing 11.6Mt of ferrous scrap recovered. In the past 6 months I have visited the two market leaders for metals recycling in the UK – EMR (European Metals Recycling) and SIMS – and based on their data, it seems realistic to anticipate that 11-12Mt of ferrous scrap is currently collected in the UK. This number closely matches Geyer and Davis’ prediction of scrap arisings, but their prediction is based on a model so is only an estimate. Therefore, AEA’s suggestion that we can increase recycling by 30% is based on a comparison of model calculations and data from 2001 with uncertain accuracy. We know with confidence that recycling rates have increased significantly since 2001, although we don’t have accurate data for either scrap arisings or recycling volumes – but it seems extremely unlikely that we can significantly increase recycling rates in the UK in the manner suggested.

In parallel with this concern about AEA’s prediction of the abatement potential of increased ferrous recycling, their prediction of a marginal cost of ~£20/tCO₂ to achieve it is also questionable. All ferrous scrap collected in the UK is currently recycled, though we export more than half of it – so much of the recycling occurs elsewhere. (Thus, if we retained more of the scrap for recycling in the UK this would make no difference to global CO₂ emissions, although it would improve UK figures.) It seems illogical that the UK should import iron ore for primary production while exporting scrap thus missing the opportunity for lower emissions secondary steel making, so why do we do this? In response to the 2008 downturn, during which demand for steel in Europe plunged rapidly, British Steel/Corus/Tata chose to maintain its output of primary steel and to moth-ball some secondary production. This reflects the different costs of starting and stopping production in primary and secondary routes, and their very high capital
investment over many years in primary assets. To close the primary production sites and convert to secondary production would be a decision taken at national level, with government consultation, and the scale, societal and economic impact of this decision simply cannot be reflected in a single £/tCO₂ measure.

The above focuses on one example to draw attention to the problems with the numbers in this report – and similar analysis applied to the other abatement opportunities mentioned in the work would be likely to reveal similar problems. So, the value of the report is to provide a broad description of the opportunities currently known, but the numbers should be treated with caution.

Estimating the potential abatement opportunity in the UK

The energy intensive industries have for 100 years paid heavily for energy, so have been strongly motivated to pursue energy efficiency. As a result, there are few remaining energy efficiency opportunities in these industries. The table below, published this year and constructed from a survey of reports from the IPCC, IEA and key sector analyses summarises known options for further efficiency in global production of key materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>PD</th>
<th>CI</th>
<th>PE</th>
<th>Implementing best practice</th>
<th>CS best practice</th>
<th>Beyond best practice</th>
<th>CS beyond best practise</th>
<th>TRP</th>
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<tbody>
<tr>
<td>Steel</td>
<td>2370</td>
<td>1.7</td>
<td>4030</td>
<td>Switch from open hearth furnace to Basic Oxygen Furnace (BOF)</td>
<td>710</td>
<td>Smelting reduction and efficient blast furnaces</td>
<td>650</td>
<td>1360 (34%)</td>
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<td>Blast furnace (BF) improvements</td>
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<td>Direct casting</td>
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<td></td>
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<td>Coke dry quenching or advanced wet quenching</td>
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<td>Coal injection</td>
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<td></td>
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<td>Improved gas recovery and power generation from coke ovens, BF, BOF</td>
<td></td>
<td>Fuel and feedstock substitution</td>
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<td>Steel finishing improvements</td>
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<tr>
<td>Cement</td>
<td>4250</td>
<td>0.6</td>
<td>3530</td>
<td>Clinker substitution: blast furnace slag, other</td>
<td>770</td>
<td>Fuel substitution and reduction</td>
<td>650</td>
<td>1420 (40%)</td>
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<td></td>
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<td>Alternative fuels, electricity savings, fossil fuel savings</td>
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<td>Kiln waste heat used for power generation</td>
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<td></td>
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<td></td>
<td>Move from wet to dry process with pre-calcining and six-step pre-heaters</td>
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<td>Reduced process emissions</td>
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<td></td>
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<td></td>
<td>More efficient grinding</td>
<td></td>
<td>Clinker substitution/blended cement: volcanic ash, granulated blast furnace slag, fly ash, ground limestone, broken glass, geopolymers</td>
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<td></td>
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<td></td>
<td></td>
<td>Kiln waste heat used for power generation</td>
<td></td>
<td>Magnesium oxide cements</td>
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<td></td>
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<tr>
<td>Plastic</td>
<td>470</td>
<td>2.4</td>
<td>1130</td>
<td>Steam cracking improvements: higher temperature furnaces, gas-turbine integration, advanced distillation columns, combined refrigeration plants</td>
<td>110</td>
<td>Feedstock substitute: biopolymer and biomass</td>
<td>130</td>
<td>240 (21%)</td>
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<td>Mill integration</td>
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<td>Membranes</td>
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<td>Improvements in: raw materials preparation, pulping (mechanical, thermomechanical, chemical), chemical recovery, papermaking</td>
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<td>General measures: equipment optimisation, etc.</td>
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<td></td>
<td>Efficient steam production and distribution</td>
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<tr>
<td>Paper</td>
<td>950</td>
<td>1.2</td>
<td>1130</td>
<td>Increased heat recovery</td>
<td>200</td>
<td>Black liquor gasifiers</td>
<td>250</td>
<td>450 (40%)</td>
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<td></td>
<td></td>
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<td></td>
<td>Mill integration</td>
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<td>Advanced paper drying</td>
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<td>Improvements in: raw materials preparation, pulping (mechanical, thermomechanical, chemical), chemical recovery, papermaking</td>
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<td>Alcohol based solvent pulping</td>
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<td>General measures: equipment optimisation, etc.</td>
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<td>Drying technologies: impulse, infrared, steam or air impingement, press drying, airless drying</td>
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<tr>
<td></td>
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<td></td>
<td>Efficient steam production and distribution</td>
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<tr>
<td>Aluminium</td>
<td>120</td>
<td>8.8</td>
<td>1070</td>
<td>Retrofit/replacement of smelters, Point feeders</td>
<td>50</td>
<td>Inert anodes/wetted cathode</td>
<td>200</td>
<td>250 (23%)</td>
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<td></td>
<td></td>
<td>Improved process controls</td>
<td></td>
<td>Fuel and feedstock substitution (Carbothermic or Kaolinite reduction)</td>
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</tbody>
</table>

**Table 1:** Summary of known energy and carbon efficiency options applied globally to energy intensive industries.

The table was designed to estimate potential global abatement opportunities by 2050, in the face of anticipated growth in global demand. It provides separate lists of technologies which are currently ‘best practice’, so could be effective if adopted more widely (as for example has

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happened recently in China as part of the 11th 5-year plan), and those which are ‘beyond best practice.’ The combination of all these options leads to the estimated % efficiency gain stated in the right column.

A crude estimate of the possible abatement potential of the energy intensive industries in the UK could be derived from this table as follows:

- Assume that the UK has already adopted all current ‘best practice’ options in the table, so the potential for future abatement is solely due to options beyond best practice.
- UK output of steel is currently stable around 12Mt/year, and UK output of cement is ~11Mt/year. If this output remains stable to 2050, by then UK output will comprise 0.5% of global steel output and 0.25% of global cement output. Applying these fractions to the beyond best practice abatement opportunity leads to reductions by 2050 of 3.2 and 1.6 MtCO₂, and if half of these are achieved by 2030, the total abatement potential for these two materials in the UK by 2030 is 2.4MtCO₂.
- According to figure 3 of the AEA report, steel and cement account for approximately one quarter of the emissions from the sectors considered, so if the above prediction of abatement from two sectors is representative of the opportunity in other sectors, the technical potential for abatement is ~10MtCO₂/year by 2030.
- The AEA report predicts a technical abatement potential of 37MtCO₂ by 2030, but in figure 10 it is shown that only 13MtCO₂ of this is due to process improvement and fuel substitution (the two options considered in table 1 above – although AEA includes increased recycling as a process improvement.)

The conclusion of this extremely crude estimation is that the AEA prediction of abatement potential due to process improvement is broadly in line with IEA and IPCC analyses.

**Beyond process efficiency and CCS to Material Efficiency**

Because there are few remaining efficiency options in these industries in the UK, any carbon tax applied to these industries in the UK or EU and not applied elsewhere would make them less competitive – it would have little or no effect in motivating the implementation of further efficiency options. As a result, most of these industries are aggressively championing CCS as the key future solution – this is the function of the ULCOS consortium of steel makers referenced by AEA, for example. The attraction of CCS to producers of primary materials is that it allows them to claim that they can continue to grow their output while moving towards “zero-carbon” material – usually with the caveat that the approach can only be pursued if the government/EU provides £N billion of investment in CCS technology. However, as discussed above, this strategy carries significant risk.

An alternative to hoping for the CCS end-of-pipe solution is to pursue “Material Efficiency” – meeting our needs for ‘material services’ with less production of materials, whether from primary or secondary sources. If we want to reduce emissions associated with heating air in buildings in the UK we know that we need to focus on the building system (insulation, heat exchange etc) and not on the energy intensive gas boiler (which is already optimised). Equivalently, if we want to make a big change to emissions from our industrial system we need to focus on the system that uses materials, and not on the already optimised energy intensive industries. This is the aim of Material Efficiency.

However, Material Efficiency has had little attention to date, although efforts have begun to develop interest in the area³ and as an appendix to this letter, I have included a summary of a major project in my group on this topic. Material Efficiency is significant because the total

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energy required to create finished goods or buildings is dominated by the energy intensive industries which generally convert minerals or scrap to some liquid form (liquid metal, pulp, liquid polymers, wet cement etc.) Finding ways to reduce demand for the output of these industries – through Material Efficiency – is therefore an obvious route to national emissions abatement. However, it is unlikely that this approach will be pursued by the energy intensive industries themselves, as they will fear a loss of revenue from reduced output. (This fear is not always well founded – for instance now that Corus are part of the Tata group, the balance of activities within the group could be changed to support more materially efficient operation, without loss of jobs.)

The AEA report makes brief reference to the concept of Material Efficiency, through discussing “product substitution and demand reduction” in section 3.3.1 and appendix 4. The numbers given for these strategies are again provided without description of the basis on which they were chosen, and as a result cannot be treated with any predictive significance. The AEA report recognises this weakness by stating in the table in section 3.3.1 that these approaches are “not incorporated in the model” although in figures 10 and 11 “product substitution” appears.

However it would be impossible at present to make any meaningful estimate of the technical or realistic potential abatement from Material Efficiency, or its cost. If the steel and cement industries in the UK were all shut tomorrow, and no imports were allowed, no lives would be lost, and in the short to medium term, almost all steel and cement products and buildings could simply be used for longer. Thus the technical abatement potential of these strategies is very high indeed – but the economic consequences cannot yet be predicted.

It should be an urgent government priority to stimulate activity to develop and exploit opportunities for Material Efficiency – these are a critical set of abatement opportunities with great potential, but existing industrial lobbies will not pursue them unless newly motivated.

Summary

In conclusion:

- The AEA report attempts a difficult task, but its predictions are difficult to believe due to a lack of detail about how they were made and the lack of attention to uncertainty.
- The prediction that the industries considered in the report could technically abate their emissions through process improvement and fuel substitution by somewhere between 5 and 15MtCO$_2$/year by 2030 is broadly credible and in line with the analyses of the major international bodies, although stated with inappropriate precision in the report.
- The report stakes great hope on the adoption of CCS, predicting that this will provide half of all abatement opportunities in these sectors by 2030, but this is risky, and should be interpreted with great caution as some of the contributors to the report have a commercial interest in over-claiming the potential benefit of CCS.
- Material Efficiency addresses the root cause of the emissions problem, but there is as yet insufficient evidence to value the opportunities it offers.
Appendix: WellMet2050

WellMet2050 is a £1.5m 5 year EPSRC sponsored research programme at the University of Cambridge aiming to give reality to the technical and business opportunities of material efficiency for steel and aluminium. We do not yet have outputs ready to feed into the AEA report, but are aiming at a major interim report in September 2011 exploring the following options:

- **Re-using metal without melting.** Steel I-beams are undamaged in use, so could be re-used if old buildings were deconstructed rather than demolished. The main barriers to achieving this are timing (deconstruction takes longer than demolition so must be initiated earlier), health and safety (recent changes in UK law have promoted a strategy of bringing materials to ground with minimum manual involvement) and certification (we currently do not have a procedure in place to provide CE marking for used steel) – but all of these can be overcome at low cost.

- **Diverting scrap to other use before melting.** Much manufacturing scrap could be of value in other applications, where smaller stock is used. Abbey Steel in Stevenage have for 30 years bought blanking skeletons from car production lines in the UK, trimmed them to shape and sold the resulting regular blanks as stock to manufacturers of smaller components.

- **Designing lighter weight products.** In every case we have examined so far, we can remove ~ one third of the metal with no loss of function. Current manufacturing routes create this excess because it is cheaper to manufacture inefficient standard section components than optimised parts. New approaches to manufacturing could significantly reduce total demand for metal, and lighter weight components may have other benefits – such as reducing use-phase emissions in transport, or reducing requirements for stiffness in other parts of a structure.

- **Improving yield ratios from stock to part.** Typically in making sheet metal components, more than twice the weight of a product must be cast as liquid metal, due to trim losses in manufacturing. Different approaches to manufacturing could reduce this drive for excess liquid metal

- **Using products for longer.** Fridges in the UK are currently discarded after 10-12 years, but could technically be designed to last much longer.

- **Using products more intensely.** 28 million cars are licensed for use in the UK at present, but each person travels by car for only 225 hours per year, so on average over 98% of car seats are not in use at any one time.

- **Improving yield ratios from liquid to part.** Metals producers refer to coils of strip, or rectangular plates as ‘products’ but no final consumer wants a coil or plate. As yet we have made little progress in developing nearer net shape casting to avoid the mismatch between metal producers’ output and manufacturers’ real requirements.

- **Improving heat management along the supply chain.** We currently operate very long supply chains in the metals industry, and by shortening them could exploit opportunities for better heat management along the supply chain. Virgin aluminium is currently always cast as a pure ingot, in order to be traded as a commodity, and then re-melted for alloying. Changing our trading practices could eliminate this melting cycle.

We are exploring these options with a team of eight people in Cambridge, and a broad consortium of corporate partners along the metals supply chain. We’re aiming both to provide credible estimates of abatement potential from these approaches, and to create industrial demonstrators to stimulate change. Results as they emerge will be published on our project website www.wellmet2050.com.