Critique of "*Carbon strategy for the cement industry*" [1]

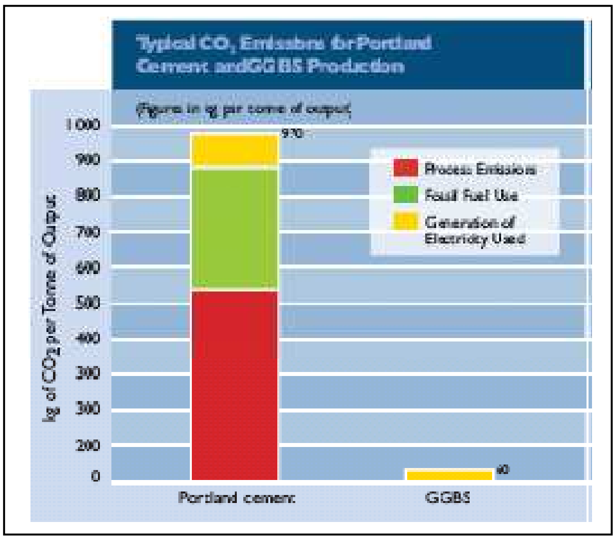
The UK cement industry is highly carbon intensive. Consumption (Portland cement and cement clinker) is about 13 Mt/yr of which 2Mt/yr was imported in recent years (2004). At ~ 0.9 tCO_2/ tonne cement, the 12 Mt CO_2 is significant in the UK emission table (2%). The high level comes half from calcination of limestone and half because of the high energy requirement in heating and clinker grinding (Figure below).

The industry has a target for reducing primary energy per tonne by 26.8% by 2010 (over 1990), which implies 'fossil' CO_2 reduction by a similar %age. This is to be achieved largely by taking waste fuels (to reach 15%) and including pfa and slag binders (to 8%). Higher fuel efficiency by changing from wet to dry kilns and by heat recovery has limited further potential. Waste fuels are giving cement quality problems and the reduction rate achieved up to 2003 has slowed. The industry does not foresee scope for further reduction and is turning to 'carbon trading' and investigating CCS (carbon capture + sequestration). They are coming to a stop. The BCA Strategy (October 2005) talks of CO_2 lifetime accounting "through construction and use phases" of built structures, effectively proposing use of PR tricks.

Traditionally, mortars using local materials have been used, including lime mortars, as cementing material. Though their use can be increased, they are too weak for structural concrete applications. Progress is being made in substituting cement with industrial by-products to form engineered cementitious composites [2]. So substitute building technology and alternative base materials indicate the way forward that strongly reduces use of Portland cement. The BGS fact-sheet (Annex 2) discusses the possibility of clay/mudstone blended with other materials, implying it's not practical, but is curiously silent about the vitrification and magnesite alternatives covered below. The British Cement Association produced a defensive response on *Novel Cements* in the face of criticism of its conservative stance (www.cementindustry.co.uk, Fact Sheet 12, May 2006),

Vitrified Industrial Wastes

Vitrification processes can dispense with limestone, using a variety of materials including pfa and blast furnace slag (instead a few % as binders). By taking tar and coal wastes from refineries, gas-works and smokeless fuel sites, the high temperature process eliminates the toxic organic material while benefiting from the energy. Toxic metals are fixed in the glassy product, as shown by leaching tests. The process is becoming established in the USA: www.ermco.org/artman/publish/article_58.shtml; http://www.minergy.com/technologies/techmain.htm. The company Glaztek was seeking to establish the process in south Wales, but recently decided on the SLI Glass site in Harworth, Doncaster. A competing company Vitrium tried but failed to buy the AEG glass-making site in Cardiff, and then sought to set up several operations around Britain <www.edie.net/news/news_story.asp?id=11140>



Ecocem cement is ground granulated blast-furnace slag (GGBS), has valuable cementitious properties and is usable as a partial replacement for Portland cement in making concrete (<www.Ecocem.ie>). It can reduce the embodied energy in concrete by over 40% and CO2, CO, NOx and SO2 emissions by ~ 50% when used at a typical 50% mix with Portland cement. Concrete made with *Ecocem* GGBS cement has higher strength, lower permeability and is more chemically stable than concrete made with ordinary Portland cement. *Ecocem* GGBS cement is routinely specified to protect concrete against sulphate attack and chloride attack, and it will also protect against ASR attack (manufactured in Ireland and Netherlands).

Figure from <www.ecocem.ie/media/ecocem_brochure_v2.pdf>

Vitrification technology is also being developed in the US for dredging wastes. Scientists at the U.S. DoE's Brookhaven Nat. Lab. are promoting a technology called Cement-Lock, developed by the Gas Technology Institute (an independent in energy and environmental technologies), in collaboration with the U.S. EPA, the State of New Jersey and public groups. The solids produced after ~1400^{o}C in GTI's kiln are ground up and mixed with cement as in the EcoCem case < www.azom.com/news.asp?newsID=1237>.

The BCA *Fact Sheet* refers to these options only in the Chinese version used industrially for two decades, sintering flyash, limestone and gypsum in a rotary kiln. It says these CSA-belite cements match Portland cement in strength and save 60% of limestone and 20% of CO2 emissions. The BCA's reasons against are given as uncertainties in the regulatory framework and market acceptance. Similar reasons are given against the variant of using 50% MSW incinerator ash as in Japan, where the product is again said to match Portland cement.

Eco-cements based on magnesite
Magnesium oxides and carbonate allow a low energy process compared with calcium. Caustic calcined magnesia requires only 2MJ per kg and can be made in a solar-powered low-temperature kiln (650^{o}C compared with 1450^{o}C for Porland cement). The TecEco process (http://www.tececo.com/technologies.tececo_kiln.php#ftn1) grinds and calcines at the same time and runs 25 – 30% more efficiently. The MgO ⇔ $MgCO_3$ $(H_2O)_3$ cycle can be used to capture CO_2 for sale or for geological sequestration. The most readily available source of Mg is seawater (1.29 g/l) which can be extracted using CO_2 carbonation. The Tasmanian inventor-enthusiast is marketing the process, but making little headway against the Portland cement companies.

Fred Glasser of the University of Aberdeen, a leading authority on cement technologies says eco-concrete has huge potential for incorporating all sorts of waste matter, including carbon-based organic wastes that would otherwise rot or burn and release CO_2 into the air. Adding inert wastes such as fly ash to Portland cement encounters strict limits. Because the cement is alkaline, mixtures can react with aggregate to crack the concrete or make it brittle, sometimes causing failure. "Magnesium cements are much less alkaline, and the potential problems are far less" says Glasser, who believes this could be a key to their eventual widespread use (F Pearce, *New Scientist*, July 13, 2002 v.75 i.2351 p.38).

The BCA *Fact Sheet* accepts that non-structural concrete blocks, bricks and pavers have been produced using TecEco's process, but dismisses it on the grounds that the UK lacks magnesite deposits, and that UK cement works are not located close to dolomitic limestone deposits. Transport impacts, capital costs and market uncertainty are their reasons for the UK not to take up the process. Note that the BCA cartel [3] has tried to ignore this alternative for 4 years, giving it no mention in their "carbon strategy" of October 2005, and that the 'independent' BGS in their April 2006 *Fact Sheet* (Annex 2; issued with government ODPM endorsement) still ignore it – even as far as saying "Dolomites and magnesian limestones are unsuitable for cement manufacture, because of their high magnesia (MgO) contents. Limestone should contain less than 3% MgO. This precludes the use of limestones (dolomites) of Permian age in England".

Special Grinding Processes
An entirely new grinding process for cement and sand is being developed at Sweden's Luleå University <www.bellona.no/en/energy/report_3-1999/11345.html>. This new process makes cracks in the finely ground grains so that a greater portion of the grain adds to the strength of the concrete. It allows the quantity of cement in concrete to be halved and could be combined with the reductions available through vitrificiation.

Sustainability
The BGS Fact Sheet produced for the UK government adds at the end that "Sustainability is also a key issue facing the cement industry... The UK cement and concrete sector is currently addressing the ways in which sustainable thinking can be applied to its manufacturing processes and to concrete construction". It avoids any critical assessment of the actual limited progress and gives no quantitative figures on CO_2. The government gives the cement industry an 80% rebate from the Climate Change Levy on the basis of reducing its primary energy consumption and CO_2, but the BGS makes no comment on the industry's "Carbon strategy" that's coming to a dead end (above).

The UK cement industry has put all emphasis on wastes as fuels – giving themselves quality problems, as with the sub-spec cement sold for several years from Lafarge's Westbury plant when burning chipped tyres - and not on changing to use waste materials or improving the process. The UK government has not intervened like the US one to promote vitrification technology. Indeed, attempts to establish it in South Wales have been rebuffed, despite the prospect of using local industrial wastes including the mounting stockpile of power station PFA (pulverised fuel ash). Worldwide, the cement industry has repeatedly been identified with the term 'cartel' – that heritage may well be the reason for the weak response to the challenge of sustainable development. In this sector Amory Lovins' belief that green technology "will happen, and happen rapidly – because it's profitable" is proving to be naïve.

[1] "A Carbon strategy for the cement industry", British Cement Association, October 2005 <www.cementindustry.co.uk/pdf/18%2010%2005%20-%20Carbon%20strategy%20Final.pdf>

[2] *Development of Green ECC for Sustainable Infrastructure Systems,* Li et al. 2004 in Proc. Workshop on Sustainable Development and Concrete Technology, Beijing, China, Ed. K. Wang, Published by Iowa State Univ., 181-192. <ace-mrl.engin.umich.edu/NewFiles/publications/2003-2005/Green%20ECC%20Paper.6.pdf>; *Engineered Cementitious Composites,* Victor C. Li 2005 <www.engineeredcomposites.com/publications/Conmat05/Li(ECC).pdf>

[3] The British Cement Association may be sensitive to being termed a 'cartel', as the EC prosecuted the larger Europe-wide 'cartel' in the 1990s. The European Commission in 1994 fined the European Cement Association (Cembureau), eight national cement associations and thirty-three European cement producers, for infringement of Article 85 of the Treaty of Rome. Their offences were a general market-sharing agreement, transnational restrictive practices and restrictive practices relating to exports. The case progressed to appeal in 2000 (la Cour and Møllgaard, *European Journal of Law and Economics,* 14: 99–127, 2002). The BCA is a trade association <www.cementindustry.co.uk> of the four major companies (Buxton Lime Industries, Castle Cement, Cemex UK Cement and Lafarge Cement UK) operating 15 plants, with common interests that include keeping competing processes out of the UK. They are acknowledged in the BGS 'Fact sheet' and lobby central government, as when they secured rebate from the Climate Change Levy and weakening of the EA's waste fuels protocol.

--*Max Wallis, Cardiff* *1 July 2006*

ANNEX 1 Magnesite-based Eco-cement <www.tececo.com/> *(written in ~2001)*

The new recyclable, low cost cement developed by TecEco is the first building material providing high thermal mass with a very low embodied energy. It can incorporate high proportions of waste, it sets by absorbing carbon dioxide in porous or semi porous materials such as bricks, blocks, pavers and mortars and with capture at source of CO_2 produced during production and the inclusion of waste organic or carbon based fibres could sequester huge amounts of carbon as the built environment is responsible for some 30 % of the raw materials we use and 40% of atmospheric emissions [1].

The manufacture of Portland cement requires a lot more energy than the production of eco-cements and results in between 0.87 [2] and 1.3 [3] tonnes of CO_2 emissions per tonne of cement produced. A figure given by Pearce [4] of 1 tonne of CO_2 emitted per tonne of Portland cement produced is generally accepted and the CO_2 produced accounts for between 5% [5] and 10% [6][7] of global anthropogenic CO_2 emissions. The firing of clay bricks also produces considerable CO_2 at around 0.28 tonne of CO_2 per tonne of bricks produced [8]. Portland cement production and hence CO_2 emission is currently in the order of 1.8 billion tonnes [9]. The quantity of clay bricks produced is substantial but not accurately known as the industry is much more fragmented. TecEco eco-cement formulations for some products such as bricks, blocks and pavers (eco-masonry products) set by absorbing CO_2 and are almost CO_2 neutral and with organically derived fibre reinforcing become a net sink. Numerous test blocks have already been made and have exceeded all expectations.

With over 600 million tonnes of fly ash waste produced annually world wide in the year 2000 [10], low utilisation in some countries and huge stockpiles (in Australia we dump around 8 million tonnes of fly ash annually), binding fly and bottom ash and other wastes with eco-cements to make eco-masonry products and other components of the built environment is a priority for TecEco (see our Short Term Business Plan [11]).

By using eco-cements not only will there be considerable abatement, but costs will also reduce due to lower energy inputs and greater waste utilisation. In a competitive industry such as construction, this is important. Amory Lovins of the Rocky Mountain Institute puts it aptly in saying that green technology "*will happen, and happen rapidly – because it's profitable"* [12]. Eco-cement formulations are environmentally sustainable and relatively cheap as the ingredients are mostly wastes.

The cost of magnesia suitable for eco-cements will also fall as the long run economies of scale of magnesite mining improve due to increasing demand for magnesium metal. Eco-cements can also be produced from lower grade magnesite not suitable for other purposes and by using renewable energy and TecEco has commenced pilot production.

Eco-cement formulations for products such as bricks, blocks and pavers, mortars and eco-cement binders for the production of "earth" buildings are made substantially from industrial wastes and have huge abatement and waste utilisation potential. Eco-cement can also be used for grouts & drill-hole cements, pellet production, controlled low strength materials (CLSM's), soil stabilisation/solidification, agglomeration of furnace feeds and waste and toxic waste immobilisation/fixation. With capture of CO_2 at source and/or the use waste carbon based fibres such as cellulose, eco-cements can be a net sink.

TecEco will develop as a research and development organisation and licence the technology all over the world. Deployment will be driven not only by the need to reduce the impact of potential carbon taxes and waste and toxic waste disposal problems, but by a much lower bottom line given economies of scale. Environmental sentiment will also provide consumer pull.

The market for cementitious materials is huge and TecEco eco-cement technology is relevant to all of it (See our Main Business Plan). TecEco do not have the resources to tackle all of it and it is therefore necessary to focus. (See Short Term Focus and our TecEco Confidential Business Memorandum)

[1] Australian Federal department of Industry Science and Tourism, Environmental & Economic Life Cycle Costs of Construction, 1998 - Detailed Discussion Paper, (section 2 - page 8)
[2] Hendriks C.A., Worrell E, de Jager D., Blok K., and Riemer P. *Emission Reductions of Greenhouse Gases from the Cement Industry.* International Energy Agency Conference Paper at www.ieagreen.org.uk.
[3] Dr Selwyn Tucker CSIRO dbce Melb, pers comm.
[4]Pearce, F., "The Concrete Jungle Overheats", New Scientist, 19 July, No 2097, 1997 (page 14).
[5] Hendriks C.A., Worrell E, de Jager D., Blok K., and Riemer P. *Emission Reductions of Greenhouse Gases from the Cement Industry.* International Energy Agency Conference Paper at www.ieagreen.org.uk.
[5] Davidovits, J *A Practical Way to Reduce Global Warming* The Geopolymer Institute info@geopolymer.org, http://www.geopolymer.org/
[6] Pearce, F., "The Concrete Jungle Overheats", New Scientist, 19 July, No 2097, 1997 (page 14).
[7] Dr Selwyn Tucker CSIRO dbce Melb, pers comm.
[8] United States Government Survey (USGS) figure for 2000.
[9] Malhotra, V.M. Making concrete greener with fly ash *Concrete International*, May 1999, pp61-66.
[10] Downloadable from our website at tececo.com.au
[11] The Bulletin (Australia), April 25, 2000

ANNEX 2 Extract from BGS Minerals Planning Factsheet *Cement* *April 2006*

http://www.mineralsuk.com/britmin/mpfcement.pdf

Alternatives/recycling

The principal objective of using alternative raw materials in cement manufacture is to optimise the mix to make best use of available materials. Other than limestone/chalk, there are no calcium-bearing sources that occur on a sufficiently large scale to be used as alternatives.

Clay/mudstone is the main source of silica, alumina and iron oxides because of its availability and low cost. However, clay/mudstone may not supply the correct chemical balance of constituents and bought in supplements are often required. These may include silica sand, PFA, and iron oxides. PFA has a higher alumina to silica ratio than most mudstones, and also lower alkalis (depending on the coal used). It is used at some cement plants to add alumina so that higher silica limestone can also be utilised. This has extended reserves. It is also used to reduce alkalis in the clinker. Ash from the fuel burn also contributes to the overall chemistry, particularly the alkali content of the cement feed. Increasingly blended alternatives are being used to replace mudstone/clay or the more expensive bought in materials such as sand and iron oxides.

Cement manufacture is energy intensive, with fuel representing some 35% of fixed costs. Imported coal was traditionally used as the main source of fuel. Alternative fuels are increasingly being introduced and include; recycled and blended waste solvents from printing and cleaning processes, tyres, paper, carpet and plastic offcuts, packaging waste, animal waste, sewage pellets, meat and bone meal and recycled liquid fuel (RLF). All these fuels have to meet strict specifications laid down by the Environment Agency. The use of these alternative fuels is not only less costly, but also reduces emissions and the amount of waste that otherwise would be landfilled. The cement industry currently burns about 50% of the used solvents available in the UK, 10% of available packaging waste and has the capacity to handle about 50% of the total volume of waste tyres produced.

The production of blended cements is increasing. These may contain for instance, singly or in combination, a proportion of pulverised fuel ash (PFA: a by-product of coal-fired power stations), blastfurnace slag (a by-product of ironmaking) and limestone. These act mainly as lower cost diluents, their main purpose being to reduce the amount of cement clinker used per unit of concrete produced. However, their use may also impart additional technical properties as both PFA and slag have cementitious properties that improve the long-term strength and durability of concrete. In the production of blended cements the amount of cement clinker, and thus the amount of primary feedstock required, is reduced by the proportion of the PFA, slag or limestone used. Indirectly, therefore, these additions also reduce the environmental impact of clinker production per unit of concrete produced.