Integrating conceptual process design and LCA for micro-algae production systems

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Background

One of the grand challenges of the transition to a circular economy is how to sustainably use the planet's resources? To tackle this challenge it is essential to address the environmental sustainability of new processes, such as micro-algae production systems during the technology development and realisation. The most common environmental assessment method is Life Cycle Assessment (LCA).

The major limitations in LCA are:

- time-consuming analysis
- data-intensive procedure
- the quality of data affects the quality of the results
- causality is ignored.

In early phases of process design important engineering decisions can be made that affect the performance. But, for new processes information on large-scale is hardly available and thus applying LCA is challenging.

Connecting process design with LCA performance

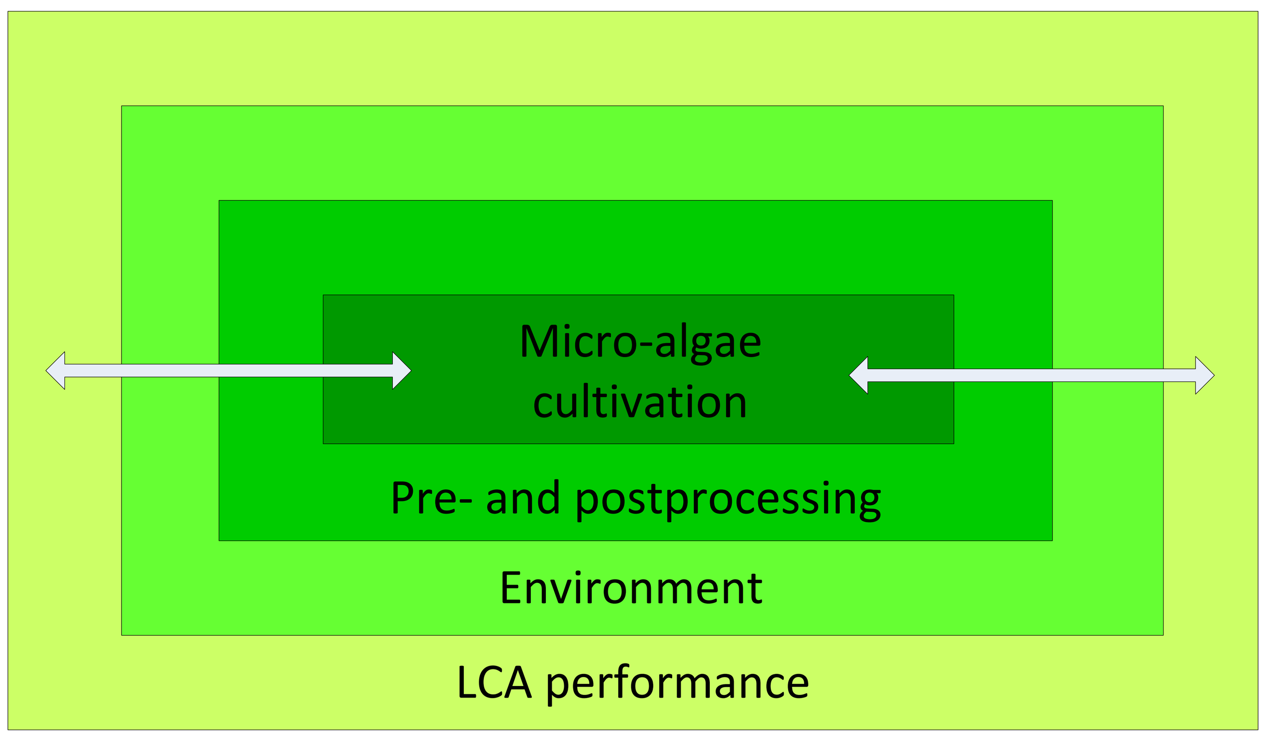


Figure 1. Linking micro-algae cultivation and processing design with LCA performance using a systems approach. In this approach the connections between cultivation, pre- and postprocessing and the environment, and the LCA performance are taken into consideration.

Our approach

We use conceptual process simulations to give an early indication of the LCA performance.

Step 1. Translate experimental data to large-scale production with mathematical modelling and engineering rules

Step 2. Simulate algae production under various production and design scenarios

Step 3. Apply LCA to the scenario simulation results

Advantages:

- environmental sustainability is evaluated already during process design
- process simulations allow linking the LCA to the mechanisms in the production processes

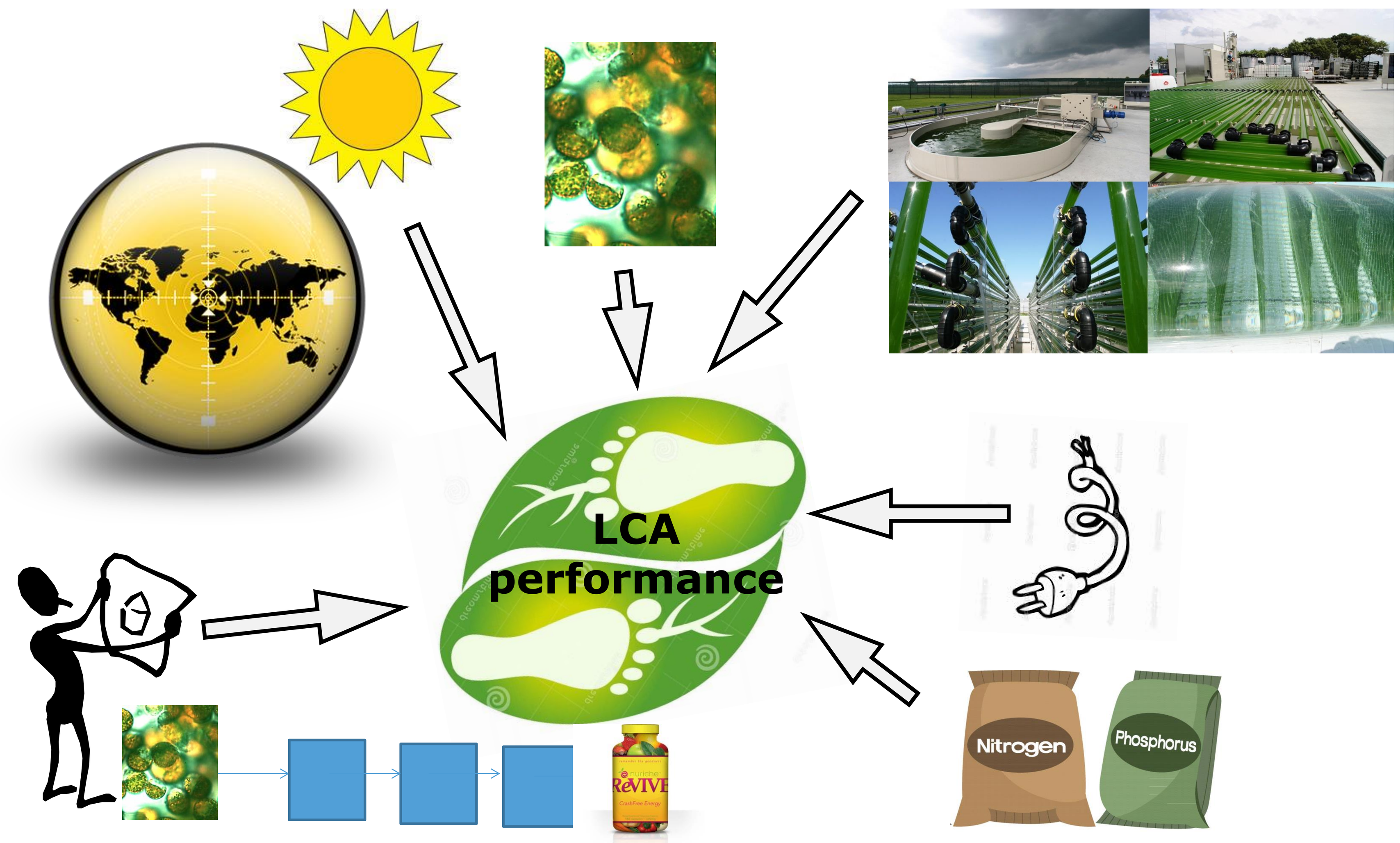
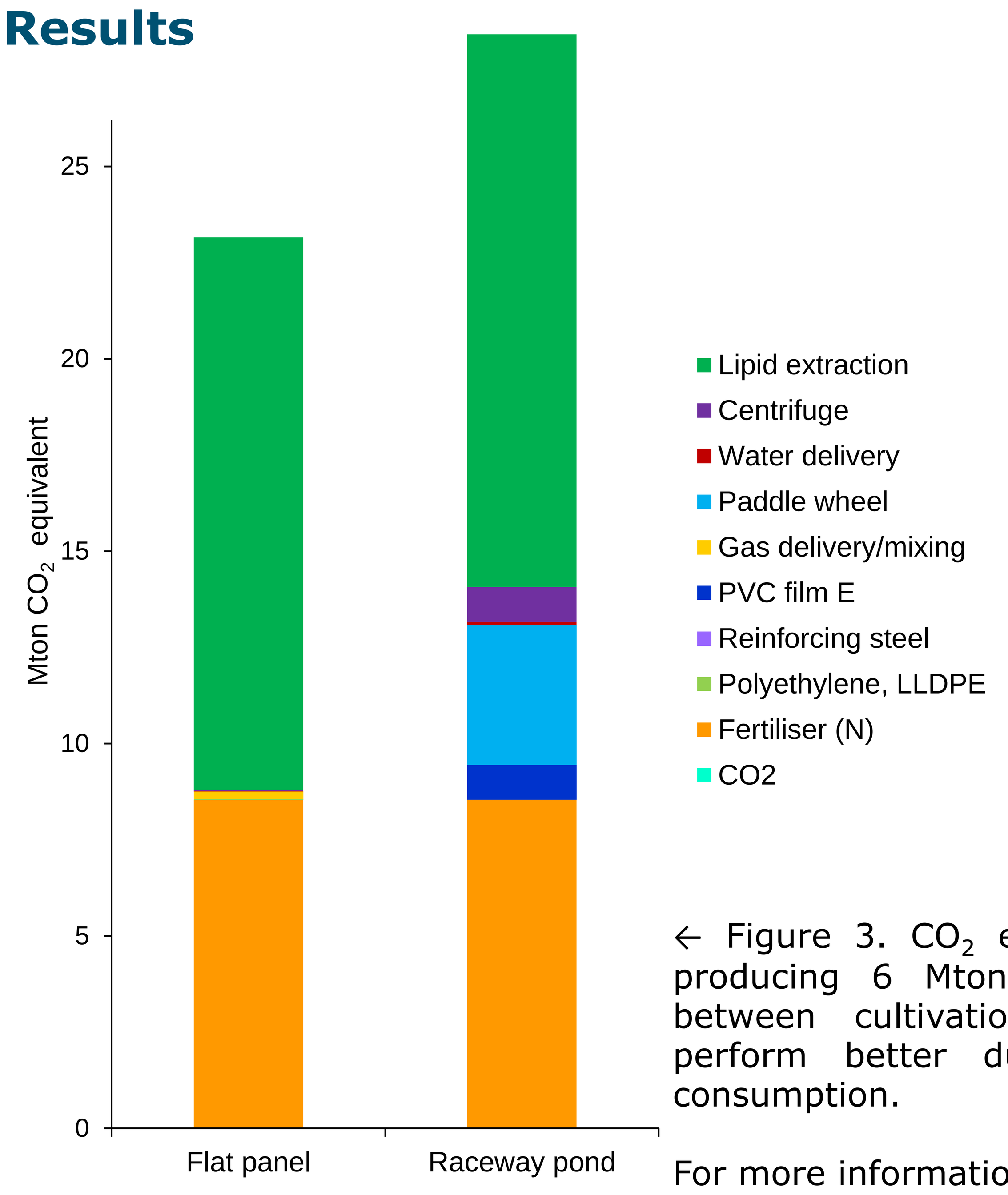


Figure 2. LCA performance is influenced by production and design scenarios

The approach allows

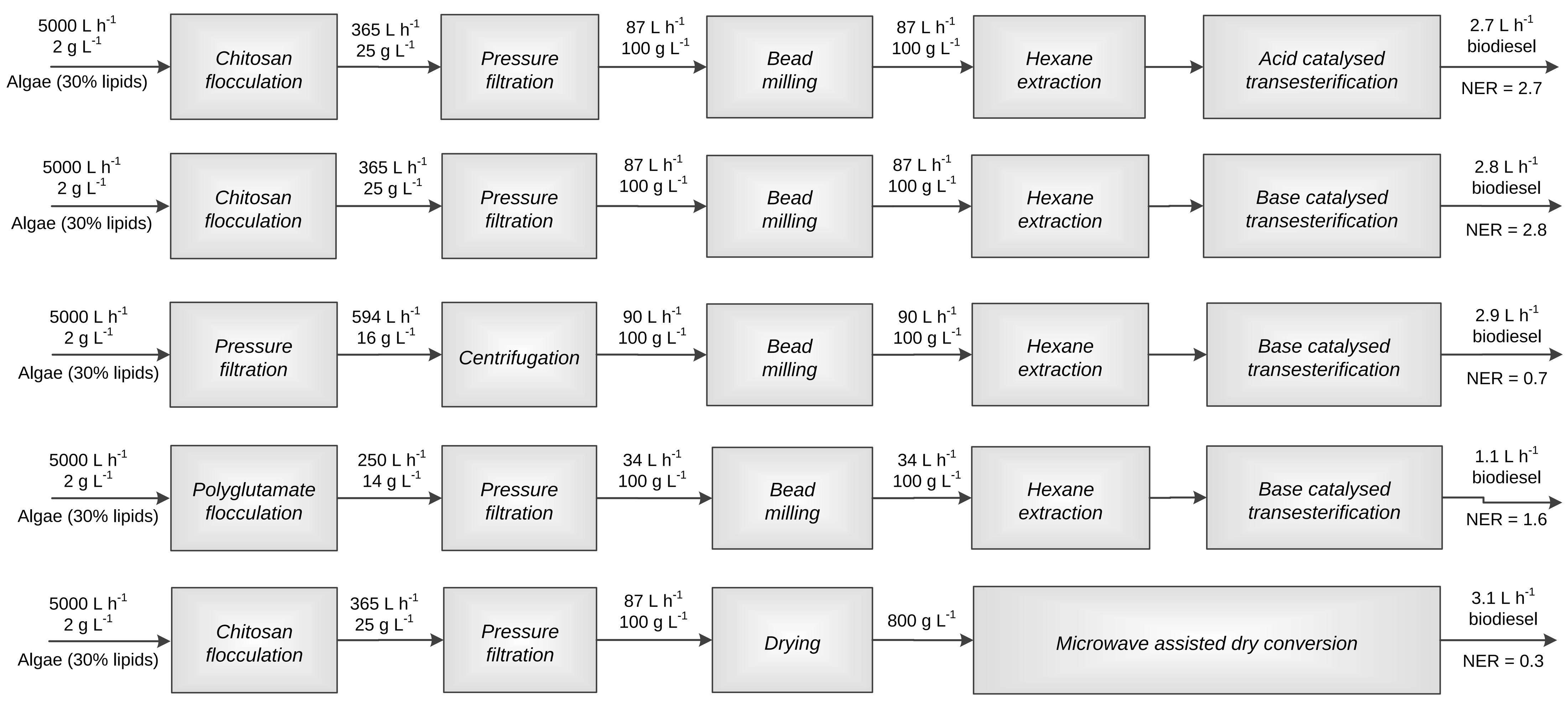
- indicating current bottlenecks in the chain
- studying how choices in the process design of micro-algae production systems advance LCA results.

Results



← Figure 3. CO_2 equivalent LCA impact for producing 6 Mton algae oil. Impact vary between cultivation systems. Flat panels perform better due to the lower water consumption.

For more information see Draaisma (2013).



↑ Figure 4. Biodiesel yield and NER for optimised micro-algae to biodiesel process chains, each consisting of other unit operations. The NER is low in path 3 (high energy in first two processes) and path 5 (drying). Biomass losses with non-optimal flocculant dosage decrease also the NER and biodiesel yield.

For more information see van Boxtel (2015).

Conclusions

The approach allows indicating the current bottlenecks in the production chain and also the potential to improve the LCA performance.

- Lower LCA impact can be obtained by optimising design and operational parameters with conceptual simulation models
- The effect of improved productivity or conversion on impact categories varies with the upstream and downstream activities

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References

Draaisma RB, Wijffels RH, Slegers PM, Brentner LB, Roy A, Barbosa MJ. Food commodities from microalgae. Current Opinion in Biotechnology. 2013;24:169-77.

van Boxtel AJB, Perez-Lopez P, Breitmayer E, Slegers PM. The potential of optimized process design to advance LCA performance of algae production systems. Applied Energy. 2015;154:1122-7.