Coupling LCA and techno-economic analysis for a sound evaluation and fair comparison of processes sustainability

G. Léonard, S. Belboom, S. Ali, G. Heyen, F. Puerari and A. Léonard

Chemical Engineering, Quartier Agora B6a, University of Liège, Belgium

Introduction

At the European level, the energy transition requires to identify efficient and sustainable technologies to mitigate greenhouse gases emissions and to address the increase of variable renewable energy sources. These technologies also need to be economically viable for the European industry to adopt them. However, technologies addressing such various goals may be very different from each other, ranging from bio-based processes to the production of CO_2-sourced energy carriers. As a consequence, efficient methods need to be developed that allow for the sound evaluation and fair comparison of relevant technologies, assessing their technical bases as well as their economic and environmental life cycle balances. At the University of Liège, we developed a methodology based on the coupling of techno-economic analysis with life cycle assessment. We applied it to the comparison of various chemical storage technologies: synthetic natural gas (SNG), methanol and dimethylether (DME). Although the initial study considered biomass as carbon source, this methodology could be applied to captured CO_2 as well. First, the results of the techno-economic study are presented, then the life cycle assessment is discussed. The advantages of combining these two chemical engineering tools are highlighted.

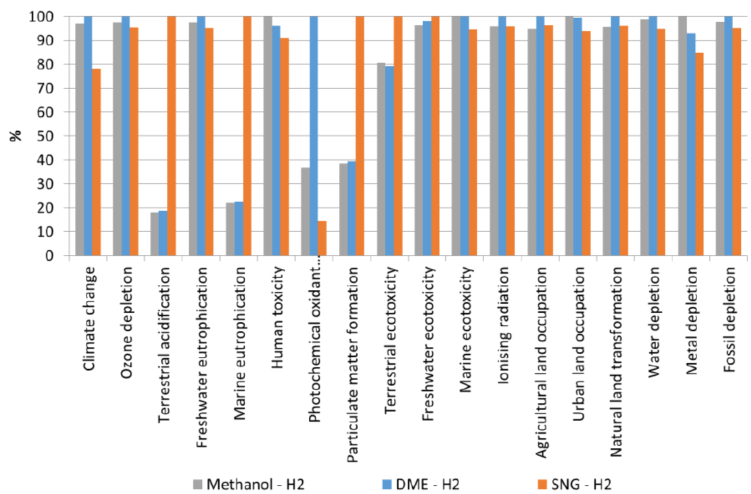
Techno-economic evaluation of processes

The techno-economic evaluation of processes is an essential element in the design and evaluation of technologies. Standardized methodologies are implemented for process design and the process is then modeled based on thermodynamics first-principles. The resulting model allows the identification and optimization of adequate equipment and operating values, as well as it allows to compute the energy efficiency of the technology. It also provides detailed input for an economic analysis of the technology, in which CAPEX and OPEX are estimated from actualized chemical engineering cost indexes. This methodology was successfully applied at the University of Liège for the case of chemical storage technologies. The production processes of SNG (reference case), methanol, and DME were evaluated, and the effect of adding H_2 obtained with renewable electricity to boost the production rate was studied. The table below presents the process energy efficiency with and without by-product valorization. Similarly, the process CAPEX and OPEX can be compared (not shown here) and used to predict and compare the process rates of return on investment.

Process/technology	**Energy efficiency (main product)**	**Energy efficiency (with by-products)**
Methanol from biomass	54.0 %	65.9 %
Methanol from biomass + H_2	71.4 %	78.8 %
DME from biomass	64.1 %	66.0 %
DME from biomass + H_2	67.6 %	76.3 %
SNG from biomass	60.0 %	-
SNG from biomass + H_2	70.2 %	-

Life cycle assessment

The University of Liège has developed experience in LCA methodology for more than 15 years. This approach was applied to the case of chemical energy storage discussed above, using the process model for a detailed estimation of the input and output flows of the process. The LCA is thus based on a sound evaluation of the technology, the availability of the process model allowing to consider best industrial practices or custom data all along the assessment. Furthermore, that method takes into account the upstream and downstream flows of the process as e.g. the raw materials but also their origin, their transportation or the product end-of-life. It allows to give a global overview of the studied technology and not only the onsite flows to adopt, as far as possible, an eco-design approach. The figure below represents the results for the case study. Based on the study's assumptions (not discussed here), it appears that SNG (in orange) seems to be the ideal energy carrier in the study's framework, leading to the lowest score in main impact categories.



Conclusion

Finally, it appears that coupling techno-economic analysis to life cycle assessment offers a flexible but common reference to compare technologies regarding their energy efficiency, cost viability and environmental sustainability. This approach should be combined with eco-design, in which interactions are considered from the very early steps between the 3 criteria (energy, cost and sustainability) leading to multi-optimization of process technical efficiency, economic viability and sustainability.

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