Matters Arising

Carbon footprint and carbon brainprint—what do they mean?

An attempt is made to define the terms carbon footprint and carbon brainprint, both of which are increasingly used in the context of climate change and sustainability. Carbon footprint is a quantitative estimate of the amount of carbon produced during the entire life cycle of a good, including manufacturing, transport to place of use, and ultimate disposal. In other words it amounts to a kind of bookkeeping, albeit one of a complicated nature with large uncertainties. Carbon brainprint is an estimate of the difference between the global carbon footprint associated with a good (which might also be a service rather than a tangible object) before some innovative carbon footprint-diminishing procedure is introduced, and the footprint after its introduction. The uncertainties are very much greater since they depend on the degree of adoption of the innovation, which might well change during the life cycle of the good. Furthermore, there seems to be some systematic bias in the estimation because one does not encounter negative brain prints—processes in which the footprint increases.

I have followed with interest the recent articles on carbon neutrality[1, 2] and carbon sequestration.[3] Carbon neutrality is, evidently, quite a difficult and subtle concept. In particular, the multiple time-scales involved (emission *now* might be neutralized by a forest growing over several future decades) make it difficult to assess quantitatively. The purpose of this brief contribution is to examine whether "carbon footprint" is a simpler concept more amenable to quantitative evaluation.

Carbon footprinting is usually referenced to a publicly available "Specification for the assessment of the life cycle of greenhouse gas emissions of goods and services" issued by the British Standards Institute (BSI).[4] For example, the footprint of a ton of cement would include the carbon dioxide released from heating chalk or limestone and from burning coal or some other fossil fuel to generate the heat.[5] This is the direct footprint. Indirect contributions would

1 Holt, G.C. Carbon neutrality—what does it mean? *Nanotechnology Perceptions* **5** (2009) 135–145.
2 Holt, G.C. Carbon neutrality—a government dilemma? *Nanotechnology Perceptions* **6** (2010) 121–123.
3 Snowdon, P. Carbon sequestration through forestry. *Nanotechnology Perceptions* **7** (2011) 149–150.
4 PAS 2050:2011. *Specification for the assessment of the life cycle of greenhouse gas emissions of goods and services*. London: British Standards Institute (2011).
5 Holt, G.C. and Ramsden, J.J. Introduction to global warming. In: J.J. Ramsden and P.J. Kervalishvili (eds), *Complexity and Security*, pp. 147–184. Amsterdam: IOS Press (2008).

Nanotechnology Perceptions **7** (2011) 223–226
Received 5 November 2011

include the carbon dioxide released from quarrying the limestone and transporting it to the kiln and all that would be released through the manufacture of the infrastructure, possibly including mechanical diggers, conveyor belts and the kiln itself, divided *pro rata* according to the expected lifetimes of the components of the infrastructure. The emissions of the people required to operate machinery, including emissions from the provision of the necessities of life, such as food and shelter, would also have to be included. The carbon footprint of a bag of cement available from a builder's merchant would have to include the emissions from transporting it from the factory and from the materials used to make the bag. The latter footprint might be negative if the bag were made from wood pulp. The footprint concept is, therefore, extremely simple but anything more than the direct footprint is likely to be very complicated in practice to compute, so much so that a guide twice as long as the original specification has also been published.[6] The carbon footprint of concrete made from cement and other materials would also include the emissions associated with forming the concrete (e.g., into a structure) and with demolishing the structure at the end of its life—in other words life cycle assessment (LCA) also becomes involved.[7]

As expected, the BSI seems to be fully cognizant of the fact that the carbon footprint is, essentially, a measurement and thus subject to uncertainty. While the full sophistication of, for example the "Guide to the expression of uncertainty measurement"[8] is not employed in PAS 2050, there is nevertheless considerable emphasis on the problem of uncertainty, which is, as one might imagine, very great for some of the contributions to a footprint. Recommendations include subjecting the calculations of carbon footprint to sensitivity analysis.

The purpose of carbon footprinting is, typically, to determine on what parts of an overall process efforts for carbon reduction should be focused. As more footprints are actually calculated, databases containing them will become comprehensive enough to be of real utility.[9, 10] In particular, this utility should include efforts to determine synergies between many parallel efforts to reduce the carbon footprints of individual processes.

The title of this contribution also promised a look at the rather less well known, and more contentious, concept of "carbon brainprint". This has been championed by the Higher Education Funding Council for England (HEFCE) and Cranfield University (England).[12] According to the website, the answer to the question "What is a carbon brainprint?" is, somewhat elliptically, "Universities make tremendous intellectual and technical advances that help other organisations and individuals reduce their own carbon footprints. This is the

---

6 The Guide to PAS 2050:2011. *How to carbon footprint your products, identify hot spots and reduce emissions in your supply chain*. London: British Standards Institute (2011).

7 Finkbeiner, M. Carbon footprinting—opportunities and threats. *International Journal of Life Cycle Assessment* **14** (2009) 91–94.

8 JCGM 100:2008. *Evaluation of measurement data—Guide to the expression of uncertainty in measurement*. JCGM (2008).

9 See, e.g., the "Carbon Footprint of Products" database (http://www.cfp-japan.jp).

10 Should the era of nanotechnology result in an ultimate shortage of atmospheric carbon dioxide,[11] one could use the same data for maximizing carbon footprints.

11 Toth-Fejel, T. A few lesser implications of nanofactories: global warming is the least of our problems. *Nanotechnology Perceptions* **5** (2009) 37–59.

12 http://www.carbonbrainprint.org.uk

universities' carbon brainprint." A precise definition does not appear to be given, but from the rest of the website one can deduce that it is defined as the carbon footprint of activities before the university disseminated its knowledge minus the carbon footprint of activities after dissemination.

Practically, this is achieved by "recording all emissions of greenhouse gases that arise directly or indirectly in the production, use and disposal of a good or service ... it is necessary to define the boundaries of this assessment ... for example, when considering the fuel used by transport, the boundary may be drawn tightly, including only the emissions from combustion, known as Scope 1, or more widely to include the extraction and refining of the fuel, known as Scope 3 ... since the carbon brainprint is a measure of total impact, it is appropriate to include all the indirect emissions [and] to consider a comparatively long period, such as 10–20 years".[12] These calculations are, essentially, covered by PAS 2050.

Laborious and riddled with uncertainty as the work of carbon footprinting is, the difficulties pale into insignificance beside what is involved in carbon brainprinting. It might, however, be possible to evaluate the brainprint of a particular patent. Let us imagine, for example, that an inventor discovered a catalyst enabling cement to be produced with much less heat. The carbon footprint would be correspondingly less, and the difference between the process with and without a catalyst would correspond to the brainprint—after taking into account the footprint of preparing the catalyst. So much for the direct brainprint. One would then have to know to what extent factories were using new catalyst. One could, of course, calculate the maximum possible brainprint achievable if every single factory in the world adopted the new catalyst—ignoring the question whether it would be possible to make enough of the catalyst (and whether the presumed consequent reduction in cost would lead to an increase in cement production). When it comes to evaluating the indirect contributions, the situation becomes very unclear. What if the inventor had been working in a large institute for 20 years before he discovered the new catalyst? Should the corresponding footprint of those 20 years be added to that of actually preparing the catalyst? If no other carbon footprint-changing invention was made during the interval, should the entire footprint of the institute be assigned to the new catalyst?

The difficulties in answering these questions are considerably increased when we consider an entire university as the introducer of a potentially carbon footprint-diminishing innovation. One must bear in mind that most universities nowadays have a large number of unproductive administrative staff whose carbon footprint needs to be accounted for, very possibly reckoned as part of the cost of introducing the carbon footprint-diminishing invention. There is also the question of the efforts to persuade factories to deploy the new invention. Such efforts might require numerous aeroplane trips to visit factories around the world.

It seems to be tacitly assumed that innovations undertaken by any given university all contribute to *diminishing* carbon footprint. In this regard, the assumptions that seem to be being made strike one as astonishingly naive. For example, one of the case studies presented on the website[12] is entitled "Improved delivery vehicle logistics". The innovation has, apparently, substantially reduced the vehicle use necessary to achieve a given amount of delivery. Typically, however, this kind of innovation results in increased delivery (or whatever the object of the service was). Hence, not only might the overall footprint increase, but the resulting volume of traffic might cause traffic jams, increasing the footprint even per unit of delivery.

One might have expected that the involvement of a university in the development of the concept of "carbon brainprint" would be a guarantee of a certain degree of rigour and profundity. Perusal of the available documents does not bear out this expectation. On the contrary, the project emerges as a rather feeble attempt to justify the public funding of universities. The bombastic assertion that "universities make tremendous intellectual and technical advances" strikes one as exaggerated and outmoded. Universities have no monopoly of knowledge. Indeed, technical innovation leading to improvement (including the diminution of carbon footprint) is far more likely to originate from privately funded industrial research than from publicly funded university research.[13]

In conclusion, the concept of "carbon brainprint" would appear to have some potential usefulness but not as it has been developed so far, mainly as an instrument for self-praise by universities. Every individual and organization has a carbon brainprint. It is probably quite misleading to consider the brainprints of individual technologies. Improved efficiency in one area may well lead to an increased footprint in another area. Unless such links are taken into account, the considerable effort required to calculate carbon footprint and *a fortiori* brainprint hardly seems justified.

Henry Matthews
Science Consultants International
Postfach
CH-4002 Basel
Switzerland.

[13] *The Sources of Economic Growth in OECD Countries*. Paris: Organization for Economic Co-Operation and Development (2003).