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EDITORIAL

# A world with $CO_2$ caps

## Electricity production in consequential assessments

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There is today a general agreement within the life cycle assessment (LCA) community that there are two types of LCA (e.g., Tillman 2000; Guinée 2002): These are often called attributional and consequential LCAs, although other terms sometimes are used as well (Ekvall and Weidema 2004). Consequential LCAs study the consequences of a choice. Ideally, the system boundaries and the data used should, then, reflect the actual changes taking place as a consequence of the choice. These may depend on the scale of the change and also on the time over which the changes occur. Attributional or accounting studies aim at describing a system as it actually was (or is, or would be) at a specific time. In such studies, the system boundaries and data should reflect what was actually happening in the system. A number of papers have been published discussing the methodology and case studies of consequential LCA (e.g., Andrae et al. 2007; Dalgaard et al. 2008; Ekvall and Andrae 2006; Frees 2008; Hofstetter and Norris 2003; Kløverpris et al. 2008; Lesage et al. 2007a, b; Sandén and Karlström 2007; Schmidt and Weidema 2008; Thiesen et al. 2008; Thrane 2006).

The same distinction is also relevant for other types of environmental systems analysis and sustainability tools (Finnveden and Moberg 2005; Ness et al. 2007). Some tools such as cost–benefit analysis and strategic environmental assessment are typically more oriented towards consequential types of analysis. Others, for example, environmental audits and accounting systems, are generally of the attributional type (Finnveden and Moberg 2005). Other tools such as different types of energy analysis can be of both attributional and consequential types, although this is often not explicitly discussed.

One of the major differences between attributional and consequential LCAs concerns the choice between average and marginal data in the modeling of subsystems of the life cycle (Tillman 2000).

Average data can be national or regional average data for production, for example, of electricity. Marginal data represent the effects of a small change as a consequence of a decision. Average data are typically used within attributional LCAs and marginal data in consequential LCAs (Tillman 2000).

In many LCAs, energy-related impacts are important for the results; thus, the choice between average and marginal data and the type of marginal data can be important for the results. In many LCAs (and also other energy systems analysis), it has been assumed that the marginal source is a fossil fuel (e.g., coal or natural gas; Mathiesen et al. 2007). This may or may not have been correct up until now. However, this situation may now be radically changing with the introduction of the tradable carbon dioxide emission permits within the European Union (EU). If it works, it will provide a cap to the $CO_2$ emissions within the EU from the sectors that are included within the trading system. If the production increases within these sectors within the EU, the increase is not allowed to increase the $CO_2$ emissions.

If the cap would have been only over the electricity production system, this would have led to a $CO_2$-free marginal electricity production. This case was studied by Mattsson et al. (2003), who calculated a complex marginal electricity for the Nordic electricity system for a number

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of different scenarios. One of these had a cap for the $CO_2$ emissions resulting in a very different marginal electricity production compared to other scenarios. Eriksson et al. (2007) used their study to define two alternative marginal electricity sources in a case study on district heating systems. The scenarios used were two extreme scenarios with a high amount of fossil fuels (here called "high gas price") and a low amount of fossil fuels ("$CO_2$ cap"; Table 1).

In reality, the system is more complicated because the emission trading system also includes emissions from some industries. This means that emissions from the energy sector can increase if emissions from other sectors decrease, and vice and versa. In a consequential LCA, these effects should also be included if they are consequences of the decision being made. But even so, it is clear that the marginal electricity source may be very different in the future compared to what has been normally assumed so far. It may very well be that the future marginal electricity source within the EU is virtually $CO_2$ free. This may have a very large impact on results from consequential LCAs.

The conclusion from this short paper is that the future marginal electricity sources need to be studied much more. It may very well be $CO_2$ neutral. In the meantime, we suggest that in cases where the electricity system is likely to a have a significant influence on the results, two scenarios should be used: one with high $CO_2$ emissions and one with low or no $CO_2$ emissions, in consequential LCAs. A similar reasoning may be applied also for other types of products which are produced from industries included in the system of tradable carbon dioxide emission permits within the European Union, e.g., metal and paper products. The discussion here has focused on consequential LCAs. However, it is also valid for consequential studies in general.

This editorial can also be seen as a part of the discussion on consequential LCA vs. attributional LCA. A consequence of using consequential LCA may be that it seems like it does not really matter what we do. Although different product systems may have different emissions, which can be seen in an attributional LCA, they may look similar in a consequential LCA. It may, of course, be argued that the approach taken here is too simplistic. Other types of consequences should also be included. For example, if we use products with lower emissions of $CO_2$, it may be easier for the politicians to lower the $CO_2$ cap in the future. This may or may not be true but is difficult to analyze and predict because political decisions are influenced by a number of different factors. In either way, it illustrates the complexities of consequential studies.

**Table 1** Complex marginal electricity production in two different scenarios for the future Nordic energy system (Mattsson et al. 2003)

| Percentage | High gas price | $CO_2$ cap |
|---|---|---|
| Wind | 11.32 | 21.79 |
| Nuclear | 00.00 | 23.09 |
| Biomass CHP | 00.53 | 35.72 |
| Coal CHP | 59.99 | 00.77 |
| Oil | 03.03 | –01.41 |
| Natural gas CHP | 25.33 | 19.95 |
| Hydro power | –00.21 | 00.10 |

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