LIFE CYCLE ASSESSMENT: AN ARGUMENT FOR A DETAILED APPROACH

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Introduction

The most important step in Life Cycle Assessment is the inventory on which the assessment is based. These data are the source of all subsequent analysis. Information relating to local effects has been known in detail for many years, since effects can be linked directly to particular emissions and such links are well understood. However, the same cannot be said when assessing the contributions made to regional effects such as airborne acidification. Life Cycle Inventories are global in extent, even for such simple components like an aluminium beverage can. Besides fossil fuels, which are traded internationally, materials processing operations are also global. For example bauxite ore can be mined in Australia, the ore beneficiated and cans constructed and filled in Europe, before being used and disposed of in North America. It is because inventories are global in extent that careful consideration must be applied when trying to use the inventory data to address regional effects.

The problem

In the example of the aluminium beverage can mentioned in the introduction, it is clear that any air emissions directly associated with mining the ore in Australia will have no effect on airborne acidification in Scandinavian countries. It may also be argued that those operations occurring in southern Europe will also have little effect in Scandinavia. The simple aggregated data from a typical LCA are therefore inadequate to deal with Scandinavian acidification. The same logic can be applied to other regional effects such as photochemical ozone creation potentials (POCPs), where in addition to the regional emissions data, knowledge of the prevailing NO_X concentrations is also required as part of the examination [1, 2]. Figure 1 shows a range of environmental effects that an inventory is often applied to, in many cases inappropriately. Note that this statement does not imply that such effects are unimportant or not worthy of study, merely that insufficient thought has been given as to whether the inventory data are appropriate in their simple aggregated form. Unless such data are being used in a discussion of a truly global effect such as global warming due to greenhouse gas emissions or depletion of the ozone layer, a more detailed breakdown of the inventory data is required. This poster suggests that it is only by conducting such an analysis of the full inventory data that national and regional environmental concerns may more accurately be addressed. A solution to this problem should, as far as possible, use the inherent detail contained within the existing inventory data to extract this regional information: any data thus extracted, and indeed the methodology behind it, should be as transparent as possible.

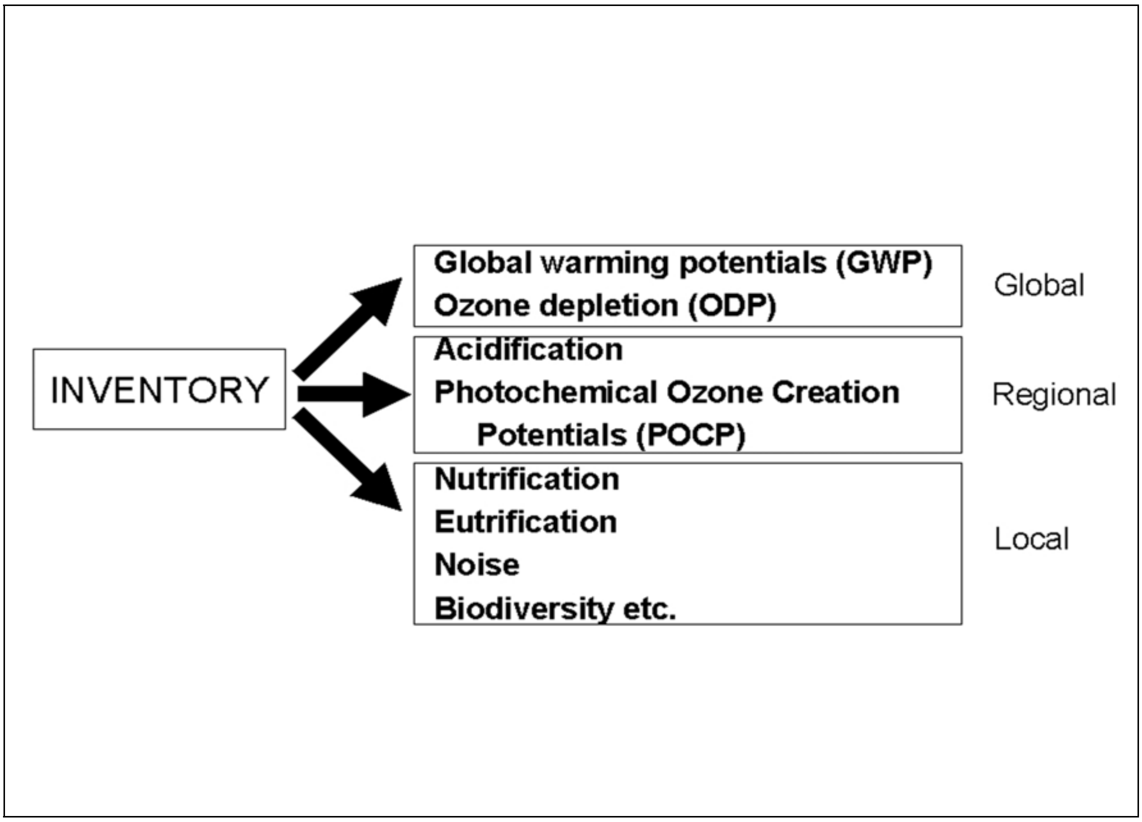


Figure 1. Some of the environmental effects that inventory data are often applied to.

A solution

The key in addressing this problem is to provide a mechanism that LCA practitioners can readily use for extracting this information from the inventory on a similar regional or global basis, depending on the environmental effect concerned. It must be stressed that the determination of regional emissions data from a carefully prepared, and above all thorough, inventory is a purely objective process: it is not open to interpretation. A major benefit of a full and detailed inventory is the ability to extract information on a regional as well as a global basis. The reason for this is quite simple. Plant operational data gathered for any inventory study automatically provide information about the local emissions of solid, liquid and gaseous wastes. To make the best use of this inherent regional information contained in the gathered data, it follows that the database and associated modelling tool used to calculate the inventory must also be able to handle this regional information.

The direct implication of this is that all materials processing operations, fuel production operations etc. that are described in the database that is used to calculate the inventory, must be provided on a regional or even on a national basis. Satisfying this condition gives the following benefit: differences between individual national or regional power generation mixes, including energy imports or exports between countries and the effects that these can have on the inventory, can be fully accounted for. As an example, suppose that in a given year the United Kingdom buys 5% of its total electricity supply from France and that in the same year France did not import any electricity from any other country. This means that for every 1 MJ of electricity taken from the wall socket in London, 0.05 MJ will actually have been taken from the French national power generation grid. This 0.05 MJ of French electricity will have associated with it various emissions that are produced (i.e. emitted) in France. The nature of these emissions will be dependent upon the mix of generation technologies used within France for the year in question. Consequently for every 1 MJ of electricity used in London, it is possible to determine those emissions produced in the UK and those produced in France.

Clearly, the reality is considerably more complicated than this simple example suggests! Figure 2 shows the imports/exports of grid electricity across part of Europe in 1999 [3]. An important feature to note in this examination of energy flows is that actual flows and their respective underlying infrastructures are accurately accounted for. If the net flows between countries were used instead, this would not reflect the true nature of things.

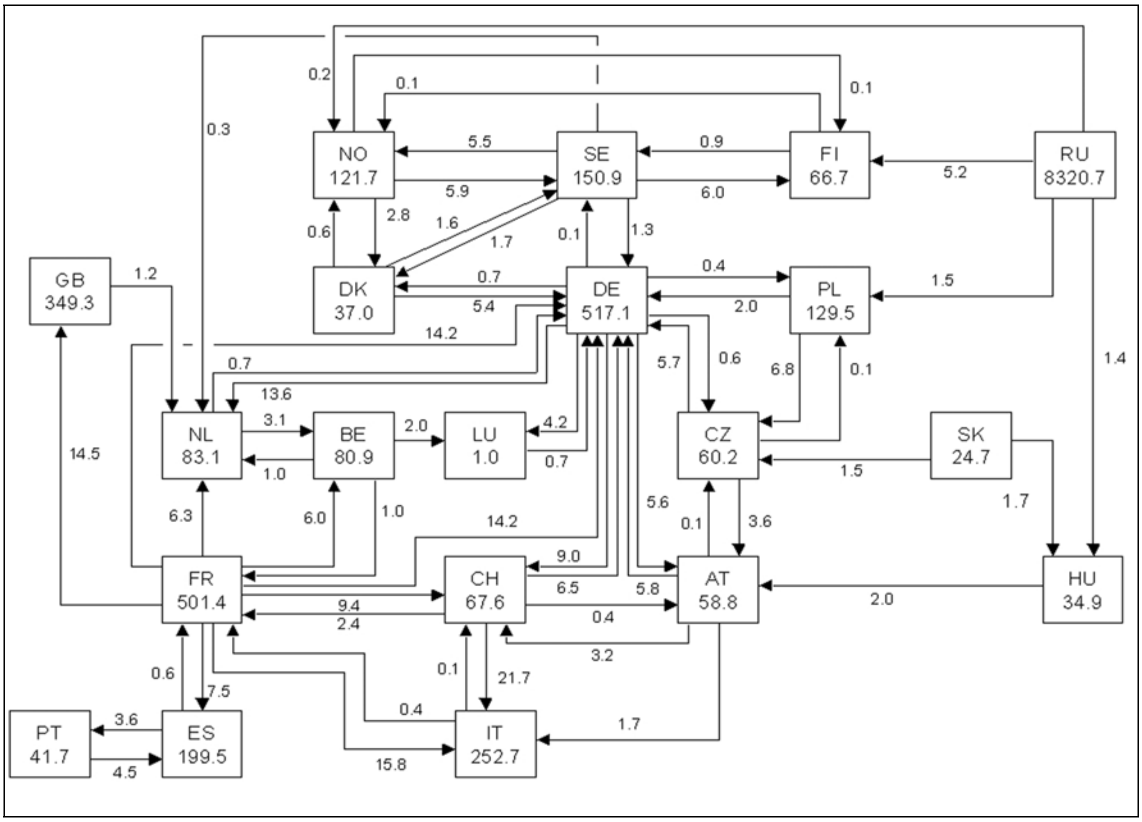


Figure 2. Part of the European public electricity infrastructure. All data are in TWh. The values inside the boxes show generation within the country. The flows show the imports and exports. Data refer to 1999.

This inter-linkage of the various national public electricity supplies, coupled with the regional information obtained when collecting the plant operating data that are also contained in the database, provides a method by which we can set up a computer modelling tool. Once established, it is a relatively straightforward process to determine which emissions occur in which countries both for any combination of operations and also for any number of countries. This technique was originally applied to the analysis of acidification due to airborne emissions and has been discussed in more detail elsewhere [4]. The method has since been extended so that air emissions, water emissions and solid waste data can now all be aggregated using the same modelling tool. Once the data have been suitably extracted using this technique, they can then be used to address more meaningfully regional environmental concerns.

A worked example of regional data extraction

The following example shows how data can be extracted from a notional data set. The unit operation described, production of a steel body pressing, has only two inputs: 15 kg of cold rolled steel, which has been produced in the United Kingdom (UK), and 3 MJ of UK public supply electricity. Table 1 shows gross (i.e. cradle-to-gate) air emissions for several commonly reported parameters.

Table 1

Gross air emissions associated with the production of a notional pressed steel body panel in the UK. Any values quoted are for illustrative purposes only. Totals may not agree due to rounding.

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
dust (PM_{10})	9844	3212	85	12503	0	0	25644
CO	8815	3893	942	322878	0	0	336528
CO_2	5063498	18361282	137093	8877057	-12	0	32438918
SO_X as SO_2	19834	50782	1022	33	0	0	71672
H_2S	0	0	0	500	0	0	500
NO_X as NO_2	10433	18881	1283	1459	0	0	32055
HCl	546	912	0	389	0	0	1847
F_2	0	0	0	1	0	0	1
HF	20	34	0	0	0	0	55
hydrocarbons not specified elsewhere	10494	2886	359	1270	0	0	15009
Pb+compounds as Pb	0	0	0	5	0	0	5
metals not specified elsewhere	1	15	0	0	0	0	16
H_2	36	0	0	4	0	0	40
CH_4	28957	1950	0	2	0	0	30909

Whilst the data presented in Table 1 are ideal for any subsequent discussion of global effects such as global warming potentials or ozone depletion potentials, they are not suitable for a similar exercise on regional effects without further treatment. The Boustead Model contains a suitable modelling tool to extract this regional information from the gross data set.

Figure 3 shows a screen image of the environmental effects modelling tool. The right-hand side of the figure shows where the user can select from one or more countries and regions over which to aggregate the data. Other parts of the screen are concerned with selection of both the unit operation under consideration and the environmental effect to be addressed.

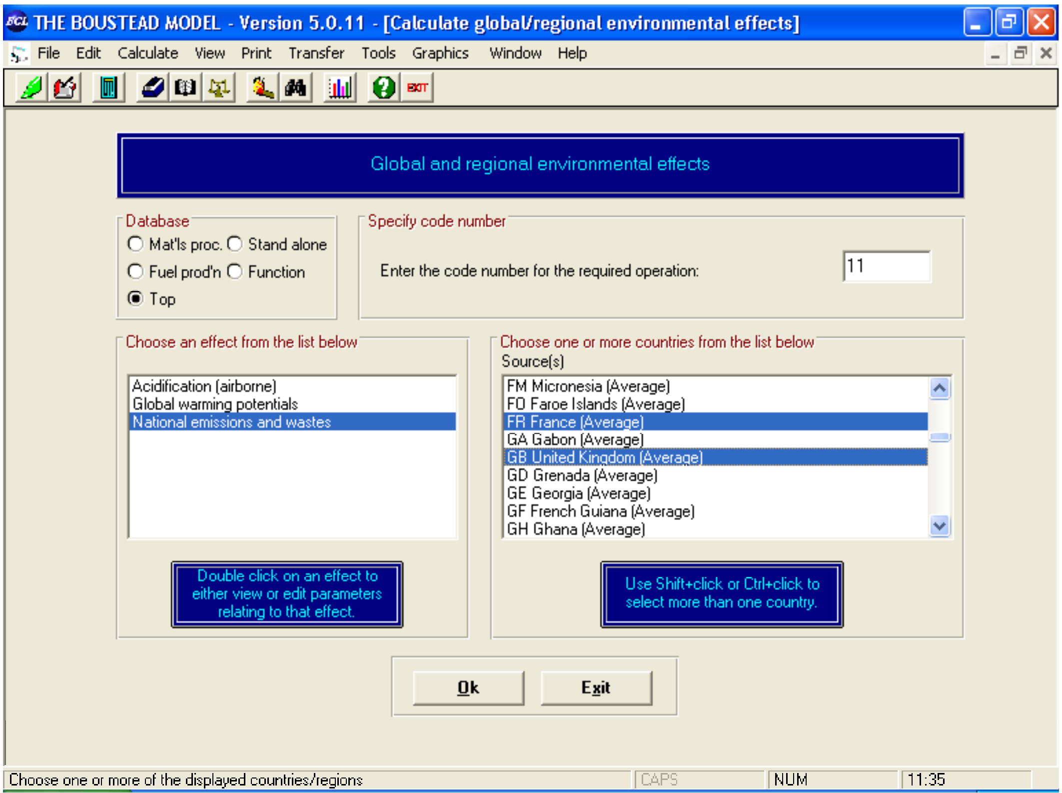


Figure 3. Screen display of the Boustead Model environmental effects module. For regional effects, the user can select one or more countries/regions from the list shown centre-right of the diagram, over which to aggregate data.

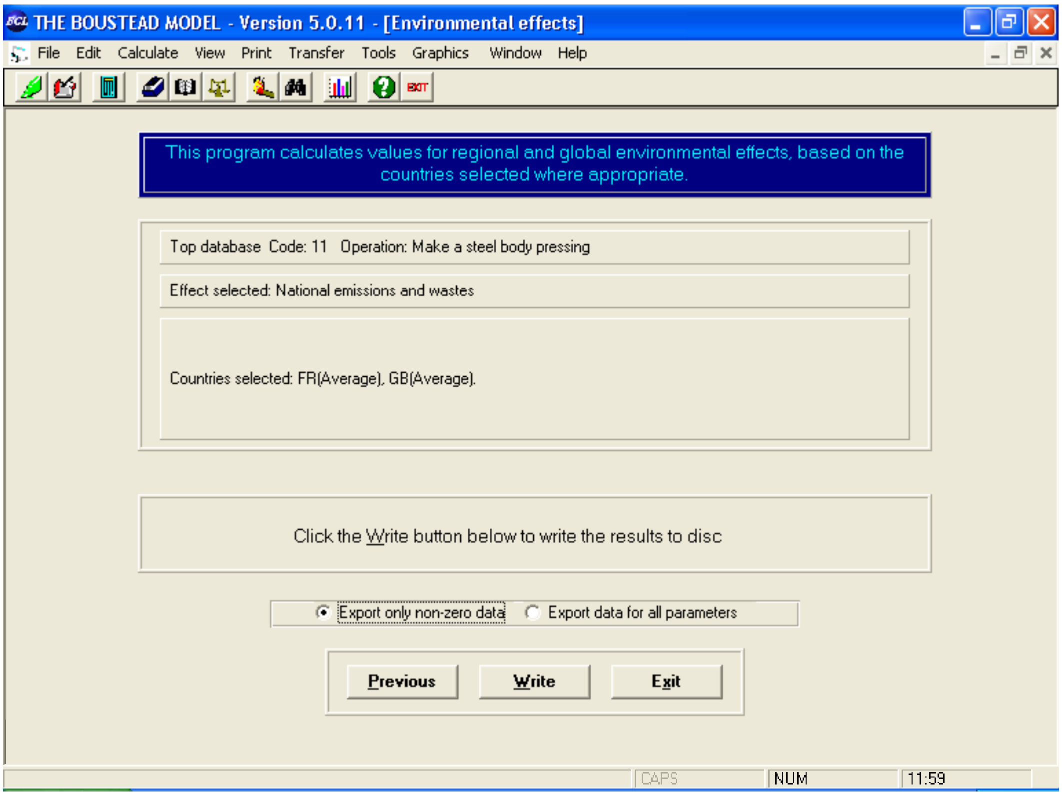
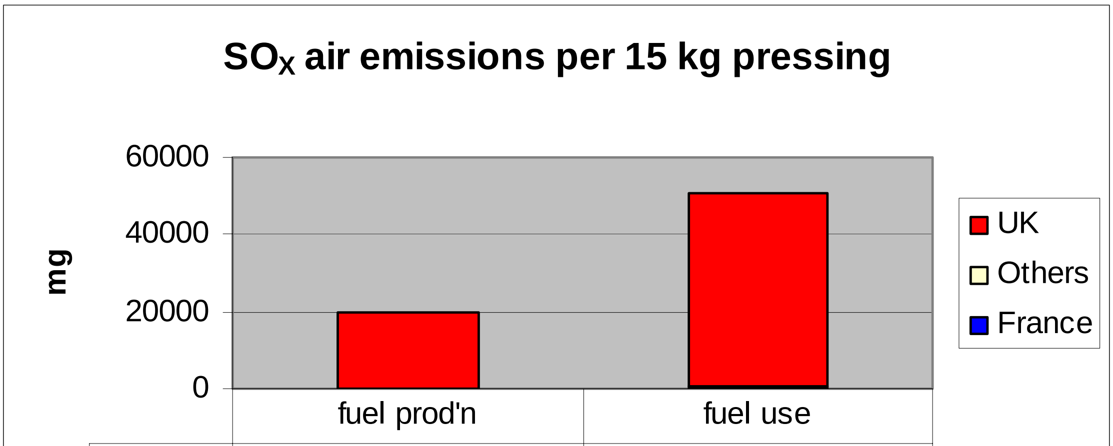


Figure 4. Screen display of the Boustead Model environmental effects module once the calculations are complete. Data are written to file for easier subsequent processing or analysis.

Clicking the OK button at the bottom of the screen in Figure 3 aggregates the data only for those unit operations that are located in the chosen areas, producing the screen display shown in Figure 4 once data have been collected from all contributing operations. The user can go back and forth between these two screens at will to amend the countries chosen and hence determine the corresponding aggregated data sets, prior to writing this data to file for subsequent manipulation or analysis.

Figure 5 shows a graph of the SO_X fuel production and fuel use air emissions data presented in Table 1, with the relative contributions made by emissions made in France and the United Kingdom indicated.



	fuel prod'n	fuel use
UK	19586	50146
Others	186	477
France	62	159

Figure 5. Chart showing the contributions made to SO_X fuel production and SO_X fuel use air emissions released in France, the United Kingdom and other countries for the example unit operation. See text for more details.

In this example of a 15 kg steel sheet pressing, it is clear that the vast majority of SO_X air emissions (over 98.7% for both fuel production and fuel use) are released in the United Kingdom, which is unsurprising given that both the steel and the public supply electricity used have been produced in that country. The emissions released in France are predominantly due to the import of French public supply electricity to the UK power grid. Emissions from other countries arise from both imports/exports of electricity and from operations that take place within those countries, e.g. aluminium ingot production, which is used to limit the reaction in the basic oxygen furnace. Whilst the figures given in Table 1 and Figure 5 are notional and based on a hypothetical case, this simple example does however illustrate the immense flexibility of this approach. Data can be aggregated for any combination of regions and/or countries, depending upon the regional effect under consideration. In a discussion of Scandinavian airborne acidification, for example, only those countries that directly contribute can be isolated and their contribution to the inventory determined.

It cannot be over-emphasised that this technique has in no way used any assumptions, formulae, or any other method to extract the data at a regional or national level from the original inventory. It is the detail itself held within the carefully constructed inventory that has allowed this regional data to be gathered both easily and impartially.

Conclusion

This poster proposes a method whereby inventory data can be broken down into a format more suited to the analysis of non-global environmental effects. In providing aggregated emissions data on a national or a regional basis, the purely objective nature of the inventory has been preserved. Such an analysis is only made possible because the detailed inventory data on which it is based already exist. This is a clear argument for providing as detailed an inventory as possible rather than opting for so-called ‘streamlined’ inventories, as with the latter the scope for further data analysis is greatly restricted.

[1] Y. Andersson-Sköld, P. Grennfelt, K. Pleijel, ‘Photochemical ozone creation potentials: a study of different concepts’, J. Air Waste Manage. Assoc. 42(9), 1992, pp. 1152-1158
[2] R. G. Derwent, M. E. Jenkin, ‘Hydrocarbon involvement in photochemical ozone creation formation in Europe’, AERE R 13736, AEA Environment & Energy, 1990
[3] I. Boustead, ‘Eco-profiles of the European Plastics Industry: Methodology’, PlasticsEurope, 2005, p. 15
[4] W. T. Dove, I. Boustead, ‘ATTCE 2001 Proceedings Volume 8’, SAE, 2001, pp. 1-4

An extended abstract of this material can be found in Volume 2, pp 481-4 of the LCM 2005 conference proceedings.