Companies on the Scale

Comparing and Benchmarking the Sustainability Performance of Businesses

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Summary

A determination of the sustainability performance of a company ought to fulfill certain requirements. It has to take into account the direct impacts from on-site processes as well as indirect impacts embodied in the supply chains of a company. This life cycle thinking is the common theme of popular footprint analyses, such as carbon, ecological, or water footprinting. All these indicators can be incorporated into one common and consistent accounting and reporting scheme based on economic input–output analysis, extended with data from all three dimensions of sustainability. We introduce such a triple-bottom-line accounting framework and software tool and apply it in a case study of a small company in the United Kingdom. Results include absolute impacts and relative intensities of indicators and are put into perspective by a benchmark comparison with the economic sector to which the company belongs. Production layer decomposition and structural path analysis provide further valuable detail, identifying the amount and location of triple-bottom-line impacts in individual upstream supply chains. The concept of shared responsibility has been applied to avoid double-counting and noncomparability of results. Although in this work we employ a single-region model for the sake of illustration, we discuss how to extend our ideas to international supply chains. We discuss the limitations of the approach and the implications for corporate sustainability.

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Corporate Sustainability Reporting

Corporations are beginning to apply the concept of sustainability at a practical level in terms of environmental and sustainability accounting and reporting (Von Ahsen et al. 2004; Schaltegger et al. 2006; Taplin et al. 2006; Daub 2007), thus addressing the various "corporate sustainability challenges" (Schaltegger et al. 2003). Since companies began publishing the first environmental reports in the late 1980s, there has been "a clear tendency towards the inclusion of societal, and sometimes also financial, issues and benchmarking of performance" (Kolk 2004, 52). Corporate sustainability accounts and reports must contain qualitative and quantitative information on economic, environmental, and social effectiveness and efficiency and integrate these aspects into a sustainability management system (Schaltegger and Wagner 2006).

One of the possibilities for companies to report on their sustainability performance is triple-bottom-line (TBL) accounting.[1] In contrast to reporting only on the financial bottom line, the TBL concept requires that companies evaluate and report their performance in all three spheres of sustainability: economic, social, and environmental. TBL accounting provides the framework and tool for considering economic, environmental, and social implications of decisions, products, operations, or future plans and is therefore helpful in improving the fundamental functions of organizations and lasting stability (Mitchell et al. 2008). The global financial crisis of 2008–09, continuing global poverty in the developing world, and the challenges of global climate change are stark reminders that the paradigm of sustainable development requires long-term thinking and decisive action in all three dimensions.

The concepts of TBL accounting and associated systems and reporting frameworks are increasingly being taken up by companies worldwide as the Global Reporting Initiative (GRI)[2] and the work of bodies such as the Organisation for Economic Co-operation and Development (OECD) build momentum. In the wake of this work, national and international regulations are changing, and companies are more and more required to report their environmental and social performance.[3] There are no strict guidelines or standards yet with which businesses have to comply, however. Although the GRI has chosen the notion of the TBL in laying the groundwork for such guidelines (Global Reporting Initiative 2002), the TBL accounting procedures envisaged by the GRI are still fraught with inconsistencies, amongst which is the so-called boundary problem (Global Reporting Initiative 2005). This brings with it a need for standardization of accounting frameworks (Steven 2004).

In the environmental arena in particular, the challenges faced by comprehensive accounting and reporting of impacts have been intensely discussed. In an effort to report their wider environmental performance, companies increasingly go beyond the traditional environmental reporting, based on a stock-taking of in-house energy and resource consumption, and instead adopt a life cycle perspective of their impacts. Rather than focusing on what goes on within the factory fences, farm gates, or company premises, a life cycle—wide assessment traces impact through the entire production and supply chain of a business.

As a consequence, more and more companies choose to report on what is now popularly called a "footprint" as a possible indicator of their wider environmental impacts. There exist so far three types of such footprints: the carbon footprint, the ecological footprint, and the water footprint. Although the use of the ecological footprint for business has been considered for some time (Barrett and Scott 2001; Holland 2003), carbon footprint assessments[4] in particular have gained enormous popularity in the last few years, with several high-profile reports, conferences, and private and public initiatives dealing with this subject.[5] The water footprint is following suit (Gerbens-Leenes and Hoekstra 2008; Madrid et al. 2008).[6]

The common theme of these footprint analyses is that the focus has shifted from reporting direct impacts from on-site processes (direct land, fuel, or water use) toward reporting indirect impacts embodied in the supply chain of a company (upstream) or caused by the use and disposal of its products (downstream). The desire to describe these indirect impacts quantitatively is also reflected in an increasing effort to standardize procedures aimed at estimating the "Scope 3" emissions of a company, as defined by the Greenhouse Gas (GHG) Protocol (WRI and WBCSD 2004), and the indirect GHG emissions associated with products (Carbon Trust 2006; SETAC Europe LCA Steering Committee 2008; WRI and WBCSD 2008)[7] as well as the full ecological footprint[8,9] or water footprint[10] of an organization, product, process, or service.

All three footprint indicators—carbon footprint, ecological footprint, and water footprint—can be incorporated into one common and consistent TBL accounting and reporting scheme, and all three indicators face the same conceptual challenges. Two issues are particularly critical when one considers quantitative TBL accounting. First, indicators must include both the direct (on-site, immediate) effects of a company and the indirect (off-site, upstream, embodied) effects associated with purchasing from a potentially large and distant web of suppliers. Only when companies adopt this life cycle perspective do accurate comparisons of performance become possible. Problems related to the choice of boundaries can be avoided when all possible indirect upstream impacts are incorporated. Second, it is important to address the question of how to assign responsibility for these indirect impacts, as all partners in a supply chain are involved in their creation and reporting on them must avoid double-counting. Accounting that is free of boundary problems and of double-counting is particularly important when it comes to comparing and ranking corporate sustainability performance in a robust and reproducible way (see also Krajnc and Glavic 2005).

Footprint practitioners mainly use two methods to evaluate the life cycle–wide impacts of organizations: process analysis and economic input–output (EIO) analysis. These approaches are distinct in the depth and the width of the analysis and have very different data requirements. Process analysis is the "traditional" type of life cycle analysis (LCA) based on bottom-up data of specific production processes. It generally produces more accurate results for direct, on-site impacts but involves significant systematic errors caused by the truncation of the life cycle system by a finite boundary (Lenzen 2001a). EIO analysis, extended with national environmental and social accounts, can handle infinite supply chain systems and hence does not suffer from truncation errors; it generally does not, however, adequately describe the production processes that are specific for most small-scale and medium-scale applications. For those reasons, the state of the art in LCA is undoubtedly a combination of the best of both methods in a hybrid analysis (Bullard et al. 1978; Heijungs and Suh 2002; Suh et al. 2004; Heijungs and Suh 2006; Heijungs et al. 2006; Ahna and Lim 2007; Crawford 2008; Minx et al. 2008b; Strømman et al. 2009). Such an approach preserves the detail and accuracy of bottom-up approaches in lower order stages (i.e., direct impacts), and indirect, higher order requirements are covered by the input–output part of the model.

The method of choice often depends on the purpose of the inquiry and the availability of data and resources. Process analysis has clear advantages for looking at microsystems: a particular process, an individual product, or a relatively small group of individual products. Input–output analysis is superior for the calculation of impacts in macrosystems and mesosystems. In this context, a footprint analysis of industrial sectors, individual businesses, larger product groups, households, government, the average citizen, or an average member of a particular socioeconomic group can easily be performed through input–output analysis (Foran et al. 2005a; SEI et al. 2006; Wiedmann et al. 2006; Junnila 2008; Matthews et al. 2008b). Foran and colleagues (2005b) show how EIO–LCA can be integrated into the TBL framework and applied to supply chain management issues at a wide range of organizational scales.

In this article, we present an input–output-based approach for calculating the TBL performance of a company, including the carbon footprint and ecological footprint as example indicators for the environmental dimension of TBL accounting. EIO is now a well-established technique for the calculation of the carbon footprint and ecological footprint of organizations or companies (Lenzen et al. 2003; Wood and Lenzen 2003; Wiedmann et al. 2007a; Matthews et al. 2008a, 2008b; Wiedmann and Lenzen 2008; see also the review by RPA 2007). The methodology is being continuously refined and extended.

Wiedmann and colleagues (2007d) suggest that multiregion input–output (MRIO) models in particular could be used to calculate ecological footprints embodied in international trade (see also Turner et al. 2007; Wiedmann et al. 2007e). Wiedmann (forthcoming) presents the first empirical results of such an analysis for energy footprints. Uncertainty analyses of input–output-based footprint calculations have been presented for the carbon footprint (Wiedmann et al. 2008b) and the ecological footprint (Beynon and Munday 2008) of a nation, with consideration of the uncertainty of technical coefficients in the underlying EIO framework.

The TBL-extended EIO accounting framework described in this article has been developed specifically to address a lack of quantification and comparability in corporate environmental and TBL reporting. It uses regularly published, publicly available data from national economic and environmental accounts. It avoids arbitrary cutoff points that could be different in different organizations. With this methodology, reporting on footprints as well as the TBL allows for comparisons within and between organizations, transparent communication of impacts to all stakeholders, and detailed information across the whole supply chain as a basis for strategic decision making. A practical example of this type of TBL accounting has recently been described by Lenzen (2008b) in three case studies of small companies and by Wiedmann and Lenzen (2008) in more general terms.

The purpose of this article is to

- describe the analytical approach to measure total (direct plus upstream indirect) impacts, such as footprints, of a producing entity in a comprehensive way;
- present a TBL accounting framework that allows for a consistent and comparable quantification of indirect impacts and their allocation to individual supply chains; and
- present case study results of a TBL analysis of a UK company in the recreational services sector.

This is followed by a discussion of strengths and weaknesses of the approach and by the conclusions.

Methodology

In the following, we outline the general principles of the methodology applied in the case study. More detailed calculation procedures are described step by step by Wiedmann and colleagues (2006).

Measuring Indirect Impacts

An introduction to the input–output method and its application to environmental problems can be found in the work by Leontief and Ford (1970), Proops (1977), Miller and Blair (1985), and Lenzen (2001b). EIO analysis is a top-down economic technique that uses monetary transactions between all sectors of an economy to account for the complex interdependencies of industries, represented by an $n \times n$ direct requirements matrix $\mathbf{A}$ (n is the number of economic sectors). For many countries, the direct requirements matrix $\mathbf{A}$ can be compiled from the input–output tables published by the national statistical agencies.

This national economic accounting framework can be extended with supplementary sectoral data from national social and environmental accounts. From these data, *direct* TBL indicator scores are calculated in the form of sector impact (e.g., direct carbon dioxide [CO_2] emissions) divided by the total economic output of that sector and compiled in an $f \times n$ matrix $\mathbf{Q}$, with f representing the number of TBL indicators (e.g., ecological footprint, energy, employment, wages and salaries).

An $f \times n$ matrix $\mathbf{M}$ of *total* TBL impact multipliers can then be calculated according to

$$\mathbf{M} = \mathbf{Q}(\mathbf{I} - \mathbf{A})^{-1} \tag{1}$$

where $\mathbf{I}$ is the $n \times n$ unity matrix. These input–output multipliers represent total—that is, direct plus indirect (upstream)—embodiments of TBL impacts per unit of final demand of commodities produced by n industry sectors. The $f \times 1$ TBL inventory $\mathbf{F}$ of a given final demand (e.g., the annual purchases of a household), represented by an $n \times 1$ commodity vector $\mathbf{y}$, is then simply

$$\mathbf{F} = \mathbf{My} \tag{2}$$

The TBL inventory **F** contains the absolute values of life cycle impacts associated with all upstream production processes of a set of commodities, such as the ecological footprint (in hectares or global hectares [gha][12]), the carbon footprint (in tons of CO_2-equivalents), or the water footprint (in liters, cubic meters, etc.) of an entity buying these commodities.

In a number of empirical applications, researchers applied the input—output formalism to compile footprint and TBL accounts of the Australian and UK economy and parts thereof (Lenzen and Murray 2001; Lenzen and Murray 2003; GFN and ISA 2005; SEI et al. 2006; Wiedmann et al. 2007b, 2007c). Comprehensive TBL accounts of the Australian economy have been published[11] and contain information on the aggregate and average performance of 135 economic sectors for ten TBL indicators, together with their main data sources (Foran et al. 2005a). The synthesis of disparate data sources is a major component of the development of a generalized input—output framework.

Avoiding Double-Counting

The generalized input—output method described above cannot directly be applied to a company. In the underlying economic model, companies are part of the production system—that is, they are seen as being part of intermediate economic transactions (intermediate demand) rather than part of final demand, which is created by private consumers (households), government, or capital investment. Simply using the total impact multipliers (matrix **M** from above) for a company's expenses would lead to double-counting, as the implicit assumption behind the derivation of **M** is that the total upstream impacts are loaded onto the final consumer. This is because the life cycle or footprint perspective demands that all impacts of a product are added up along its production chain ("from cradle to shelf") and are accounted for only once, when the final product is bought by a consumer (final demand). In other words, traditional life cycle and footprint analyses by definition assume full consumer responsibility; the impacts of any producer (producer responsibility) must be zero.

As with many other allocation problems, an acceptable consensus probably lies somewhere between producer and consumer responsibility. To assign responsibility to actors participating in these transactions, one has to know the respective supply chains or interindustry relations. This problem is addressed by Gallego and Lenzen (2005), who describe a consistent framework for sharing responsibility along economic chains. The result is that in reality, both the final consumers and their upstream suppliers play some role in causing footprints: The suppliers use land, energy, and water to produce and to make decisions on how much of resources to use and emissions to allow, whereas consumers decide to spend their money on upstream suppliers' products. The concept of shared responsibility recognizes that there are always two entities playing a role in causing impacts: the supplier and the recipient. Hence, responsibility for impacts can be shared between them. Naturally, this applies to both burdens and benefits.

Lenzen and colleagues (2007) apply the concept of shared responsibility to the example of ecological footprint analysis of a particular production (supply) chain. The work demonstrates and discusses a nonarbitrary method of consistently delineating the supply chain footprints into mutually exclusive and collectively exhaustive portions of responsibility to be shared by all actors (see also Lenzen 2007).

In this work, we assume that suppliers and demanders of any commodity take on a 50% share of the responsibility that the production of the commodity entailed. As a consequence, a producer that causes 100 units (tons of emissions, hectares of land, or liters of water) for on-site operations accounts for only 50 units for its own direct footprint, as the remaining 50 units will be passed on to the customers of the producer.

Comparing Performance

How can the TBL or footprint performance of one company be compared with that of another? Obviously, companies have different sizes, have different numbers of facilities, employ more or fewer people, and have a smaller or larger network of suppliers. Absolute numbers of impacts need to be put in perspective or are otherwise meaningless. Two important preconditions need to be fulfilled before an attempt can be made to compare the performance of different companies. First, the quantification of impacts needs to be based on the same system boundaries, and, second, impacts need to be expressed in meaningful, relative units that are independent of company size.

The boundary within which a company accounts for its environmental, social, and economic effects is usually defined as the area over which it has direct influence and can exercise control. Such a definition faces a number of challenges, however. The level of influence and control vary from organization to organization and from year to year, which invalidates comparisons within and between organizations. Moreover, extending the boundary beyond the immediate control of the organization still begs the question of exactly where to draw the line.

EIO analysis is particularly suited to provide an answer to this question, as the whole national economy constitutes the system boundary of the analysis. No cutoff point for the inclusion or exclusion of processes has to be chosen, as all possible economic transactions are automatically captured. The boundary can easily be extended to the whole world economy under the assumption that the rest of the world has the same economic and technological structure as the national economy. Indeed, this is the case in all single-region input—output models that include full trade flows to and from this economy. One can relax the assumption by employing an MRIO model that allows for a more sophisticated evaluation of international trade. A detailed discussion of this option, however, is beyond the scope of this article, and therefore we refer to recent literature on MRIO modeling (Lenzen et al. 2004a; Peters et al. 2007; Turner et al. 2007; Wiedmann et al. 2007d, 2007e; Wiedmann forthcoming).

One option to deal with the second requirement is to use the total economic output of a company or a sector as the denominator. This approach was taken, for example, in the Australian TBL sector accounts that describe economic, social, and environmental impacts against a common unit of $1 of final demand. The latter constitutes a convenient and meaningful numeraire, because it is the destination of gross domestic product (GDP), the common measure of national economic performance. Social indicators, such as employment, can be described as the minutes of employment generated per dollar of final demand. Environmental indicators, such as GHG emissions, water requirements, and ecological footprints, can be described as kilograms of CO_2-equivalents per dollar of final demand or the like.

In this work, we present a case study of total TBL/footprint impacts of a company as an absolute *impact* (e.g., in global hectares [gha]) and as a relative *intensity* (e.g., in gha/£). Such intensities have been utilized ever since input—output analysis was described by Wassily Leontief (1936). They are the straightforward results of input—output calculations. In most cases, intensities refer to measures of overall activity of a company, expressed in monetary units (dollars, pounds, etc.). We think that monetary activity of a company is a reasonable measure for its size and better suited than other possible denominators, such as numbers of employees. The relative TBL or footprint intensities of a company can be directly compared not only to those of another company evaluated with the same method but also to the average performance of the sector to which the company belongs. Those sector benchmark data are an intrinsic part of any TBL input—output model, as they form the very backbone of the model data.

Unraveling the Supply Chain

As mentioned above, one can solve the boundary problem by taking a full life cycle perspective and by taking into account the structure of the whole economic system as described in national input—output tables. This structure is best depicted as an ever-expanding "tree of interdependence" that starts at a particular economic entity and stretches across upstream production layers, containing sectors at different production stages linked together by supply chains. Thus, a particular impact associated with a good or a service cascades from primary industries producing raw materials, via secondary (manufacturing) industries, into the sector or company that delivers the final product to the consumer (see also Lenzen and Murray 2003).

The general decomposition approach described in the following was introduced into economics and regional science in 1984 under the name *structural path analysis* (SPA; Crama et al. 1984; Defourny and Thorbecke 1984). To systematically determine environmentally important production chains, one can decompose the total factor multipliers derived in equation (1) into contributions from all input paths by "unraveling" the Leontief inverse using a series expansion. A multiplier m_i for industry i can then be derived that represents the sum over a direct factor input q_i, which occurs in industry i itself, and higher order input paths (Lenzen 2002, 2003; Suh and Heijungs 2007).

Such an SPA covers the entire upstream supply chain. It "unravels" a company's impacts into single contributing supply paths. It gives extensive details of the impact of a sector's or company's activities. It allows one to investigate the location of impacts within the supply chain. In the case of a company, the control over the input procurement process then provides one with the possibility of substituting impact-intensive suppliers with more sustainable suppliers. For environmental applications of SPA, see, for example, the work by Minx and colleagues (2008a), Lenzen and colleagues (2004b), Peters and Hertwich (2006), Treloar (1997), Wood and Lenzen (2003), and Wood (2008).

Introducing a Tool for TBL Accounting

The input–output-based LCA and TBL accounting framework presented here has been applied to dozens of organizations in reporting on their sustainability performance—companies, government departments, nongovernmental organizations (NGOs).[13] Experiences were collected in a 3-year pilot project. It became clear that the data collection burden for the organization has to be as small as possible. As a result, the TBL model was developed into the software tool[14] Bottomline[3], in collaboration with the organizations; this tool enabled them to create a comprehensive sustainability report solely by importing existing financial accounts and some additional on-site impact data.

The model uses the financial information to calculate upstream, indirect impacts in terms of physical indicators. Direct physical impacts, such as on-site emissions from heating, are entered separately. The available TBL indicator set includes a number of economic, social, and environmental indicators; the particular indicators vary with the national economy. Most often used are the carbon footprint, ecological footprint, and water footprint, but other resource use and pollutant indicators are also available. All TBL indicators can be compared to the average performance of the sector to which the company belongs (see the next section).

The TBL model and tool employs input–output-specific analytical techniques, such as sector benchmarking, SPA, and production layer decomposition for all indicators. The model quantifies "shared responsibility" by delineating impacts into mutually exclusive and collectively exhaustive portions of responsibility to be shared by all agents along a supply chain.

The software tool has been extensively road-tested over 3 years. Users felt that the assessment of their organization's indirect impacts was a valuable feature because it identifies abatement options, enables meaningful benchmarking, avoids loopholes in reporting, and informs about risk. Further development of the tool includes hybridization through the addition of process-specific data for certain supply chains and the extension to an MRIO framework that covers international trade flows.

Other corporate environmental and LCA tools are available, some of which offer the possibility of benchmarking, but, to our knowledge, at the time of writing only very few software or online tools enabled a boundary-free assessment of a company's operations by making use of input–output analysis.[15] Such tools' functionality and versatility is improving steadily, however, and new and improved tools can be expected to become available in the near future.

Model and Sector Benchmark Data

For this work, we adapted the input–output framework described above to the UK economy to calculate the ecological footprint of a UK company. The UK version of Bottomline[3] is based on a static, single-region, open, basic-price, 76-sector industry-by-industry input–output model of the UK economy as of 2000, augmented with a database of environmental, social, and economic indicators for 2001.[16] All monetary and emissions data are taken from the national economic and national environmental accounts published by the UK Office for National Statistics (ONS 2007a, 2007c). UK Supply and Use Tables for 2000 are used for the input–output model (ONS 2006; Wiedmann et al. 2006), and sectoral emission data for GHGs, air pollutants, and heavy metals for 2001 are from UK Environmental Accounts (ONS 2007b). Employment data are taken from the 2001 Census of Population: Employment by sectors, UK 2001.[17] Ecological footprint data per sector were derived according to the method described by Wiedmann and colleagues (2006).

The model framework is described by Foran and colleagues (2005a), with a summary available from Foran and colleagues (2005b). A short summary of the methodology can also be found in the work by Wiedmann and Lenzen (2006).

TBL Indicators

We evaluate the performance of a UK company with respect to the following TBL indicators. Some of these indicators can be regarded as positive, where more is deemed good (all economic and social indicators), whereas negative indicators are characterized by "less is better" (all environmental indicators).[18]

Economic Indicators

Gross operating surplus (GOS) is defined as the residual of a producer's total inputs, after subtraction of all intermediate inputs, compensation of employees, net taxes, and subsidies. It consists of operating profits and consumption of fixed capital for capacity growth and replacement (depreciation). GOS indicates the capacity to innovate through turnover of the capital stock as well as the capacity for expansion and investment.

Total intermediate uses are the sum of the supply of goods and services by all industries in the economy. The term describes the indirect turnover generated by a particular producer and thus indicates the general stimulus created in the whole economy by that producer.

GDP is the sum of income, profits, taxes less subsidies, and complementary imports. GDP is a typical measure of the production of an economy. The indicator shows the direct and indirect contribution of one company to GDP.

Social Indicators

Employment is measured in full-time equivalents of employed work and includes employers, own account workers, and contributing family workers. The unit is employment years (emp-y) or employment minutes (emp-min).

Income is the general compensation of employees, including wages, salaries, superannuation, and workers' compensation payments. This indicator is related to employment but, in addition, can indicate whether parts of the supply chain receive unequal wages and salaries.

Government revenue consists of taxes less subsidies on products for intermediate demand, other net taxes on production, and net taxes on products for final demand (incorporated in the sales price). Taxes contribute to support the national commons, such as health, education, defense, social benefit payments, and public transport.

Environmental Indicators

Ecological footprint is "a measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates using prevailing technology and resource management practices" (GFN 2008a), measured in global hectares (gha). We distinguish the following land types as subcomponents of the ecological footprint: CO_2 area, cropland, grazing land, forest, fishing grounds, and built-up land.[19]

Carbon footprint is a measure of the exclusive (i.e., not doubled-counted) total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product (Wiedmann and Minx 2008, 5). This includes activities of individuals, populations, governments, companies, organizations, processes, industry sectors, and so on. Products include goods and services. In any case, all direct (on-site, internal) and indirect emissions (off-site, external, embodied, upstream, downstream) need to be taken into account. One can add other GHGs to form a "climate footprint" indicator; however, this was beyond the scope of this article.

Air pollutants are an aggregated indicator relating to emissions of various polluting substances to air. The following pollutants are included: particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), benzene and 1–3-butadiene, sulfur dioxide (SO_2), nitrogen oxides (NO_x, including nitric oxide [NO] and nitrogen dioxide [NO_2]), and ammonia (NH_3). The last three gases are also presented as an aggregated indicator of acidifying air pollutants (unit kg of SO_2 equivalents).

Heavy metals emitted into the air are also considered. The most important sources of heavy metal emissions are combustion of fossil fuels and waste. We include ten heavy metals in the analysis (see table 1).

Case Study Data

Two types of input data from the organization under investigation are required for the calculation of TBL and footprint impacts with this model: (1) financial accounts and (2) on-site fuel use, land use, and emissions data. The financial accounts of the company or organization include all expenditure and revenue data from 1 year, ideally as detailed as possible. This consists of all financial transactions required to operate the business, from purchasing of materials, goods, and services through to financing and insuring. On-site data include the consumption of fossil fuels needed for heating and driving and direct land appropriation as well as direct emissions to air and water, if applicable. This type of data should be in physical units (e.g., kilowatt-hours or liters of fuels, hectares of built land, or kilograms of emissions).

Financial Data

The business investigated in this study is a small company in the United Kingdom that produces, sells, rents out, and distributes film, DVD, and video material; employs three full-time staff; and has an annual turnover of approximately

Table 1 Absolute triple-bottom-line (TBL) impacts of Company V

Indicator	*Company V's impact*	*Unit*
Gross operating surplus	25,988	£
Total intermediate uses	268,128	£
GDP	107,755	£
Employment	2.30	emp-y
Income	67,947	£
Government revenue	13,820	£
Ecological footprint	10.6	gha
of which:		
CO_2 area	*7.03*	*gha*
Cropland	*0.45*	*gha*
Grazing land	*0.15*	*gha*
Built-up land	*1.95*	*gha*
Fishing grounds	*0.11*	*gha*
Forest	*0.90*	*gha*
Carbon footprint (CO_2)	27.24	t
Air pollutants	162	kg
of which:		
Benzene	*234*	*g*
1-3 Butadiene	*65.2*	*g*
Volatile organic compounds	*30.0*	*kg*
Particulate matter	*3.41*	*kg*
Carbon monoxide	*52.0*	*kg*
Acid rain precursors	*68.5*	*kg SO_2-e*
of which:		
Sulphur dioxide	*33.5*	*kg*
Nitrogen oxides	*38.3*	*kg*
Ammonia	*4.43*	*kg*
Heavy metals	64.5	kg
of which:		
Chromium	*3.38*	*kg*
Cadmium	*0.14*	*kg*
Mercury	*0.30*	*kg*
Nickel	*5.84*	*kg*
Vanadium	*35.0*	*kg*
Lead	*3.54*	*kg*
Arsenic	*1.21*	*kg*
Copper	*1.73*	*kg*
Selenium	*2.02*	*kg*
Zinc	*11.4*	*kg*

Note: GDP = gross domestic product; CO_2 = carbon dioxide; emp-y = employment years; gha = global hectares; kg SO_2-e = kilograms of sulfur dioxide equivalents.

£400,000.[20] For the purpose of this article, the business shall be called Company V. The sector in the UK economy to which the company belongs is recreational services (SIC code 92), and the subsector is motion picture and video distribution (SIC 92.12).[21]

Expenditure and revenue data were provided for the financial year 2002 – 2003. Account categories ("analysis codes") from the company's accounting software were mapped to the 76 standard input–output categories used in Bottomline[3], which cover the whole economy. The accounts include *all* the company's expenditure, ranging from spending on goods such as fuels, materials, equipment, and furniture to services such as rent, maintenance, and insurance as well as salaries and taxes. As the tool uses UK economic transaction data from 2000, we corrected prices for inflation using consumer price indexes by commodity group.

The TBL or footprint performance of Company V can be compared to that of the recreational services sector for which the respective data are included in the input–output model.

Fuel Consumption and Land Use Data

Fuels and resources used on the premises, at the production facility, or by vehicles directly owned and controlled by a company fall into the category of *on-site* or *direct* impacts. This is because the emissions from fossil fuel use literally occur on site and at the very moment of combustion; land appropriation also occurs on the very site the buildings or facilities are located. The GHG Protocol for corporate GHG accounting classifies this type of emissions (or generally impacts) as Scope 1 (WRI and WBCSD 2004).

The building where the company's office is located is heated with heating oil (fuel oil), for which total consumption in kilowatt-hours (kWh)[22] was available for 2002. We did not carry out any temperature (weather) correction to reflect the actual amount of fuel used and CO_2 emitted. We derived the proportion for Company V's office by using floor-space data from the building. We also used this information to calculate the share of built land appropriation. The fuel oil consumption data in kWh are direct data input into the tool, where they are subsequently converted into the direct/on-site CO_2 emissions via conversion factors from the UK Department for Environment, Food and Rural Affairs (DEFRA 2007). Mileage data from the two vehicles owned and run by the company were converted into direct CO_2 emissions.[23] This is seen as a more accurate procedure than using expenditure data on petrol. We also needed to input the monetary amounts paid for car fuel and heating oil (see above), however, to calculate the *indirect* emissions that are embodied in the extraction, refining, and distribution of the fuels.

Direct emissions of other pollutants (e.g., heavy metals) do not apply for Company V. Emissions (impacts) from electricity usage fall under GHG Protocol Scope 2. The electricity use occurs on site, but the emissions are released by the power plant somewhere else. We used annual electricity consumption data (in kWh) from actual meter readings attributed to Company V's offices and converted these to the equivalent monetary amount paid by the company, using the average market price for the financial year 2002–2003. This step is necessary as the tool treats emissions from electricity as indirect and quantifies them by using the input–output calculus.

Case Study Results

Table 1 shows the total (direct plus upstream indirect) impacts of Company V for all TBL indicators chosen. Aggregated indicators, such as the ecological footprint,[24] air pollutants, acid rain precursors, and heavy metals, are broken down further into their subcomponents.

The absolute numbers in table 1 mean little if not put in relation to the size of the company. The relative performance measured in impact per pound (£) of total output (total expenditure) is therefore listed in table 2 and depicted in figure 1 for main or aggregated indicators. Company V performs significantly less well than the sector in the carbon and ecological footprint and profits (GOS). Other indicators are close to sector average. Compared to the sector, Company V employs slightly fewer people per pound but pays slightly higher salaries.

Table 2 Relative triple-bottom-line (TBL) intensities of Company V and the whole recreational services sector in the United Kingdom

Indicator	*Company V*	*Total sector intensity*	*Unit*
Gross operating surplus	15.5	21.6	p/£
Total intermediate uses	160	132	p/£
GDP	64.4	66.6	p/£
Employment	1.72	2.18	emp-min/£
Income	40.6	34.0	p/£
Government revenue	8.26	11.0	p/£
Ecological footprint	0.460	0.280	gm^2/£
CO_2 area	*0.400*	*0.230*	gm^2/£
Cropland	*0.004*	*0.004*	gm^2/£
Grazing land	*0.012*	*0.011*	gm^2/£
Built-up land	*0.019*	*0.010*	gm^2/£
Fishing frounds	*0.016*	*0.019*	gm^2/£
Forest	*0.013*	*0.007*	gm^2/£
Carbon footprint (CO_2)	163	112	g/£
Air pollutants	*0.97*	*0.90*	*g/£*
Benzene	*1.40*	*1.14*	*mg/£*
1-3 Butadiene	*0.39*	*0.37*	*mg/£*
Volatile organic compounds	*180*	*103*	*mg/£*
Particulate matter	*20.4*	*19.1*	*mg/£*
Carbon monoxide	*311*	*292*	*mg/£*
Acid rain precursors	*409*	*497*	*mg SO_2-e/£*
Sulphur dioxide	*200*	*173*	*mg/£*
Nitrogen oxides	*229*	*219*	*mg/£*
Ammonia	*27*	*91*	*mg/£*
Heavy metals	385	451	mg/£
Chromium	*20.18*	*7.08*	*mg/£*
Cadmium	*0.86*	*0.88*	*mg/£*
Mercury	*1.81*	*1.14*	*mg/£*
Nickel	*34.9*	*45.8*	*mg/£*
Vanadium	*209*	*312*	*mg/£*
Lead	*21.1*	*16.1*	*mg/£*
Arsenic	*7.23*	*3.16*	*mg/£*
Copper	*10.3*	*10.7*	*mg/£*
Selenium	*12.1*	*6.1*	*mg/£*
Zinc	*67.9*	*48.1*	*mg/£*

Note: GDP = gross domestic product; CO_2 = carbon dioxide; emp-min = employment minutes; gm^2 = global square meters. Italics indicate sub-categories.

Figure 2 shows the intensity comparison for all disaggregated indicators. High relative impacts appear in the ecological footprint components of CO_2 area, built-up land, and forest. Indirect emission intensities of VOCs and some heavy metals (in particular, chromium and arsenic) are also much higher than the sector average, whereas ammonia emissions are much lower.

This comparison flags important impact areas that deserve further attention. A more detailed analysis (see below and in the appendix in the Supplementary Material on the Web) is required to identify the causes for these impacts and suggest possible abatement actions, however.

First, we look at the location of impacts in the upstream production chain. The relative

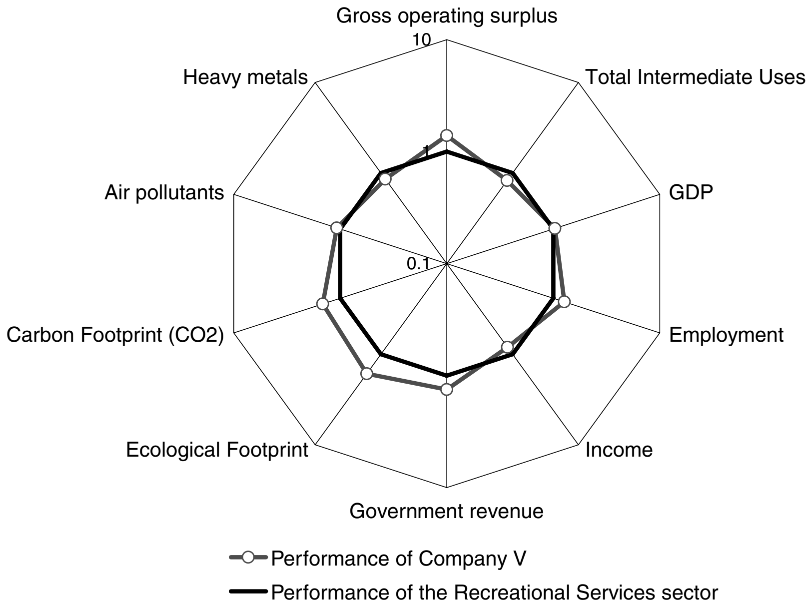

Figure 1 A spider diagram presentation of the relative performance of Company V in selected triple-bottom-line (TBL) indicators (in impact per £; logarithmic scale; sector benchmark is normalized to 1). The company's intensities are depicted by the line connecting the dots. The regular polygon in the center of the diagram (thick black line) shows the average TBL performance of the recreational services sector, which allows a benchmark comparison between the company and its sector. Company TBL values with above-average performance are closer to the center, and below-average values are positioned closer to the outside boundary (the smaller the area enclosed by the dots is, the smaller is the total footprint of the company). GDP = gross domestic product.

company performance for the total ecological footprint (0.46 $gm^2/£$) in comparison to the sector performance (0.28 global square meters per pound [$gm^2/£$]) is shown in figure 3. The column is divided into contributions from different layers of the upstream production system, which mean different layers of suppliers to Company V. The first layer is the company itself, which contributes with on-site impacts through direct use of heating oil and office space (Layer 1 is equivalent to Scope 1, as defined by the GHG Protocol; WRI and WBCSD 2004). The second layer represents contributions from all direct suppliers to Company V, the third layer represents contributions from the suppliers of the suppliers of the company, and so on (all layers higher than Layer 1 are equivalent to Scope 2 plus Scope 3 upstream, as defined by the GHG Protocol).

The breakdown shows that less than one third (29%) of the total ecological footprint can be attributed to direct or on-site impacts of Company V (see figure 3, first-order section, light gray area). The rest (second and higher orders) are all indirect impacts from other sectors in the economy. About two thirds (63%) of these indirect impacts can be attributed to direct suppliers of Company V, as they are located in the second layer of the upstream production process.

But who are the suppliers of Company V, and where exactly do these indirect impacts come from? Figure 4 qualifies this result in that it shows not only how much is added to the indirect ecological footprint in each production layer (or supply chain link) but also to which broad sectors of the economy this ecological footprint can be attributed. To capture more than 90% of the total ecological footprint of Company V, we have to take into account at least four production layers. This is difficult to achieve

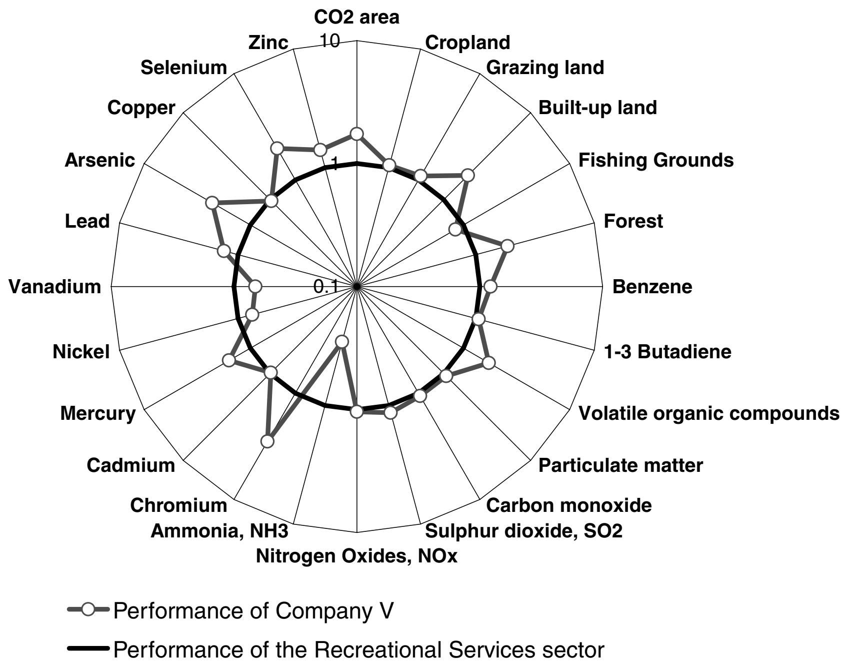

Figure 2 Relative performance (intensities) of Company V in disaggregated impact categories (in impact per £; logarithmic scale; sector benchmark is normalized to 1). CO_2 = carbon dioxide.

with process-based information alone, as used in traditional, process-based LCA. Unless four or more production stages of *each* major supply chain line are taken into account, it is possible that significant amounts of the total impact are not captured.

The consumption of electricity by Company V is the area that contributes most to the indirect footprint. Other major contributions come from equipment, chemicals, wood and paper, and forestry. Note that the footprint contribution from forestry does not come from a commodity bought directly by (supplied directly to) Company V. The impact only starts in Layer 3 (supplier of supplier), and table 3 reveals that the footprint impact comes from wood products purchased by Company V.

Table 3 shows the results of an SPA of the total ecological footprint, providing a further refinement of the location of total ecological footprint contributions from individual commodity supply chains (this analysis can also be done for each indicator separately; see the appendix in the Supplementary Material on the Web). Detailed results derived from the application of SPA include

- a description of the path, identifying the sectors involved;
- the path value (i.e., the absolute impact of each supply chain path);
- the path order (i.e., from which upstream supply layer the path originates, indicating the length of the path and the distance from the company);
- the path coverage (i.e., the relative contribution—in percentage—to the total TBL impact or footprint of the company).

Overall, 28.9% of the total ecological footprint of Company V is direct or on-site; significant indirect contributions come from the consumption of electricity (10.2%), furniture (4.6%), forest resources used for wood products (4.5%), paper (3.9%), and inorganic chemicals bought by the company (3.4%). Further examples of higher upstream (third order) contributions include electricity used to produce electrical

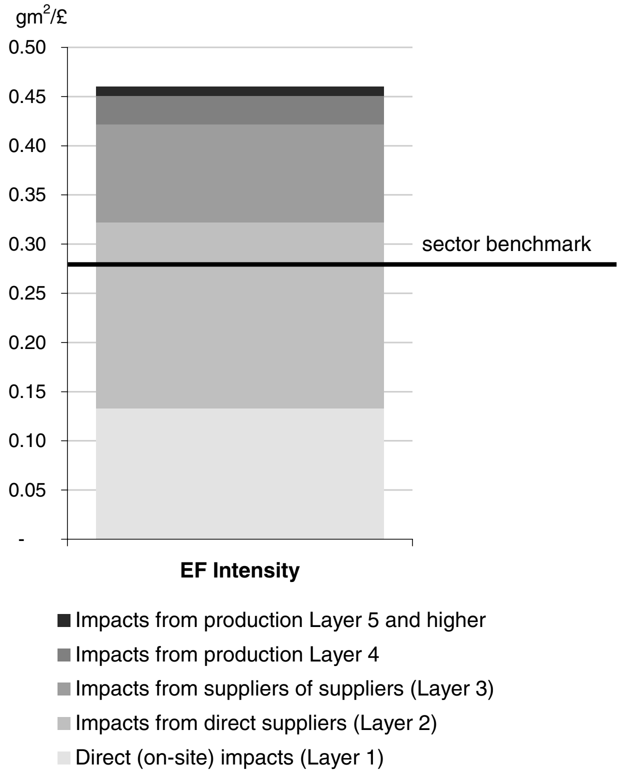

Figure 3 Comparison of total ecological footprint (EF) intensity of Company V (Layer 1) and its sector of recreational services (benchmark line) in global square meters per pound (£). Most indirect impacts come from suppliers (Layer 2) and suppliers of suppliers (Layer 3) of Company V.

machinery used by the company (2.2%), agricultural impacts from the production of food for the company (1.8%), and paper production for the company's publications (1.2%).

Note that around one quarter of the total ecological footprint is embodied in a large number of further paths—ranked higher than 20 and therefore not listed in table 3—each contributing less than 0.75% to the total. Those paths represent more intricate and distant supply chains, and although their individual contributions are tiny, they add up to a significant proportion of the total. This reflects the complexity of modern economies and the sheer challenge if this information were to be pieced together with bottom-up data and methods.

More information can be obtained if SPA is applied to disaggregated TBL indicators, such as the individual land types of the ecological footprint or individual air pollutants. In the appendix (in the Supplementary Material on the Web) we present, as an example, SPA results for the carbon footprint, forest and built-up land footprint, VOCs, chromium, and arsenic. These are the indicators that were identified with high relative intensity in figures 1 and 2.

This detailed supply chain impact analysis points to the following products and services as contributing most to the total impact (see Supplementary Tables S1–S6 in the Supplementary Material on the Web):

- wood products (forest footprint, chromium, arsenic);
- furniture (carbon footprint, VOC, arsenic);
- printing, publishing, and paper (forest footprint, VOC);
- inorganic chemicals (chromium);
- glass products (chromium, arsenic);
- electricity (carbon footprint, arsenic);
- gas distribution (VOC);
- legal, consultancy, and other business services (built-up land footprint); and, finally,
- the company itself, through on-site impacts (built-up land footprint, carbon footprint).

Energy consumption, because of high absolute and relative values for the carbon footprint, is a

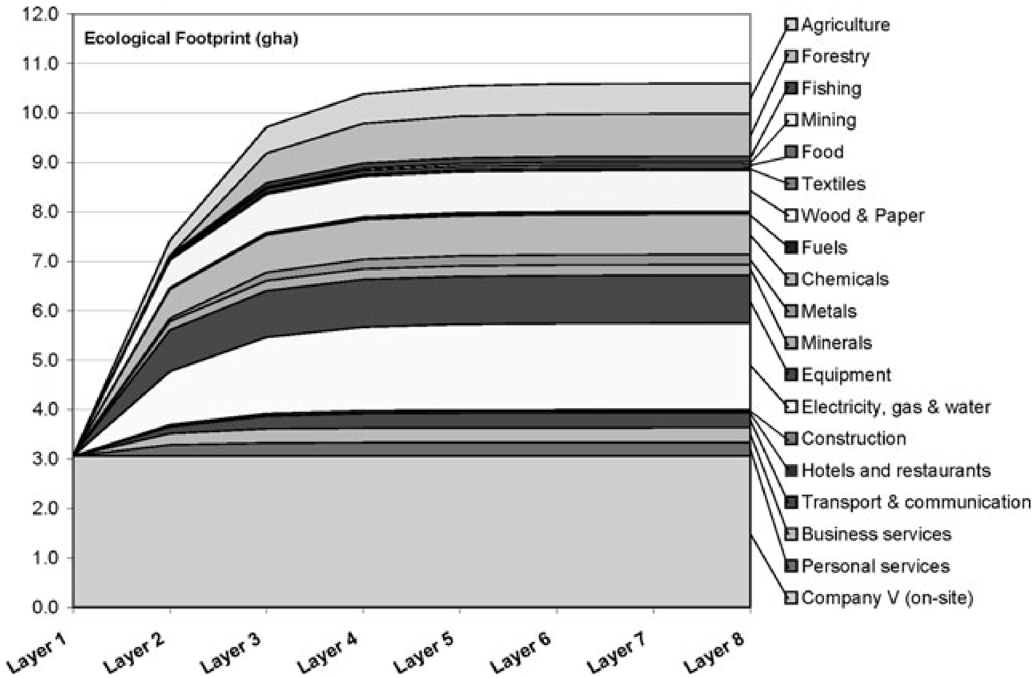

Figure 4 Production layer decomposition of the total ecological footprint (10.6 gha) of Company V. The company's direct footprint of 3.06 gha is in Layer 1 (direct or on-site impact—this translates through to the right-hand side of the diagram, where the total ecological footprint is added up). Suppliers of Company V (Layer 2), suppliers of suppliers (Layer 3), and so on all contribute to the indirect ecological footprint, with electricity production being the largest contributor. Note that forestry only starts adding impact from Layer 3 onward.

major impact area of the company and one where there is room for improvements. Consumption of fossil fuels and electricity leads to direct and indirect emissions of CO_2. Furthermore, the SPA of the forest footprint identifies the main products associated with the appropriation of forest resources. Company V refurbished its offices in 2002, using wooden doors, floors, and furniture. This explains why wood products contribute over 50% to that year's forest footprint and to indirect chromium and arsenic emissions. Other contributions come from the use of paper for printing and publishing, and even the use of some services has significant indirect impacts with some indicators.

Discussion

Assessing the sustainability performance of a company is a multifaceted and challenging endeavor. By using an input–output-based LCA model and indicators spanning the entire TBL, we provide a cross-cutting snapshot of impact hot spots and an estimation of how Company V performs compared to others. Because it uses analytical techniques such as SPA, the top-down model provides enough detail to establish

- which of the operating inputs embody the largest impacts,
- whether these impacts occur at direct suppliers or at more remote supply chain locations,
- and which single supply chain paths carry the largest impacts.

Users perceive especially the latter information as very helpful, because it can be used for organizational planning and priority setting for informed action toward financial, social, and environmental sustainability. In particular, it points to alternatives for effective procurement

Table 3 Results of a structural path analysis of Company V's total ecological footprint

Rank	*Path description*	*Path value (gha)*	*Path order*	*Percentage of total impact*
1	Company V	3.06	1	28.9
2	Electricity production > Company V	1.08	2	10.2
3	Furniture and miscellaneous manufacturing > Company V	0.490	2	4.62
4	Forestry > Wood and wood products > Company V	0.473	3	4.46
5	Paper > Company V	0.412	2	3.89
6	Inorganic chemicals > Printing and publishing > Company V	0.358	3	3.38
7	Agriculture > Company V	0.322	2	3.04
8	Electricity production and distribution > Electrical machinery > Company V	0.231	3	2.18
9	Legal, consultancy, and other business services > Company V	0.210	2	1.98
10	Agriculture > Food and drink > Company V	0.192	3	1.81
11	Electrical machinery and equipment > Company V	0.138	2	1.30
12	Paper > Printing and publishing > Company V	0.130	3	1.23
13	Inorganic chemicals > Company V	0.123	2	1.16
14	Water supply > Company V	0.118	2	1.11
15	Wood and wood products > Company V	0.110	2	1.04
16	Membership organizations > Company V	0.104	2	0.98
17	Cement, lime, and plaster > Company V	0.094	2	0.89
18	Forestry > Printing and publishing > Company V	0.091	3	0.86
19	Office machinery and computers > Company V	0.087	2	0.82
20	Fishing > Food and drink > Company V	0.080	3	0.75
20	All other paths	2.70		25.4
	Total ecological footprint	**10.6**		**100**

Note: The total ecological footprint embodied in the supplies from upstream producers is broken down into contributions from commodities traded through supplying sectors. The list shows path values and orders (i.e., how large and how far away the impacts are). The total ecological footprint of Company V is 10.6 gha.

policies, which may be applied instead of potentially expensive on-site measures.

As the underlying calculation method is based on a top-down environmental—economic model, the presented analysis has some clear limitations one needs to take into account when interpreting the results.

First, all model data refer to economic sectors (76 in the model used here) and not to specific products or processes. This is enough granularity to distinguish two companies, for instance, that have the same total turnover but buy goods or services from different categories. The model cannot distinguish, however, whether the company bought recycled or virgin paper, certified wood products, heavy-metal-free chemicals, and the like. The main purpose of a top-down analysis such as this is therefore to obtain a broad picture of impacts across many indicators and a "hot-spot" analysis of the nature and location of impacts across supply chains. This screening process can be done with relatively little time and resources. It provides a benchmark indication and a "priority list" for action, targeting the major impacts areas. It cannot be as precise and specific as a bottom-up process analysis, but it can point out where such a more detailed analysis should be carried out in the most resource efficient way. As mentioned in the introduction, a hybrid LCA is the state of the art in this area, and we refer to the literature for further discussions about this subject (e.g., Suh and Nakamura 2007).

The national accounts and other data used in the model lag a few years behind the current year. This is, in particular, the case for input—output data, which need sophisticated methods to be compiled (for the situation in the United Kingdom, see e.g., the work by Wiedmann et al.

[2008a] and Beadle [2007]). In the case of Company V, however, there is only a 1-year gap between the financial accounts and the model data.

It would be most useful, in any case, if such an annual analysis could be repeated every year to capture unavoidable spikes and dips in a company's performance. It is certainly the case that companies invest more in some years than in others, and the model captures this investment as an impact in the year the payment is made. Again, there might be a time gap between, say, the environmental impact of the production of an expensive piece of equipment that has occurred in the past and the depreciative payment for this equipment, which might go on for several years. The reporting mechanism then needs to make sure that the impact is reported in full, either in the 1st year or over the full depreciation period.

Relying on one indicator alone is never sufficient to derive a definitive judgment about a company's sustainability performance—even and in particular if it is an aggregated indicator, such as the ecological footprint. Therefore, we advocate reporting a wide spread of TBL indicators to allow a differentiated assessment. The indicators we have presented in this work are roughly in line with the impact categories used in LCA—climate change, human health, acidification, eutrophication, photochemical ozone creation, and so forth. We refrain from weighting and aggregating single indicators but choose to present all results individually, as done in this article.

A useful outcome of the analysis presented is the distinction between direct and indirect impacts. This is because direct (on-site) emissions and impacts still receive most of the attention, not least because this is where a company has most control and influence over change (e.g., which fuel or system is used for heating). Nevertheless, companies also have some influence over their suppliers and therefore their indirect emissions or TBL impacts. One example is Wal-Mart, which has asked its about 70,000 suppliers to disclose their GHG emissions.[25]

The aspect one must bear in mind when considering direct versus indirect impacts is the one of double-counting. Scope 1 (direct) emissions of a power plant are Scope 2 emissions (from electricity use) of another company, and Scope 1 emissions of any company can be Scope 3 (indirect) emissions of others. If counting is unchecked, the unavoidable consequence of this "mutual footprinting" is double-counting of impacts. This is why we apply the concept of shared responsibility, as introduced above, and split all impacts into 50%/50% portions.

Conclusions

Numerate TBL accounting at the company level highlights a number of key issues that are important to the sustainable development agenda. Especially if all upstream impacts stemming from a web of supply chains are taken into account, new insights and useful information for the concept of industrial ecology in general and corporate decision-making in particular can be gained. With the approach described in this work, we are able to allocate TBL, carbon footprint, and ecological footprint loadings of products and services used by a company as well as the impacts' location in their respective upstream supply chains.

The results of such a detailed analysis provide valuable insights into the causes for and the location of impacts. On the basis of the findings, the company in this example is now looking into the possibility of reducing its high consumption of electricity and fossil fuels. Some energy-saving measures have already been put in place. The business will also look into its use of paper and its printing processes (and associated use of chemicals). Impacts associated with furniture and wood products can be attributed to purchasing and refurbishing in this particular year and are not likely to occur on an annual basis. If new purchases are due, however, the company will inquire with the suppliers about the environmental impacts of their products.

Thus, the analytical approach presented in this article has proven methodologically robust as well as useful in practical terms. Its strength lies in the simplicity of operation, on the one hand, and its comprehensiveness, on the other hand. At the moment, the input–output model used is based on a single region (the United Kingdom), with the assumption that imports have been generated with domestic production technology. One possibility to overcome this limitation is the implementation of an MRIO model, as described by Turner and colleagues (2007) and Wiedmann and colleagues (2007e, 2008a).

International corporate reporting approaches, such as the GRI or the GHG Protocol are increasingly oriented toward inclusion of indirect (upstream and downstream) impacts. This will require the ongoing development of data sets, indicators, models, and tools that match the requirements of these initiatives and enable economy-wide accounting without boundaries. The approach and tool presented in this study contribute to this goal.

Whatever method is used to calculate the TBL impacts of an organization, it is important to avoid double-counting along supply chains or life cycles. This is not least because there are significant implications for the practices of carbon trading and carbon offsetting (see also Lenzen 2008a).

Acknowledgements

A previous version of this article was presented at the International Ecological Footprint Conference in Cardiff, United Kingdom, 8–10 May 2007 (Wiedmann et al. 2007a).

Notes

1. The term *triple bottom line* was introduced by John Elkington (1997) in his book *Cannibals With Forks: The Triple Bottom Line of 21st Century Business*.
2. www.globalreporting.org
3. The European Union (EU) Accounts Modernisation Directive (AMD), for example, introduces requirements for (large) companies to include a balanced and comprehensive analysis of the development and performance of the business in their director's report. The analysis should "include both financial and, where appropriate, non-financial key performance indicators relevant to the particular business, including information relating to environmental and employee matters." (EU study 2001/45 3/EC) This part of the EU AMD is effective for financial years beginning on or after 1 April 2005.
4. For a definition of the term *carbon footprint*, see the work by Wiedmann and Minx (2008).
5. See, for example, the publications by Carbon Trust (2006, 2007), www.london-business-conferences.co.uk/carbon.management.asp, or www.iqpc.co.uk/ShowEvent.aspx?id=133900.
6. See also www.water-footprint.com.
7. See also the Publicly Available Specification (PAS) 2050 for assessing the life cycle GHG emissions of goods and services developed by the British Standards Institute and the Carbon Trust (www.bsi-global.com/en/Standards-and-Publications/Industry-Sectors/Energy/PAS-2050).
8. www.footprintstandards.org
9. Editor's note: For a discussion of a framework standardizing corporate carbon performance analysis, see the article in this journal by Hoffmann and Busch (2008).
10. www.waterfootprint.org
11. www.isa.org.usyd.edu.au/publications/balance.shtml
12. Global hectare (gha) is used as the unit of the ecological footprint and is defined as "a productivity weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the Ecological Footprint). The global hectare is normalized to the area-weighted average productivity of biologically productive land and water in a given year" (GFN 2008a).
13. See www.isa.org.usyd.edu.au and www.censa.org.uk.
14. See www.bottomline3.com. The name of the tool is pronounced "Bottomline cubed."
15. One prominent tool is the EIO–LCA model developed by the Green Design Institute of Carnegie Mellon University in the United States (Hendrickson et al. 1998). The online model estimates the materials and energy resources required for, and the environmental emissions resulting from, economic activities. Users can build customized products or create hybrid sectors using another sector as a baseline and modifying its default values. Other LCA tools are based on process analysis and use bottom-up data, although there is a clear tendency toward hybridization—that is, the inclusion of more and more secondary data derived by input–output analysis, driven by the need to fill data gaps and to extend system boundaries as described above. See, for example, the LCA software tools SimaPro (www.pre.nl/simapro/default.htm) and GaBi (www.gabi-software.com).
16. See www.bottomline3.co.uk.
17. See table KS011a, "All people aged 16–74 in employment" (www.census.ac.uk, http://census.ac.uk/casweb, census.ac.uk/cdu/2001).
18. More information on these indicators and on data sources can be found at www.bottomline3.co.uk.

19. We follow the convention used in the 2008 edition of the National Footprint Accounts provided by Global Footprint Network not to include the "nuclear energy footprint" any longer. We also use the latest terms for land types. The demand on biocapacity required to sequester (through photosynthesis) the CO_2 emissions from fossil fuel combustion is referred to as CO_2 *area* (see GFN 2008b) and not as *carbon footprint*. We see the latter term as an indicator on its own, not as a part of the ecological footprint, and measure it in mass units, not in area units (Wiedmann and Minx 2008, 5).
20. 1 British pound sterling (£) = 1.967 US Dollars ($) = 1.326 Euros (€) on the date of calculation (15 January 2008).
21. Standard Industrial Classification 2003.
22. One kilowatt-hour (kWh) $\approx 3.6 \times 10^6$ joules (J, SI) $\approx 3.412 \times 10^3$ British Thermal Units (BTU).
23. We did this by using gCO_2/km data from www.vcacarfueldata.org.uk.
24. Our analysis for the ecological footprint is in line with standards published in 2006 (GFN 2006; note, however, that the 2006 edition of these standards does not explicitly deal with the calculation of ecological footprints of companies).
25. See www.cdproject.net/wal-mart-case-study.asp and www.cdproject.net/corporate-supply-chain.asp.

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Supplementary Material

Additional Supplementary Material in the form of an appendix may be found in the online version of this article. This appendix contains tables that provide detail on the analysis of the example provided in the main text of the article:

Table S1. Structural path analysis of Company V's total (direct plus upstream indirect) forest footprint.

Table S2. Structural path analysis of Company V's total (direct plus upstream indirect) built-up land footprint.

Table S3. Structural path analysis of Company V's total (direct plus upstream indirect) carbon footprint (carbon dioxide [CO_2]).

Table S4. Structural path analysis of Company V's total (direct plus upstream indirect) emissions of volatile organic compounds (VOCs).

Table S5. Structural path analysis of Company V's total (direct plus upstream indirect) emissions of chromium.

Table S6. Structural path analysis of Company V's total (direct plus upstream indirect) emissions of arsenic.

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