COMPARABILITY OF LIFE CYCLE ASSESSMENTS (LCA) IN PROCESS DESIGN BIOREFINERY PROCESSES

Daniel Koch, Anton Friedl, Bettina Mihalyi

E166 - Institute of Chemical, Environmental and Biological Engineering at TU Wien

INTRODUCTION

The incremental growing of human population and technological advancement is leading to a shift in the priorities of decision makers. Challenging topics are gaining attention such as the increasing energy demand, resources availability and the mitigation of emissions. To tackle these, the concept of sustainable development is widely promoted. Presently its common definition is, that the needs of today's generation are to be fulfilled without hindering the freedom and possibilities of future generations to fulfil their own needs. [1] Assessing a given system on sustainable development is highly complex and often does not yield one simple and clear solution. A task like this is also described as a wicked problem.

Life Cycle Assessment LCA has proven to be a powerful method to analyse the environmental impacts of a product, a service or a process. Broad areas of the LCA methodology are standardized through the ISO standards 14040 and 14044. The idea is a holistic approach, including all life cycle stages with its inventories (material and energy flows) from raw material extraction to the end of life scenario, cradle-to-grave. The informative value of a LCA result depends heavily on the quality of available data, chosen methodologies (e.g. allocation for multi-product systems), as well as the defined scope and goal of the assessment. [2]

FUNDAMENTAL OF THE PROBLEM

At the beginning LCA was focused on established product systems but for the application of the precautionary principle it should already be implemented in an early stage process design phase, in addition to classic process simulation tools. It is essential for a technical realisation of environmental sustainability to include life cycle thinking already in process development.

In order to increase independence from fossil resources, biomass based refineries are the centre of interest for many research groups. This innovative technology also is intended to support a sustainable development and to minimise the environmental load. Even within the different concepts for biomass based refineries there are a selection of process paths to obtain the so called platform chemicals in a certain quality. But looking at different impact categories of the whole life cycle, not all of them have a better environmental footprint than the conventional process.

This study investigates how LCA can help to find the most ecological respectively the sustainable process paths in an early stage of process design using a case study on the issue "lignocellulosic biorefinery". To yield the different products in this biorefinery the lignocellulosic biomass has to be pretreated to provide the various fractions, cellulose, hemicellulose and lignin, for downstream upgrading (further refining procedures). Through this study two common research questions should be answered: "Is it possible to make profound decisions from an LCA documentation in the literature without conducting one exclusively with the specific application and frameworks?" and "How far are LCA results from different assessments about the same process principle comparable?"

METHODOLOGY

An extensive literature research is carried out to find answers for the research questions. Results of different life cycle calculations are analysed in detail. The recently most assessed lignocellulosic biomass pretreatment method, the dilute acid process, was selected for this case study. It is commonly used for second generation bioethanol biorefineries.

Important aspects of the LCA methodology were precisely investigated to have a good basis of comparison, including: goal and scope definition, functional unit, land use change, biogenic carbon sequestration, allocation of products and feedstock. All recognised differences and shortcomings are evaluated, eventually recalculated and documented.

RESULTS AND CONCLUSION

Process development also involves choosing one of many different process chains to reach the desired outcome. The environmental impacts need to be assessed for these decisions to promote a sustainable development.

Analysing the environmental implications for a specific process from different LCAs in literature comes with a large number of uncertainties and a high variation range. Comparing two different process path possibilities only through LCA results from the literature is hardly helpful. Life cycle calculations that can be found are remotely comparable to exactly the same two process paths of interest. There are usually many varieties for the goal, the scope and the data quality. Each process development has unique goals which cannot be ignored when trying to transfer a life cycle calculation result with different unique aspects onto it. Taking a selection of more than one life cycle calculation result from the literature into account, comes with a lot of detail work for each process and a higher deviation of the results. The variation of the results in all steps, setting goal and scope, choosing the methodologies, data quality of the life cycle inventory (LCI), timeframe and more aspects of the LCAs either lead to incomparability of the results or to no significant recommendation. Trying to understand the variations and looking into the calculations in detail to take deviations in each level into account comes with a very high effort, even if the LCA is done with ISO compliance there are certain presumptions, boundary conditions and calculations which are not exposed.

While it is already challenging to compare the environmental impact of different commercial processes by consulting the literature, it is even more increasingly unfeasible for processes in the design phase where even more uncertainties, flexible parameters and a larger number of assumptions are present. Therefore it is imperative to apply an exclusive LCA as decision support along with each process development. Ideally it is done together with the engineers developing the process.

REFERENCES

[1] Brundtland G. H., “Report of the World Commission on Environment and Development: Our Common Future.” 1987

[2] Curran M. A. „Life Cycle Assessment: a review of the methodology and its application to sustainability.” Current Opinion in Chemical Engineering, 2:1-5, 2013