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Carbon accounting and carbon footprint – more than just diced results?

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Abstract

Purpose – The purpose of this paper is to discuss the growing public interest in climate protection and the desire for climate-friendly consumption which has led to a previously unimagined demand for Carbon Labels on products and various approaches to calculating the carbon footprint of firms or individual products.

Design/methodology/approach – A principal problem in calculating the carbon footprint is the input required to genuinely map the emissions from cradle to grave, in other words the product life path as is customary in a life cycle assessment. Small- and medium-sized companies especially encounter major problems in practice when trying to calculate their footprint and take aspects of upstream CO_2 emissions from their suppliers into account as well. The different options regarding how to balance and to include these emissions are compared.

Findings – Such analyses are indispensable against the background of decreasing vertical integration in industrialised countries. This is the classic question concerning the boundaries of balancing, but here with far-reaching consequences, as incorrect selection of the limits will also falsify the results and conclusions.

Originality/value – The paper demonstrates that there are new methods that can be used to determine CO_2 emissions in supply chains from stage to stage recursively and simply pass the data on to the next actor in the chain. A company then only needs to take the data from its direct trading partners into account and can dispense with comprehensive life cycle analyses. This would make CO_2 calculations easier but it requires a discussion about the question for what kind of decisions the different approaches are really helpful.

Keywords Product life cycle, Supply chain management, Pollution control

Paper type Research paper

1. Introduction

With the new worldwide discussion on climate change, triggered by IPCC (2007) publications, the Stern (2006) report and the activities of Al Gore, there is great public demand for quantifying human influences on climate. How high are the CO_2 emissions of a specific flight or journey? What product carries what backpack of emissions? How does my personal annual CO_2 balance look? So-called CO_2 calculators on the internet are becoming exceedingly popular (Padgett *et al.*, 2008).

Accordingly, the objective is to evaluate typical or individual everyday human activities on the basis of their contribution to the greenhouse effect. CO_2 emissions have become established as an indicator for this, but they are expanded by further greenhouse gases (GHG) stated as CO_2 equivalents. Consequently, not only the CO_2

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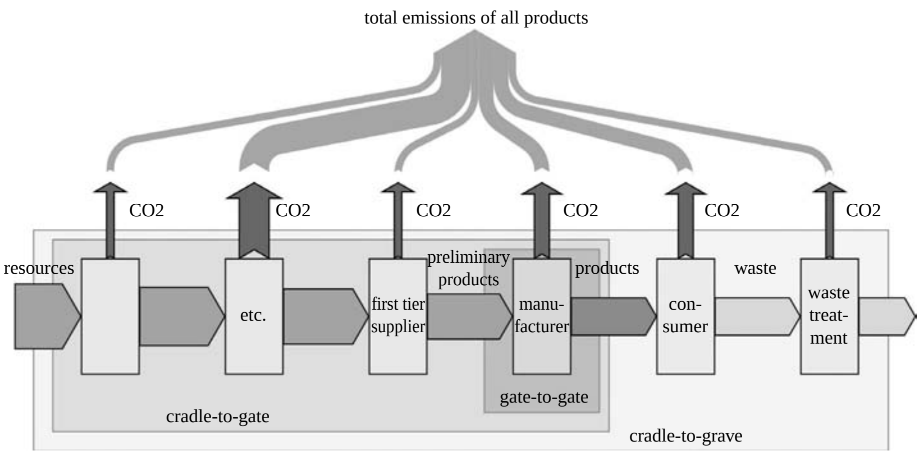
emissions of fossil origin, but also the emissions of methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons or sulphur hexafluoride (SF_6) have to be taken into account. After all, the release of 1 kg of SF_6 corresponds in climate impact to the emissions of almost 24,000 kg CO_2 (IPCC, 2007). Despite this, we frequently hear talk of CO_2 balancing or carbon accounting. What we mean in this case is the balancing of CO_2 equivalents (Figure 1).

2. Indirect emissions in corporate carbon accounting

The GHG Protocol Initiative suggested ways of corporate accounting and reporting of CO_2 and GHG already a few years ago (WRI, 2004). The essential aspect here was that both direct and indirect GHG emissions have to be taken into account. At corporate level, the direct GHG emissions are those which the company releases itself, e.g. by burning fossil heating materials, by chemical production processes, or by exhaust gases from the company's own vehicle fleet. However, the indirect emissions that develop outside the actual company through the use of energy, raw materials or services are often far greater. For example, every kilowatt hour electric current delivered from the electricity grid is linked to GHG emissions. The same applies for externally provided process heat, or compressed air for industrial processes. Moreover, the raw materials and goods purchased by companies too come carrying a "backpack" of the GHG emissions they have already caused in their previous life.

If a company neglects these indirect emissions, its contribution to climate change can be substantially falsified. For example, a company that produces no direct CO_2 emissions and buys its electricity from a neighbouring coal-fired power station can show good results, even though it uses a great deal of electricity. A company that generates its own electricity, e.g. in a highly efficient cogeneration plant, would be disadvantaged. The use of raw materials with a large GHG emission backpack would have no influence on the corporate balance either.



Notes: Accounting only the gate-to-gate emissions would underestimate the emissions. The cradle-to-gate-approach reflects the cumulative emissions at point of sale (POS). In this diagram all products of the company are taken into account

Figure 1.
Typically the emissions occur scattered along a supply chain from cradle (taking resources from nature) to grave (dumping the waste)

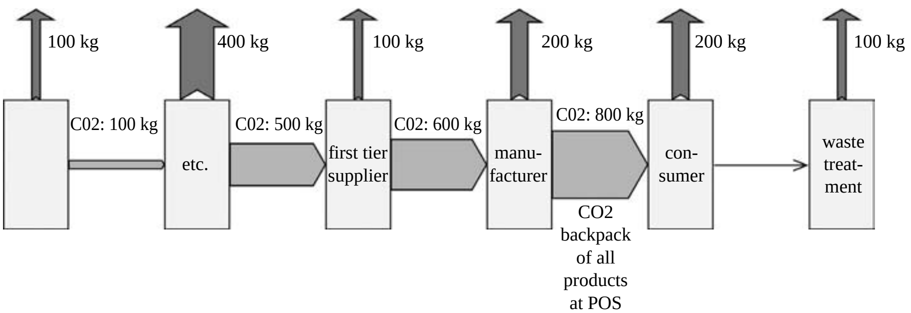
That is why it is indispensable to select the balancing boundaries correctly in accounting and reporting of GHG emissions, and to include both direct and indirect emissions. This is the only way to include the accountability companies have for energy and raw material consumption and for selection of suppliers too. After all, a company does not only make decisions about the technical standard and the emissions of its own production processes. It can also decide whether greater or lesser quantities of energy and raw materials are needed (e.g. by applying economic processes and corresponding product design), and it can even co-influence the supply chain by selecting its suppliers appropriately. If the company is willing to pay a somewhat higher price for pre-products with a lower backpack of emissions, this might even avert the need for expensive emission mitigation measures of its own (Haubach *et al.*, 2008).

3. The effort needed to collect data

However, the recommendations available on carbon accounting say nothing about how a company can collect data on such indirect emissions with low effort. Such comprehensive balance sheets fail in operative practice at the hurdle of the outlay involved. The balances then once again only contain the direct emissions, possibly extended by the emissions resulting from electricity consumption (GHG Protocol Initiative calls these scope 2 emissions).

Companies have two fundamental options involving indirect emissions:

(1) The company investigates the GHG emission backpacks of the purchased energy supplies, raw materials and services. For this, it is generally not sufficient to question only the direct supplier (first tier supplier). After all, these suppliers are only part of a supply chain that has to be taken into account as a whole. Accordingly, the company must pursue and balance the entire upstream supply chain for all relevant energies, raw materials, etc. This process then admittedly provides a real image of the direct and indirect emissions of a company, but it is extremely costly. Above all, the balance has to be repeatedly adapted as soon as anything changes in the production structure, in the supply chain, or in the composition of suppliers. Consequently, it would have to be repeated regularly and completely (Figure 2).



Notes: This backpack is essentially the carbon footprint (in this case of the whole company). However, it is mostly estimated using generic processes for the supply chain. Furthermore, the inclusion of consumption and waste treatment is difficult because these steps occur after the POS

Figure 2. The cumulative emissions could be displayed by the emission "backpack" at each point of the supply chain up to the POS (all figures are fictitious)

Such analyses are completely unrealistic in practice, as although a company can exert influence on its direct suppliers via appropriate contracts, it cannot bring any influence to bear on the sub-suppliers, etc. That is why many data along the supply chain cannot be collected from the end of the chain.

(2) Such a total survey could be avoided if standard values were used to calculate the purchased energies, raw materials and services. These could be average values for a country or a technology, so-called generic values such as are also used in life cycle assessments (LCA). It has become established practice in product LCAs to detach the processes from their concrete local and temporal surroundings and – practically – to idealise them. The data either originate from typical, comprehensive process analyses of certain products or technologies, or they can partly be derived from the input-output calculations of entire national economies – but only with very low levels of precision and resolution.

The advantage of this approach would be that the indirect emissions of a company could be estimated quickly and easily. The disadvantage would be that these are then not the actual indirect emissions of the respective company. After all, the actual technical, time-related and geographical production structure in the supply chain or the individual composition of the suppliers has not been taken into account. And this is where major differences *vis-à-vis* the real situation arise, differences that may be just as large as the fluctuation ranges of GHG emissions for the idealised processes are in real life.

This approach is unsuitable for steering management decisions (e.g. regarding the selection of suppliers) because the results are not accurate enough. The results are equally unsuitable for informing the public, as with such values the company does not map out its specific situation, but instead only a fictitious product that is oriented to average framework conditions.

Further difficulties occur when one considers that the products can cause emissions after leaving the company too. About 80-90 per cent of the emissions caused by a car are generated in the phase of use, not during production. The same applies for products such as, e.g. refrigerators or light bulbs. Stating the manufacturer's GHG emissions for production, even including the indirect emissions from the supply chain, can therefore lead to drastically erroneous decisions by consumers.

These questions relating to balancing are particularly difficult for small- and medium-sized companies to answer. Such firms are either unable to invest in the outlay for a detailed survey, or they lack knowledge of methodology on how to balance correctly. If carbon accounting is to be established on a broad footing, it is necessary to introduce approaches that can be used easily by all in practice and still produce useful information despite this, in other words approaches that support decisions for both manufacturers and consumers.

4. Benchmarking with carbon accounting

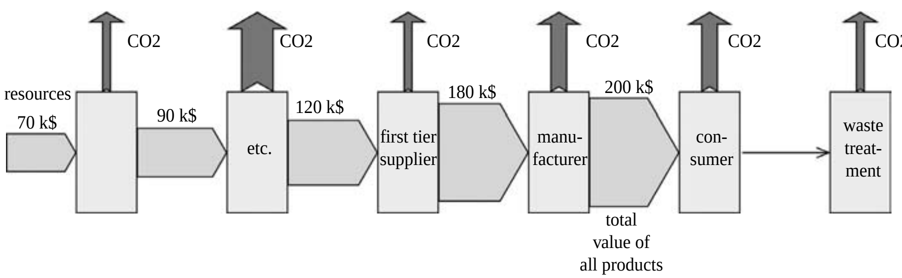
The GHG emission balance at company level has a further disadvantage. The yardstick for comparison is lacking. If a company causes 10,000 tons CO_2 a year, is this a lot or a little? Is it good or bad if the CO_2 emissions increase by 20 per cent compared with the level for the preceding year?

What is lacking here – and also in the recommendations of the GHG Protocol Initiative – are suitable and informative reference values at company level that can readily be applied in practice. The GHG emissions are inevitable and undesirable co-products of the production of something desirable, in other words products or services. The emissions can only be related to this generated benefit. If the benefit increases, e.g. the production quantity of a company grows by 30 per cent and the CO_2 emissions by only 20 per cent, this can be considered as successful efficiency boosting in the company.

A popular approach in environment circles is to quantify the benefit through the number of products, in other words to calculate solely on the basis of production figures. For instance, how many cars has a company produced? However, if different products (large and small cars) appear in the calculation, or if the company's product range changes, the reference quantity becomes difficult. How does one offset or add the various products? In business and the economy, of course, the monetary value of the products is applied – this expresses the benefit that society (or the market) assigns to the product. Based on this assumption it is possible to state a scalar quantity as reference quantity, for example company turnover. In the supply chain, the added value can be shown by the increasing downstream value of the whole product flow (Figure 3).

Corresponding processes have been developed to map corporate climate performance (Schmidt and Schwegler, 2008). The "emission intensity" states how many kilogram of GHG emissions are necessary to create an added value of $1 or €1. This value can relate either to the individual production stage, in other words to a specific company, or to the entire supply chain. In the former case the calculation looks at how efficiently and with how few GHG emissions this company creates added value. In the latter case, the cumulative intensity of the entire supply chain is calculated (Figure 4). This means that all indirect emissions are taken into account and related to the total value of the product output. Here, the total value of the product output corresponds to the market value of the product at the point of sale (POS).

The advantage of this approach is that recursive balancing systems can be derived that are very easy for company staff to apply. In order to calculate its cumulative emission intensity, a company must first know its own direct GHG emissions and secondly the cumulative emission intensities of its direct suppliers. The company no longer has to analyse the supply chain completely, but only its own first tier suppliers.



Note: It could be extended to include the real emission data of each step in the supply chain

Figure 3.
The value added in a supply chain reflects the real production conditions and supplier relations of the company (all figures are fictitious)

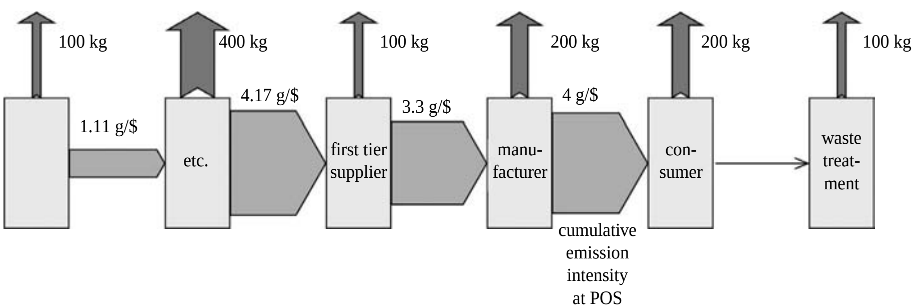
If every company were to proceed in this way, then the backpack of emissions for the goods supplied could be passed on from the supplier to the customer – in the form of the cumulative emission intensity.

The advantage of this is that every company within the actual supply chain can determine how high its direct and indirect emissions are – either in absolute terms in tonnes per year, or in relative terms in tonnes per euro or dollar. The data are based on the real supplier structure, i.e. if the company changes suppliers or raw materials, etc. this has direct impacts on its GHG emission balance.

5. Carbon footprint of products

Wackernagel (1994) and Rees (1992) first introduced the concept of the ecological footprint (Wackernagel and Rees, 1996). Interestingly, enough it was not related to a product or a company, however, but instead quantified the area needed per capita (or per nation) to maintain a lifestyle.

The carbon footprint has become established as a term in which the GHG emission balance of a product is to be stated. Currently, the carbon footprint plays a major role in the question of how products bearing a carbon label are to be labelled, and whether they can be designated as practically emission-free by the use of appropriate compensation measures. The product's carbon footprint forms the quantitative foundation for this. That is why a number of institutions are currently involved in investigating the question of what a carbon footprint is (British Standard Institution – BSI, 2008). In concrete terms a draft on a Public Available Specification (PAS 2050) from BSI exists, in other words a kind of preliminary form for a standard. The GHG Protocol Initiative has announced a corresponding publication. There are also efforts within the ISO and SETAC to standardise the carbon footprint. The pressure exerted by the market is high. This is because many companies currently want to label their products and thus attract public attention. This is no longer a matter of balancing individual selected and strategically important products, as in the case of a costly LCA. The carbon footprint is linked to the hope that a large number of products can be analysed. The Tesco retail chain in the UK even announced effusively in 2007 that it would have 50,000 products analysed (Rigby *et al.*, 2007). However, they have since backed down from this plan.



Note: The CO_2 backpack can be easily calculated at each point by multiplying the CEI with the (pre-) product price

Figure 4.
The cumulative emission intensity is the ratio of the CO_2 backpack and the cumulated value of the material flow (all figures are fictitious)

Wiedmann and Minx (2007) make the following definition:

> The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product.

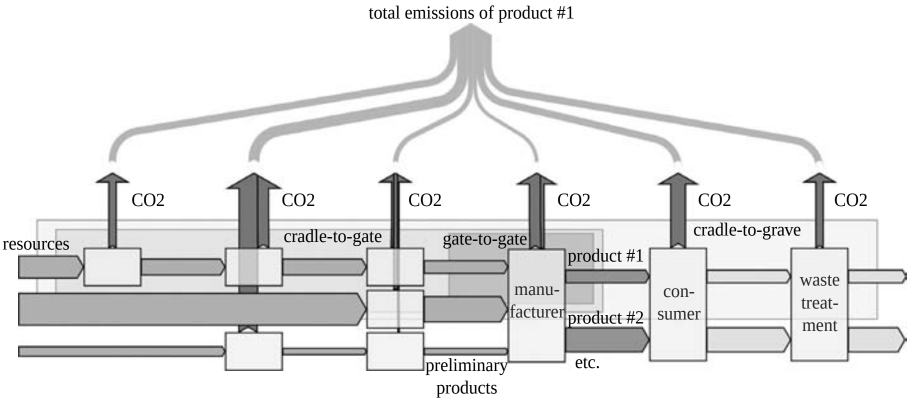
This virtually makes the carbon footprint a simplified product LCA that is drawn up only for the impact category of greenhouse effect. To this end the GHGs released by the product have to be quantified. All other substances and impacts are neglected.

The benchmark for the carbon footprint is the product or a service, in other words an objective quantity (e.g. pieces, kg, . . .), similar to the functional unit in the LCA. The essential feature of the carbon footprint is that the indirect emissions are included. If an original equipment manufacturer wishes to inform consumers about the carbon footprint of a product, not only must he take his own direct emissions into account, but he must also consider the indirect emissions. However, in this case these comprise not only the total indirect emissions of the manufacturer – but he must also take into account the concrete product reference. This means that he must analyse the indirect emissions in the supply chain that contribute to this specific product. This is a substantially more complex exercise if the company produces a wide range of different products (Figure 5).

This data collection problem is at least as large for the company as the problem of corporate carbon accounting, probably even distinctly greater. After all, it is no longer sufficient to survey the company's supply chain. In addition, the company also has to distinguish between the contributions it makes to the products.

6. Data collection for the carbon footprint

The carbon footprint can either be drawn up with real data from the company's supply chain (the input is then immense and can only be executed for a few products), or with typical average values for energies, raw materials, etc. (in other words generic values). However, this does not then produce the carbon footprint of the specific product, but instead that of a fictitious product.



Note: Gate-to-gate, cradle-to-gate and cradle-to-grave approaches need product-specific data from the company, the supply chain etc

Figure 5.
In this perspective only single products are taken into account

Thus, the question arising is similar to that which has already been discussed in the LCA segment (Frischknecht, 1998, 2006; Weidema, 2001). With so-called attributional data such as are typically offered in databases (Ecoinvent), it is admittedly possible to draw up the LCA of a product quickly and simply. However, the result is then not the balance sheet of the specific product, as the delivery relations and the concrete production conditions have not (or only incompletely) been included in the calculations. The classic example of this is always the question of what electricity mix was used for the LCA. Were national average generating conditions assumed (with a mix of coal, nuclear power, hydro-power, etc.)? Or electricity purchased specifically from a modern gas-fired power station of a special provider? Or even electricity from renewable sources?

Using generic values leads to fuzziness in the result with respect to the actual size of a product's carbon footprint. Above all, however, such an approach does not offer the product manufacturer any directions. Hence, the manufacturer is specifically not motivated by a carbon footprint produced from generic values to purchase electricity generated with lower emissions, or to change his supplier accordingly. That is because this change would hardly be reflected in his carbon footprint. For this purpose detailed data need to be taken into account. Ultimately, however, the goal of the carbon footprint involving indirect emissions is precisely to bring about such reactions by a manufacturer. After all, what do we hope to achieve through the information supplied to consumers? That consumers reflect on their choice and incline more towards lower-emission products, and also that the companies improve their products – including their supply chain.

However, not everyone sees this in the same way. The planned PAS 2050 (status February 2008) states, "It is the implicit intention of this PAS to allow for the comparison of GHG emissions between equivalent products and to enable the communication of this information." At the same time, however, it establishes, "It is not the purpose of this PAS to provide ... calculation of the differences in GHG emissions from using all alternate supply chain options". The benefit of such carbon footprints must be doubted if they are unable to map out such differences.

For precisely this reason the use of I/O tables from overall macroeconomic calculations (Suh, 2004) must be considered as sub-optimal for producing carbon footprints. The resolution by branch or product groups is so slight that only estimated values regarding the approximate size of the carbon footprint of the product are obtained. However, real mitigation measures can hardly be quantified with this method.

There is a further source of fuzziness. Wiedmann and Minx (2007) demand that the carbon footprint be applied to all life phases of a product, in other words to the use and waste disposal phases too. This approach has been taken over from an LCA, where cradle-to-grave is also balanced. Carbon footprints are to be published primarily for the purpose of informing consumers. The data from the use and waste disposal phases are not yet available at the time the product is sold. It is only possible to make assumptions as to how the product will be typically used and what emissions it then causes. It would be more expedient at this point to offer consumers two items of information – the carbon footprint as a cradle-to-gate balance, and for example the energy efficiency class of the product – as is already common practice for, e.g. refrigerators.

Instead of using generic data, the only expedient alternative remaining would be to draw up a very detailed analysis for each product, virtually a reality-driven process-related LCA for GHG, and to designate this as a carbon footprint. As this is very complex and costly, such a approach can only be limited to a few products. With this, one would not achieve the desired effect of being able to balance and label thousands of products with a carbon footprint. With each technical modification of production, with each change in selection of suppliers, etc. it would be necessary to correct the carbon footprint for the corresponding product, to adapt the product label, etc.

7. Extension of carbon accounting to carbon footprints?

Section 4 suggested performing corporate carbon accounting with the aid of cumulative emission intensity and calculating this recursively from stage to stage along the supply chain. The advantage of this approach would then be that it requires much lower effort and despite this the results would map the real emission situation in the supply chain.

If a company has calculated a certain cumulative emission intensity (in kilogram per euro or dollar sales) for itself, this emission intensity can also be related to its products. The carbon footprint of the product is then calculated from the cumulative emission intensity of the manufacturer and the market value of the product.

This would break through an essential paradigm of the LCA. The carbon footprint would no longer reflect the technical-causal and ecological conditions in the production of the respective product, but instead the conditions for the entire company and its supply chain. If, for example, one were then to buy a product with a comparatively low-carbon footprint, one could not be certain that this is in fact a product produced with low emissions. But one would certainly know that the manufacturer of this product produces comparatively low-emissions overall – taking into account the supply chain and real conditions.

With these new characteristic data one would then be "on the safe side" as it were, and decisions could be based safely as regards the selection of manufacturers. This can ultimately be more helpful for influencing planning procedures in the company, leading towards more climate protection. No non-existent accuracy would be simulated in the product carbon footprint. After all, one would be wrong to conclude that the LCA or an LCA-like carbon footprint proceeds using "technical-causal" analyses. An LCA tries to approach this requirement, but does not satisfy it. Even in a detailed LCA many concrete production structures ultimately remain unknown and have to be estimated using generic data and many assumptions. Thus, the LCA only maps a "generic product", but not exactly the product that is finally waiting on the supermarket shelves.

8. Conclusions

The problems discussed in this paper indicate that the way CO_2 balancing is conducted cannot be separated from the purpose for which the results are put. What decisions – and above all whose decisions – is the information intended to support? The answers to these questions determine which of the various possible methods with varying demands made of data precision are to be applied.

LCAs and carbon footprints would only support corporate decision making if they were extremely detailed and reflected specific real production conditions. Here, it is more expedient to avoid classic concentration on products and instead focus analyses on the company and its supply chain. This could be based on regular surveys of suppliers' cumulative emission intensities and the company's own emissions, as proposed in Section 4. Such a system could be introduced on a broad basis and take the specific trading partners into account. Emission reduction measures would have a direct bearing on the results.

If consumers are to be supported in shopping decisions, for instance by a product label (Walter and Schmidt, 2008), it is necessary to take manufacture, product properties and product use into consideration. Only an LCA or a detailed carbon footprint could point up differences between various products here. However, such approaches are very costly and hence not very efficient. It makes more sense to offer consumers other key indicators that are more significant, comprehensible and verifiable. For instance, such indicators might be whether the product is made from secondary raw materials, whether it is produced locally (= less transport), or whether it was produced using only renewable energy resources. One very efficient alternative would be to quote the cumulative emission intensities of the manufacturer, though strictly speaking this would not simply represent a product assessment but instead an assessment of the whole manufacturer.

The customer must be informed about the utilisation and waste disposal phases of the product too. How much energy does the product consume in use? (How) Can this be influenced? A Carbon Footprint definitely needs such complementary information.

Finally, there is the field of emissions compensation. Cash paid for the CO_2 emissions caused by a product is used to fund projects with which emissions can be saved. Such compensations are already popular for air passenger traffic. Emission calculations for these flights are kept very simple. They are not oriented to specific aircraft, weather conditions, flight routes, etc. but instead are based on average values (essentially the mean distances flown). If this system is transferred to compensating emissions caused by product manufacture, simplified carbon footprints that roughly estimate the emission volumes using generic values or input/output analyses and calculate the cash amount of the compensation payment on this basis could be used. The prime aim would be to fund meaningful environmental protection projects with cash provided by business and industry. The companies involved could include this aspect in their advertising and publicity. What is important here is not whether a product generates 6 or 8 g CO_2, but instead whether the figure is 6 or 30 g or even 100 g. For this, the carbon footprint as cradle-to-gate balance is quite sufficient, as private energy use (e.g. electricity) can be recorded and compensated separately via individual household metering.

Consequently, the various approaches to balancing with their different strengths and weaknesses can be applied expediently in the respective decision-making contexts. However, it is first necessary to explore their advantages and disadvantages, and also who really benefits from the information when a specific decision is considered and taken.

References

BSI (2008), "PAS 2050 – Specification for the measurement of the embodied greenhouse gas emissions in products and services", Draft, British Standard Institution – BSI, London.

Frischknecht, R. (1998), *Life Cycle Inventory Analysis for Decision-making: Scope-dependent Inventory System Models and Context-specific Joint Product Allocation*, Eidgenössische Technische Hochschule Zurich, Zurich.

Frischknecht, R. (2006), "Modelling of product systems in life cycle inventory analysis: synopsis of attributional and consequential LCI models – properties and differences", Report for the BMBF Project on the Scientific Cooperation to Foster the German Network on Life Cycle Inventory Data, Forschungszentrum Karlsruhe FZK, Karlsruhe.

Haubach, C., Schwegler, R. and Schmidt, M. (2008), "Kumulierte Emissionsintensitäten als integrativer Bestandteil der strategischen Investitionsentscheidung", *Umwelt-wirtschafts-forum*, Vol. 16 No. 3, pp. 155-8.

IPCC (2007), *Climate Change 2007, The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Padgett, J.P., Steinemann, A.C., Clarke, J.H. and Vandenbergh, M.P. (2008), "A comparison of carbon calculators", *Environmental Impact Assessment Review*, Vol. 28, pp. 106-15.

Rees, W.E. (1992), "Ecological footprints and appropriated carrying capacity: what urban economics leaves out", *Environment and Urbanisation*, Vol. 4 No. 2, pp. 121-30.

Rigby, E., Harvey, F. and Crooks, E. (2008), "Tesco to 'carbon label' its products", *Financial Times*, 19 January, available at: www.ft.com/cms/s/0/966e2910-a765-11db-83e4-0000779e2340.html?nclick_check = 1 (accessed 29 June 2008).

Schmidt, M. and Schwegler, R. (2008), "A recursive ecological indicator system for the supply chain of a company", *Journal of Cleaner Production*, Vol. 16 No. 15, pp. 1658-64.

Stern, N. (2006), *The Economics of Climate Change*, Cambridge University Press, Cambridge.

Suh, S. (2004), "Materials and energy flows in industry and ecosystem networks: life cycle assessment, input-output analysis, material flow analysis, ecological network flow analysis, and their combinations for industrial ecology", dissertation, Leiden University, Leiden.

Wackernagel, M. (1994), "Ecological footprint and appropriated carrying capacity: a tool for planning toward sustainability", PhD thesis, University of British Columbia, Vancouver.

Wackernagel, M. and Rees, W. (1996), *Our Ecological Footprint*, New Society Press, Gabriola Island.

Walter, S. and Schmidt, M. (2008), "Carbon Footprints und Carbon Label – eine echte Hilfe bei der Kaufentscheidung?", *Umweltwirtschaftsforum*, Vol. 16, pp. 175-81.

Weidema, B. (2001), "Two cases of misleading environmental declarations due to system boundary choices", *Proceedings From: 9th SETAC Europe LCA Case Studies Symposium, Noordwijkerhout, The Netherlands*, 14-15 November, available at: www.lca-net.com/publications/casestudies01/ (accessed 29 June 2008).

Wiedmann, T. and Minx, J. (2007), "A definition of 'carbon footprint'", Research Report 07-01, ISA UK.

WRI (2004), *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard*, World Resources Institute – WRI, Washington, DC.

Further reading

DEFRA (2007), "Methods review to support the PAS process for the calculation of the greenhouse gas emissions embodied in good and services", Report to the UK Department for Environment, Food and Rural Affairs, Stockholm Environment Institute, University of York and Department for Biobased Products, University of Minnesota, London.

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