16th Discussion Forum on Life Cycle Assessment: Input-output Life Cycle Assessment

Plenary Session: Abstracts

DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.040.pdf

From Input-Output Tables to Modelling Environmental Issues

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The aim of this presentation is to give a brief overview of the development which occurred in taking into consideration of environmental issues in the framework of Input-Output analysis during the last thirty years of the twentieth century. The first attempt was made by Leontief himself in 1972 in a paper related to air pollution. This opened the way to a multitude of both theoretical and applied works. We will first consider the efforts made in order to describe the interaction between environment and economy in a pure Input-Output accounting framework and as an extension of National Accounts. Then we will show how these accounting frameworks allow us to evaluate the energy content of the final demand or the emission of pollutants and to study the evolution of these phenomena over time through structural decomposition techniques. We will finally focus our attention on modelling using the applied general equilibrium approach, concentrating on the way environmental issues can be introduced in these models.

An Introduction to Input-Output LCA Theory and Methodology, its Strengths and Weaknesses and a Comparison between Input-Output LCA and Process LCA

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.033.1.pdf

This presentation will attempt to clarify the essential equivalencies and differences between Process Life Cycle Inventory analysis (PLCI) and Input-Output Life Cycle Inventory analysis (IO-LCI). The assumption is made that forum participants have a working familiarity with PLCI (although such familiarity is not required), and enough of an introductory familiarity with IO-LCI to be interested in it. The assumption is also made, based on 5 years of discussion with LCA practitioners and users, that there are important opportunities to clear up some misconceptions about how PLCA and IO-LCA differ. The presentation will address the following questions:

- How do the assumptions, methods, and data sources of PLCA and IO-LCA differ?
- How does IO-LCA work?
- How do the results and conclusions from PLCA and IO-LCA tend to differ?

The presentation will review the essential nature of PLCA in the context of matrix methods, and then introduce IO-LCA from this same perspective, highlighting the differences and equivalencies in data sources and usage. It will review the relative strengths and weaknesses of these two complimentary (and ultimately combinable) approaches to Life Cycle Inventory analysis.

A Hybrid Approach for the Life Cycle Inventory Assessment

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.034.1.pdf

Streamlining life cycle inventory analysis (LCI) is an indisponsable condition to make LCA cost effective and therefore applicable to a wide spectrum of users. On the other hand, a satisfactory degree of accuracy has to be achieved when performing the LCI. The paper will present an approach which completes the generally used Process Chain Analysis by a model based on Input-Output-Tables and data on sector specific elementary flows. The model based on Input-Output-Tables serves as a background inventory data (BID) system which is used to estimate consistentely the environmental interventions caused by the supply of products and services not included in the process chain, but necessary for the product system in question. The presented approach is characterized by the following items:

- A monetary balance is performed for each process of the process chain in order to estimate the amount of 'missing commodity inputs.'
- There are fixed rules on how the amount of 'missing commodity inputs' of each process is estimated and how it is assigned to the sectors of the Input-Output-Tables depending on the kind of product which is supplied by the process in question. This allows an automatic and therefore effective use of the Input-Output-Tables as a BID system.
- The amount of 'missing commodity inputs' is assigned to the sectors of the Input-Output-Tables in a consistent manner, i. e. does not depend on the structure of the process chain. E.g., the manufacturing of a product can be modelled by one process or by a set of proecceses. In both cases the approach leads to the same result.
- The BID system is derived from Input-Output-Tables in a manner that also imports and the depreciation of investments are included in the assessment.
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Related presentations:

1) Marheineke, T., Friedrich, R., Krewitt, W.: Application of a Hybrid-Approach to the Life Cycle Inventory Analysis of a Freight Transport Task. In: SAE 1998 Transactions – Journal of Passenger Cars, Section 6 Volume 107. Society of Automotive Engineers (SAE), Warrendale PA, U.S.A.

2) Marheineke, T., Stekeler, J.: Ein Hybrid-Ansatz zur ganzheitlichen Bilanzierung – Möglichkeiten und Grenzen am Beis-piel einer konkreten Transportaufgabe im Verkehr. Vortrag auf der 16. VDI/VW-Gemeinschaftstagung Ganzheitliche Betrachtungen im Automobilbau , 27. – 29. November 1996, Congresspark Wolfsburg. In: VDI-Bericht 1307, VDI-Verlag GmbH, Düsseldorf 1996

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The Hybrid Approach Merging IO and Process LCA

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.035.1.pdf

A hybrid model that integrates LCA system with IO system is presented with a case study of a flowering material. The model inter-connects upstream and downstream cut-offs by process based system with input-output system using consistent mathematical framework. Required pre-treatments including price update, base year change, matrix adjustments for both LCA model and IO model for integration is described. The result of the case study is compared with pure process based LCI and pure IO based inventory. The result shows that the hybrid model gives consistent result than pure IO model due to its system completeness and process-specificity. Sources of difference between results are discussed in terms of base year difference, price difference, truncation errors, level of aggregation in commodity classification, etc.

Life Cycle Assessment of the PV Power Production Using the Hybrid Approach

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.036.1.pdf

Hybrid methodology links normal process chain analysis (PCA) with economic input output (I/O) analysis. Compared to the PCA, hybrid LCA allows to analyze the complete life cycle from cradle to grave without defining distinctsystem boundaries. In addition to this, the hybrid approach could be a time efficient way of LCA as it helps to avoid a too thorough assessment of parts of the life cycle of only minor importance.

This methodology has been used to assess the production of electricity with photovoltaic systems. The system analyzed is a grid-connected 5 kW rooftop PV system based on polycristalline silicon cells. As far as possible actual production data have been used representing the current state of the art. The hybrid approach is based on the method described by Marheineke et al. 1999 and Marheineke 2002.

The presentation will show the results of the LCA using the hybrid approach and will compare them with those obtained by PCA.

The results, analyzed for the impact factors 'Greenhouse Effect', 'Acidification of Eco-Systems', 'Nutrification of Eco-Systems' and 'Primary Energy Consumption', based on the hybrid LCA exceed those using PCA by about 40%. These differences between the two methodological approaches are caused in the PV power production and here mainly due to services and depreciation of machines and buildings which are not quantified in the PCA approach. Therefore normal process chain analysis could strongly underestimate the burdens associated with the production of power in photovoltaic systems.

Literature:

Marheineke, T.; Friedrich, R.; Krewitt, W.: Application of a Hybrid-Approach to the Life Cycle Inventory Analysis of a Freight Transport Task. Society of Automotive Engineers SEA 1998 Transactions- Journal of Passenger Cars. Warrendale PA. USA 1999

Marheineke, T: Ganzheitliche Bilanzierung der Energie- und Stoffströme von Stromerzeugungstechniken. PhD-thesis in preparation. University of Stuttgart 2002

A Bayesian Hybrid LCA Model of Stochastic Embodied Greenhouse Gas Emissions in Construction Materials

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.037.1.pdf

A new method for stochastic embodied greenhouse gas emissions modelling is proposed. The method progressively integrates process analysis data into a prior probability distribution of embodied greenhouse gas emissions drawn from a disaggregated expansion of the U.K. Environmental Accounts. The UK Environmental Accounts are disaggregated using techniques from Maximum Entropy econometrics with the stochastic data extracted through use of random sampling from the space of potential supply trees feeding any given product sector. Data integration and posterior distributions are formed using Bayesian statistical techniques realized through application of the Markov Chain Monte Carlo (MCMC) discrete approximation method. The model offers the benefit of robust error estimation and the ability to 'learn' through the progressive integration of new process analysis data.

A stochastic model is developed to permit analysis of potential CO_{2eq} emissions reductions obtainable through preferential selection of low embodied CO_{2eq} material suppliers within material supply chains. Such analyses are important for assessing the extent to which emissions reductions can be achieved through economic mechanisms that drive preferential selection of low embodied carbon materials back through the supply chain – such as carbon taxes and emissions trading. This work is explained further in:

Shipworth, D. 2002, 'A stochastic framework for embodied greenhouse gas emissions modelling of construction materials' Building Research & Information, Vol. 30, No.1 pp.16-24.

Comparison of the Impacts of the EPFL Computer Network Using Process and Input-Output LCA

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.038.1.pdf

The objective of this study was to assess the life cycle environmental impacts of the computer network of the Swiss Federal Institute of Technology in terms of the related primary energy consumption. The necessary equipment were assessed using two approaches to Life Cycle Assessment: Process Life Cycle Assessment (Process LCA) and Input Output Life Cycle Assessment (IO-LCA).

Both approaches show that the PCs (control units and screens) are dominating the system energy use. This is clearly because of the high number of PCs necessary for the computer network. The use phase plays a dominant role, but the embodied energy consumption during infrastructure production plays a significant role, increasingly important with the use of notebooks or flat screens. The results of the IO-LCA were a factor about 2 larger than the results of the Process LCA. The use phase does not show a very large difference. This is probably because the process LCA gives strong results for the primary energy related to the electricity consumption and the important contributions to the electricity sector might be easier to point out. On the other hand, the necessary energy for the production phase shows very large difference (factor 2 to 4.5). The main source of this difference is the larger number of inputs considered by the IO-LCA (e-g air transportation for PC which plays a significant role) together with the differences regarding the geographical and temporal sources of the data.

The importance of the personal computer necessitates a deeper analysis. Various studies show a factor 10 in the difference in the value of the embodied primary energy of one computer. On a per kg basis these studies show a good agreement about 200 MJ per kg of computer. The value obtained for the IO-LCA is just higher than 600 MJ per kg, the difference is a factor 3. Together with the uncertainty related to the average price and computer weight, the difference between the process LCA and the IO-LCA can be explained by:

1. the contribution not taken into account with the process LCA;

2. the luck of accuracy at the sector level;

3. the energy efficiency improvements between 1992 and 1997.

For example, the contribution of the sectors like: air transportation, wholesale trade, automotive rental or hotels and lodging places are significant and not taken into account in the process LCA. However, more information on the process LCA study are needed if one want to point out more precisely the origin of the differences and improve its reliability.

Evaluating Sustainability at the Communal Level

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Presentation: DOI: http://www.scientificJournals.com/db/PDF/ehs/2002.04/ehs2002.04.039.1.pdf

In Switzerland, local communities are encouraged to apply the sustainable development principles in Agenda 21. An essential question for city planning and management is : With more than 40 chapters, Agenda 21 offers many possibilities for actions. How to establish priorities in a coherent way?

This research aims at developing a straightforward tool, usable at the communal level, to determine the socio-economic and environmental impacts of various alternatives in order to set sustainable development priorities.

Each city has its own social structure which influences local practices. These practices affect sustainable development performances. The link between practice and performance can be made with flow analyses and Input/Output analyses. Input/Output methodology enables to estimate environmental and economical impacts – including employment – with the same framework. The main problem in Switzerland is the lack of accurate and detailed statistical data. Swiss matrixes with regional satellites are currently being estimated on the basis of other countries data.

The first case studies – different wood valorization projects – calculated with adapted American data and compared with traditional Life cycle Assessment, show that the approach is interesting and worth deepening.