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Carbon neutrality—a government dilemma?

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Following on from a previous article[1] attempting to understand the meaning of carbon neutrality and exposing some of the mysticism surrounding carbon emissions and sequestration at a human rather than a global level, it is interesting to note that the current Coalition Government in the UK has developed a new unit of currency called the "taxpayer year",[1a] and it seems appropriate to introduce a comparable unit to measure carbon neutrality. While some government measures provide incentives for individuals and businesses to reduce carbon emissions, the Government itself faces a dilemma in following its own advice. Namely, in dealing with the consequences of recession government spending will be reduced and the previous Government's commitments to the construction industry regarding the need for new houses will also be reconsidered. On the one hand, the review of energy sources leading to a reduction in the use of fossil fuels together with the general reduction in government and consumer spending should improve the country's carbon balance, while on the other hand the planned reduction in the science budget and in particular the "rationalization" (meaning reducing the available resources) of nanotechnology[2] will probably diminish the benefit that science could have yielded in terms of improved energy efficiency and diminished dependency on materials that in their production emit copious quantities of carbon.

An interesting aspect of this dilemma is provided by house building requirements. The previous Government, after an analysis of population trends, concluded that significant new house building would be required, especially in the more affluent parts of the south of England. Typical of these anticipated requirements were developments containing of the order of 5000 houses to be built over the next 10 years in selected areas, many as new towns but others as extensions to existing towns. Such developments entail the use of considerable quantities of cement. The manufacture of cement is one of the most prodigious producers of carbon dioxide,[3]

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[1] G.C. Holt, Carbon neutrality—what does it mean? *Nanotechnology Perceptions* 5 (2009) 135–145.

[1a] The term was actually coined by Joe Murphy in the *Evening Standard* of 23 June 2010, commenting on George Osborne's Budget speech the previous day, in which a "taxpayer year" was equated to the tax contribution from median annual earnings.

[2] http://www.bbc.co.uk/news/uk-politics-10728357
UK nanotech centres may be axed, says science minister, BBC News 23 July 2010.

[3] 1995 Intergovernmental Panel on Climate Change (IPCC), Working Group II, p. 661: 0.75 tons of CO_2 per ton of cement from energy use plus 0.50 tons of CO_2 per ton of cement from the calcination of the limestone.

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typically 1.25 tons of carbon dioxide per ton of cement.[4] To achieve carbon neutrality of these new developments, the Government or the building industry or the cement manufacturers would have to ensure sequestration of the equivalent amount of carbon dioxide, possibly through "carbon offsets". However, I shall show that the actual numbers only serve to demonstrate the impossibility of going much beyond the Kyoto agreement in terms of diminishing the quantity of emitted carbon.

Housing development

A typical housing development has 5000 dwellings at the Government-recommended density of 40 houses per hectare,[5] implying an area of 125 ha. For comparison, a 25 mile stretch of the M2 motorway, covering 750 acres or 303 hectares, used 417,000 tons of cement.[6] A housing estate with its infrastructure of roads and cement foundations plus the cement in the brickwork will likely use as much cement per hectare as the building of a modern road. The carbon released as a consequence of the typical housing development is thus estimated at some 59,000 metric tonnes.

Carbon sequestration

Carbon sequestration by trees is one of the most effective means of capturing atmospheric carbon. Table 1 shows the carbon sequestered as tree biomass.[7] Both hardwood and softwood trees are similar, with hardwood trees being more effective at sequestration but generally taking longer to grow.[7] Assuming a radial growth rate of about 1 cm per annum, Table 1 also shows the yearly carbon sequestration per tree and implies that for a 20 m radius plot with four small, four intermediate and two large trees some 186 kg of carbon are sequestered per year. The plot size is 0.125 hectares and over a 10 year period it should sequestrate nearly 2000 kg of carbon.

Table 1. Carbon sequestration by trees.

Tree type	r / m[a]	h / m[b]	m / kg[c]	s / kg[d]	t / year[e]	c / kg[f]
Hardwood	0.015	2	1.27	0.64	–	–
Pine (small)	0.015	2	1.13	0.57	3	0.19
Pine (intermediate)	0.15	10	565	150	15	10
Pine (large)	0.5	20	12600	2900	40	72

[a] Tree radius.
[b] Tree height.
[c] Tree aboveground biomass given by $\pi r^2 h$ and assuming a tree specific gravity of 0.8.
[d] Sequestered carbon calculated as $m^*/2$, with biomass m^* given by $\exp(-2.53 + 2.43 \ln(200r))$ for pine.[7]
[e] Time to grow to the given radius assuming 1 cm per year from 3 years old.
[f] Sequestered carbon per annum.

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[4] Mass of C is approximately 0.27 that of CO_2, thus 0.34 kg C is emitted per kg cement.

[5] http://www.woking.gov.uk/planning/policy/localplan/density.pdf
Status of Supplementary Planning Guidance on Housing Density (adopted March 2000): 100–173 habitable rooms per hectare, implying 25–50 dwellings per hectare.

[6] UK Ministry of Transport Report, http://www.cbrd.co.uk/histories/openingbooklets/pdf/m2motorway.pdf

[7] T.R.H. Pearson, S.L. Brown and R.A. Birdsey, *Measurement Guidelines for the Sequestration of*

Carbon neutrality

Assuming the typical housing development takes 10 years to build, and that to achieve carbon neutrality the carbon emitted in its construction is sequestered over the same interval by trees, then an area of almost 4000 hectares of forest is required. That is, for every housing development more than thirty times its area would have to be set aside for wood or forest, see the Summary in Table 2.

Table 2. Summary of carbon neutrality requirements.

Medium density housing	M2 motorway segment	Carbon emission from the cement used in 125 ha housing	Forest to offset housing emissions over 10 years
125 hectares	303 hectares	59×10^6 kg	4000 hectares

This is a somewhat simplified example of carbon neutrality and might suggest a new unit of "forest hectare year" (FHY), equivalent to the sequestration of about 1.5 metric tonnes of carbon. Given these numbers, the implication is that the Government would not only have to allocate green belt land for new houses but would simultaneously have to compel a vast area of farmland to be converted to woodland or forest—an unlikely proposition given the enormous reduction in food output that would result from the conversion.[8]

Technology may or may not come to the rescue here. Recent proposals[9] to alter the structure of cement and thus reduce the carbon dioxide produced in its manufacture are in their infancy and financial crisis-driven government reductions in research spending will only hinder the achievement of a nanotechnology solution. But then, as George Bernard Shaw remarked, "A government that robs Peter to pay Paul can always depend on the support of Paul." One can only wish the Government well in the sagacious resolution of such dilemmas.

Forest Carbon, United States Department of Agriculture Forest Service Northern Research Station General Technical Report NRS-18 (2007).

[8] Although the fact that under the European Union's Common Agricultural Policy some farmers are currently paid to leave land uncultivated may offer room for a more palatable compromise.

[9] http://boston.bizjournals.com/boston/stories/2010/05/10/daily46.html (13 May 2010). The MIT $100k business plan competition awarded its top prize—and a $100,000 cheque—to C-Crete Technologies, a company founded by two Massachusetts Institute of Technology graduate students developing nanotechnologies to fabricate cleaner, stronger concrete. The company claims its nanoengineered cement reduces by one half the CO_2 emissions associated with making concrete in the traditional way.