Life Cycle Environmental Impact of the Internet infrastructure in a University

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Abstract
Information and communication technologies (ICTs) are rapidly developing and will shape our future society. In understanding the shape of the future information era, it is also important to identify the environmental aspects of ICTs. However, Life Cycle Assessment (LCA), a systematic evaluation tool for products and services, often lacks ability to capture services inputs and capitals, which is crucial in ICTs. In this study we employed input-output analysis besides traditional process LCA to overcome this problem and to identify environmental impacts of Internet infrastructure within the Swiss Federal Institute of Technology (EPFL). This study aims at detailing the Internet infrastructure and evaluates the environmental impact of its various components. The methodology developed starts with a first screening performed with an Input-Output LCA software (MIET). This has been done starting from the detailed expenditures allocated to the Internet infrastructure within the Swiss Federal Institute of Technology in Switzerland. Data from other LCA studies and databases were then included using an hybrid approach. It permits to better evaluate environmental impacts of complex systems. In particular it enables to assess overhead services and infrastructure, which have received less attention in traditional LCA. The results of the first screening show that the electricity and the manufacturing of personal computers are dominating. But other contributions like maintenance, paper, management and computational services in case of computer breakdown have significant impacts, showing that an environmental friendly computer is also a reliable one. The inclusion of process data on electricity consumption, computer manufacturing, computational services and particular characteristics of the institute's energy consumption were then combined in a process technology matrix. The results change significantly showing that the first screening of the methodology is useful to point out what should be more detailed but gives results that should be interpret with great care.

Keywords
Information and communication technology, Internet, environmental impact, LCA, input-output.

INTRODUCTION
Impacts on the environment caused by information and communication technologies (ICT) are of particular interest for sustainable development. Although they have negative direct and indirect effects, services like teleconference, telework and others could also be used to decrease the impact on the environment. ICTs have particular characteristics: They evolve very rapidly, they need significant inputs from service industries, and have numerous indirect effects. Process life cycle assessment (LCA) is an efficient tool to evaluate the environmental impact of a product. It is rather adapted in taking into account e.g., detailed manufacturing processes, but rather inefficient in assessing, e.g. the services involved. Input-output LCA, on the other hand, has strengths if one focuses on generic services that have inputs mainly from other services and capital equipment sectors. The input-output approach divides the economic system in sectors and models the interacting flows. It is then possible to calculate the total industrial output related to one particular final demand (price of good or service that is to be assessed). Environmental data per sector per unit of output are then used to evaluate the overall impact of the output. This top-down approach has advantages since it ensures a global view and takes into consideration all direct and indirect contributions efficiently. On the other hand it has the disadvantage of a high level of aggregation. For instance, it makes it impossible to distinguish between two different models/variations of a product, like two different models of mobile phones. In addition, differences in prices and economic structures in different countries (for instance electricity prices and their corresponding technologies in the U.S. vs. those of Switzerland) can lead to significant errors if the input-output data are geographically incorrect or outdated. Therefore, the development of a hybrid method that enables to combine advantages of both approaches is most promising for the assessment of the environmental impacts of ICTs. In the presented study this approach is applied to the Internet infrastructure of a university, the Swiss Federal Institute of Technology Lausanne (EPFL).

METHOD
In this study, the input-output evaluation is carried out with the MIET software and database [2], which uses U.S. data from 1996. Additionally, data from two process-LCA studies are used for the inventory analysis of the equipment (hardware), the Atlantic Consulting study [3] and the study from Tekawa [4]. The other LCA data (electricity, paper and other commodities) are taken from the Swiss BUWAL database. The Internet infrastructure of the EPFL requires a set of equipment in order to run the system (Table 1) that has to be inventory.
In LCA, it is of great importance to identify key issues and to avoid detailed assessments of negligible elements within the life cycle. Therefore, the monetary expenses of the Swiss Federal Institute Lausanne (EPFL) in 2001 together with MIEC [2] were used to perform a first screening of the impacts with the input-output approach. This enabled the determination of the key sectors that have to be studied in more detail.

In this context an important question in assessing the multi-function infrastructures and overheads is 'how to allocate them to each one of their outputs?'. In this case, various allocation factors were determined: 1) The ratio of time used for Internet applications to total use time; 2) The ratio of space used by the hardware to total available space; 3) The ratio of the value of the hardware dedicated to Internet use to the total value of the equipment. Thus, the EPFL expenditures for the Internet infrastructure were allocated using various methods. For example allocation of the impacts caused by computer manufacturing to Internet applications has been performed by multiplying the CO₂ emissions of the computer production with the percentage of time in which the computers are used for Internet applications. Other examples are the building construction expenses allocated to Internet in relation to the space needed for the equipment. Similarly, the security expenses were allocated relatively to the equipment value, etc. The idea is to use the input-output approach to prioritize the further investigation. We thus performed a first screening. In this study the resulting focus is on 1) electricity consumption and 2) manufacturing of personal computers and peripheral equipment. Other types of contributions will be assessed in more detail in the future in order to test if they are really not as significant as those two elements of the life cycle.

**Table 1: Necessary equipment for the Internet infrastructure of the EPFL.**

<table>
<thead>
<tr>
<th>Device</th>
<th>Number (km for *)</th>
<th>Average price per product ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control unit</td>
<td>6745</td>
<td>2000</td>
</tr>
<tr>
<td>Screen</td>
<td>6745</td>
<td>500</td>
</tr>
<tr>
<td>Notebook</td>
<td>355</td>
<td>2500</td>
</tr>
<tr>
<td>Server</td>
<td>68</td>
<td>4'821</td>
</tr>
<tr>
<td>Switch</td>
<td>90</td>
<td>32'000</td>
</tr>
<tr>
<td>Router</td>
<td>22</td>
<td>18'000</td>
</tr>
<tr>
<td>Printer</td>
<td>400</td>
<td>2'000</td>
</tr>
<tr>
<td>Cable*</td>
<td>121</td>
<td>2'000</td>
</tr>
</tbody>
</table>

**Figure 1: CO₂ emitted for the Internet Infrastructure at the EPFL.**
RESULTS
Starting from the EPFL expenditures allocated to the Internet infrastructure, a first screening of the environmental impacts with the input-output approach was performed (see Figure 1). The results show that electricity consumption, maintenance (salary), production of personal computers, and in-house computer services are dominating the impacts. On the other hand some contributions are negligible: materials for buildings, electric installation materials, electric installation contracts, security equipment, electric installation maintenance, security equipment maintenance, as well as buildings maintenance.

Electricity consumption
As explained above, electricity consumption has been identified as the most important impact, therefore it was tested for sensitivity regarding different data sources and calculation methods. Figure 2 shows the CO₂ emissions calculated with MIET (U.S. data) and the data given by the Swiss BUWAL database for the European (UCTE) or Swiss electricity mix (with process-LCA for the latter two). As could be expected, the geographical location as well as the calculation method is very relevant for the results.

Figure 2: Comparison of the calculated CO₂ emissions using the input-output method (MIET) and the process LCA (UCTE and Swiss mix).

Computers and peripheral equipment
Results of process-LCA and input-output LCA are used to assess more in detail the manufacturing of the computers and peripheral equipment. A comparison is presented in Figure 3.

Finally, Figure 4 shows the screening evaluation on the basis of the Swiss electricity mix and the values taken from the process LCA studies. This figure shows that the result has been significantly changed compared to that of Figure 2. Hardware maintenance, informatics services, and paper and consumable informatics supplies are now dominating the impacts. These changes may imply two things: Better accuracy of the process specific data or incompleteness of the process analysis. The latter can be improved by taking into account the cut-offs of the process analysis that are employed. This has not yet been done and could enhance the system boundary completeness.

The input-output approach is very useful in providing a first screening of the environmental impacts of a complex system like the Internet infrastructure of a university. In addition, it gives the opportunity to estimate the impacts of services like maintenance activities or network management. For identifying these impacts, one important source of uncertainty is the allocation method, which can influence the results significantly. Therefore the selection of the appropriate method is of high importance.

Figure 3: Comparison of the process and the Input-Output method for the evaluation of the computers and the peripheral equipments impacts.

Another issue to discuss are differences using process-LCA compared to input-output LCA. These can be explained by the fact that up- and downstream cutoffs can usually not be quantified, since they are unknown. A method to estimate the impacts neglected by cutting of the system boundaries will be developed and applied to the presented case study in the future. The electricity mix employed also plays an important role; the efficiency and the mixes are very different from one country to another, as demonstrated by the variations between the U.S. and Switzerland (see Figure 1).

It has to be noted that in the presented calculation, only the direct electricity contributions have been evaluated with the European and Swiss data. However, as all industrial sectors use electricity, the impacts of the other contributions should decrease with the use of the Swiss mix as well. On the other hand, the Swiss electricity mix is not relevant for all activities that do not occur within Switzerland. The use of the hybrid LCA approach must thus be performed very carefully as data from various sources and different economic structure have to be combined.
CONCLUSIONS AND OUTLOOK

In this paper a methodology for the assessment of the environmental impacts of the Internet infrastructure of the Swiss Federal Institute of Technology Lausanne is introduced. A first screening is performed using the input-output LCA approach. This can help in expanding the system boundaries and therefore contribute to more comprehensive results. However, parameters that vary from region to region can play an important role when determining the dominating impacts. The specificity of the system studied must be preserved. These parameters can usually not be taken into account when employing pure input-output LCA.

To tackle these challenges, the integrated hybrid approach, developed by Suh and Huppes [1], will be applied to the presented case in depth in the near future. More process LCA data and collected data, i.e. based on a more comprehensive product system, will be used to improve the results. In particular, the electricity sector will be studied to take into consideration the shares of the Swiss mix and the imported electricity. More attention will be given to the allocation of the expenditures for the Internet infrastructure and to the modeling and evaluation of the impacts of the involved services. Finally, upstream and downstream cut-offs will be evaluated and a traditional hybrid method and the integrated hybrid approach will be compared.

REFERENCES


