Decision support for biotechnological produced peptides in a design stage by Sustainability Assessment

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Abstract

Environmental friendliness of products is becoming more and more important in the societal discussion. In the same time an increasing importance is attributed to social effects of products as well. These two topics, regarded over the entire life cycle of a product, establish together with the cost aspect the basis of products` "sustainability".
Within an EU-funded project a systematic approach for an early stage sustainability assessment is applied using the methods Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Life Cycle Working Environment (LCWE) for the evaluation of sustainability of the production and application of biotechnical produced self assembling peptides.

Introduction

The three columns of sustainability – environment, economic and social issues – of a product or a technical system can be influenced most effectively at an early stage of development. The more the development has moved toward the completion the larger efforts will be necessary in order to implement any technical change (see Figure 1). This leads to the idea of an early-stage decision support regarding the columns of sustainability.

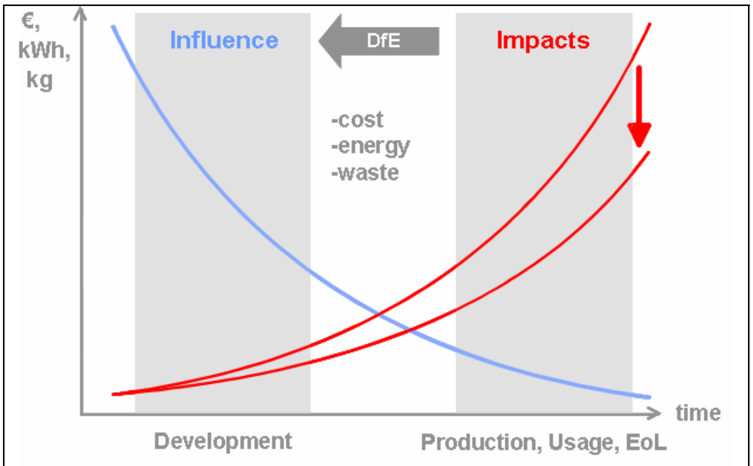

Figure 1: Simulation of costs and environmental effects during R & D is crucial

Sustainability analysis can be carried out in order to support the decision making by providing "integrated decision support" in the R&D-stage of a product. It combines assessments covering environmental, economic, technical and social aspects. Therefore, a development study with pre-analysis and consequential simulations enables the pre-estimation of the sustainability of the technical processes. In the EU-funded project – "Bio-based Functional Materials from Engineered Self-Assembling Peptides (BASE)", an integrated consideration of all life cycle aspects is made.

BASE - Bio-based Functional Materials from Engineered Self-Assembling Peptides

The BASE project aims at advancing the science and technology of sustainable and functional materials. Specifically it targets innovative nano-coatings for plastics, metals and ceramic objects, exploiting the self-assembly capabilities of short (<25) amino-acid sequences (=peptides) in industrially relevant applications.
Self-assembly is a method of spontaneous organisation of molecules into higher order structures and defined by set boundary conditions (e.g. pH, temperature hydrogen-bonding strength, ionic strength, polarity of the solvent and nature of substrate).
The innovativeness resides with the shortness of the peptides and associated structure forming capacity to create tailored bio-inspired functionality. Short peptides offer a more manageable science and open a window towards a cost effective availability through biotechnological routes.

Sustainability Analysis

"Sustainability" is according to the Brundtland Report (1987) defined as equal consideration of

- environmental (by LCA - Life Cycle Assessment),
- economic (by LCC - Life Cycle Costing) and
- societal aspects (by LCWE – Life Cycle Working Environment)

supplemented by a technical characterisation of products, processes and services.
Within the BASE project sustainability analysis is carried out during the development phase using the method of LCA, LCC and LCWE, which are described below.

Environment - Life Cycle Assessment

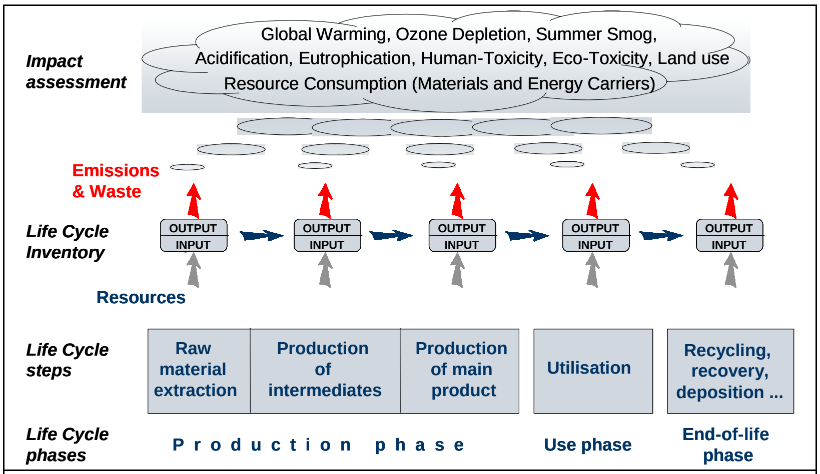

Figure 2: Prinicple of Life Cycle Assessment

Life Cycle Assessment (LCA) is a method to determine the environmental impacts of a product or a system during its whole life cycle including the production and supply of all precursor substances, operating supplies, auxiliary materials, energies etc.

It is an addition to traditional research and development assessment, in which usually only cost and the function of the new technology are focused. In LCA all relevant impact categories are assessed, taking into consideration the goal of the study. Within the approach in BASE, the indicator Primary Energy Demand and the impact categories Global Warming Potential (GWP100), Photochemical Ozone Creation Potential (POCP), Eutrophication Potential (EP) and Acidification Potential (AP) are chosen.

Economy – Life Cycle Costing

Life Cycle Costing (LCC) is a method to establish the total cost of ownership or the total production cost of a product or a service system.
A particular aspect in this analysis is that, unlike the situation in LCA, in which all the proc-

esses of the value chain need to be considered, the economy offers the ‘rucksack-principle’ of prices, i.e. prices of products have the comfortable nature of counting up the whole value chain of the production. With a product bought for a certain price, one does not have to bother about the origin of this price, whether it is derived from the costs of a certain production step or from the profit of the producer, or even if the producer is making any profit at all. The costs within the boundaries of the other players can be viewed as a black box, without requiring any differentiation [1].

Society – Life Cycle Working Environment

Life Cycle Working Environment (LCWE) methodology [3] measures the work-related social effects of processes and products. It is based on the same product life cycle model as the LCA, ensuring consistency with the LCA- and LCC-part of the study. Similar to LCA, an insight into all processes of the system is required in order to assess the impacts. Regarded categories are listed up in the following, each with the considered aspects.

Qualified Working Time (QWT) - Establishment of qualified jobs and support of socio-economic welfare:

- Duration of work
- Qualification profile of work
- Training / Qualification on the job

Health & Safety of Working Time (HSWT) -Protection of human health:

- Lethal and non-lethal accidents
- Heaviness of work (noise, dust, heat, cold, contact with irrigating or unhealthy substances, odour etc.)

Humanity of Working Time (HWT) - Humanity and flexibility of working conditions:

- Worst forms of child labour
- Child labour
- Forced labour
- Right to organise in trade unions

Sustainability in early design stage

As already mentioned, the above described three aspects (LCA, LCC, LCWE) establish the basis of a sustainability analysis, which scheme is outlined in the following Figure 3.

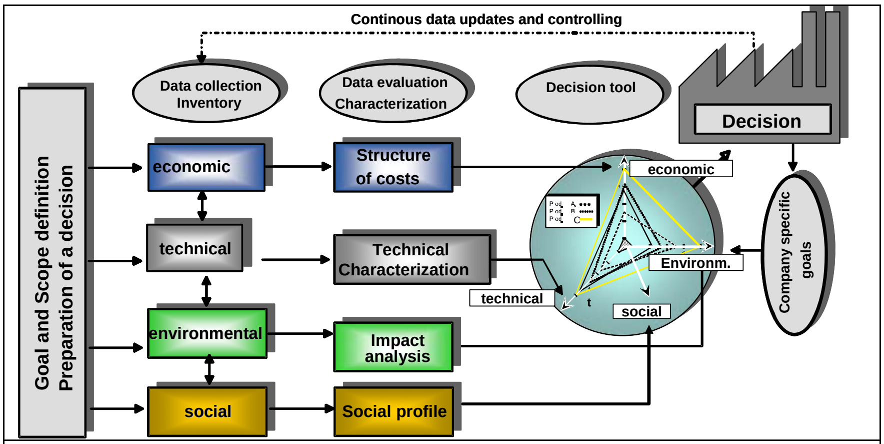

Figure 3: Systematic Sustainability Assessment

In the BASE project, the concept of sustainability analysis is applied to the production of biotechnological produced peptides for several applications. The principle competing conventional applications serve as benchmarks.

The sustainability analysis in the BASE project is to be made in an early design stage. Two major issues concerning this accompanying assessment approach for the novel biotechnological materials occur:

- The principle production route is not known yet (in detail).
- The material properties are not finally analyzed and thus the targeted applications can change during development phase.

In the BASE project the sustainability analysis is implemented with the following approach, illustrated in Figure 4. The biotechnological production process and its procedural modelling in a LCA software has to go parallel to the development and adaptation of potential applications.

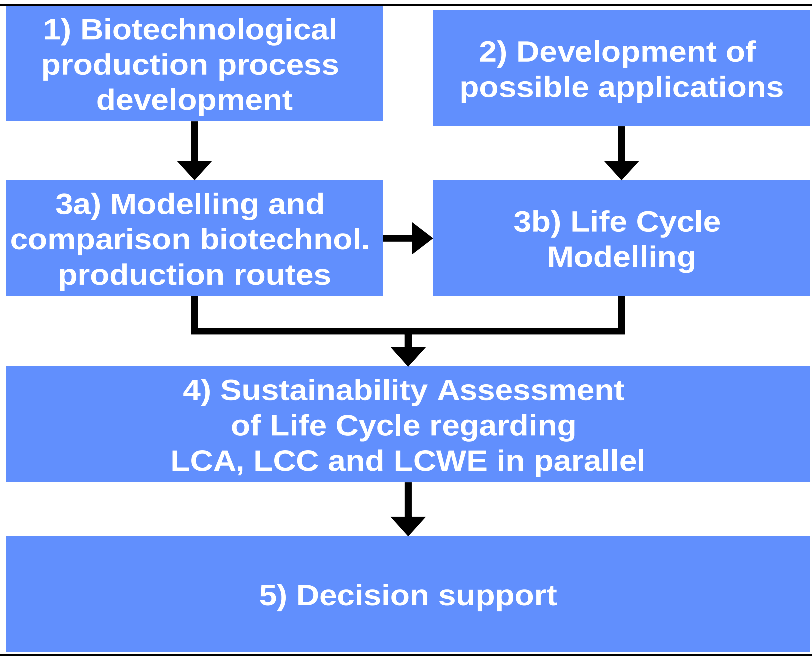

Figure 4: Flow scheme of accompanying assessment approach

1) Biotechnological production process development

Within the first step, the biotechnological production process development takes place. This development steps include the:

- Laboratory synthesis of known peptides and their evaluation
- Experimental biosynthetic production of peptides using different production routes, like
  - Fermentation process using yeast (pichia pastoris)
  - Fermentation process using bacteria (E.Coli)
  - …

2) Development of possible applications

In parallel with 1) the potential targeted applications have to be identified. This includes the characterisation and determination of basic material properties/features and further the identification and quantification of totally new material qualities. Thereof possible commercial applications have to be developed and principle competing, already in the market available solutions that serves as a benchmark within the assessment, has to be identified.

3a) Modelling and comparison biotechnical production routes

Putting on this technical development the life cycle models for the different production routes of peptides have to be set up in a LCA software (GaBi), see an exemplarily model for a biotechnical yeast fermentation process in Figure 5. This model must be adapted according to the development of step 1).

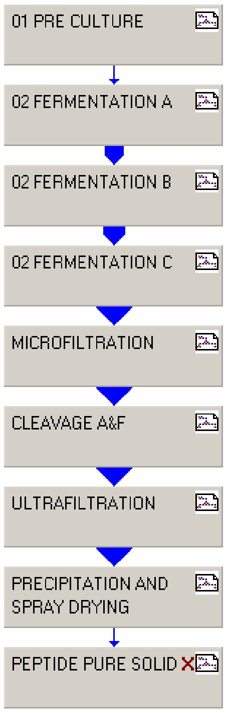

Figure 5: LCA model for "picchia pastoris" fermentation process

3b) Modelling of the application life cycle

Using the findings and data from 1) and 2) the life cycle model has to be set up as well regarding the production, the utilization and the end-of-life phase as well for the life cycle of the newly developed peptides within their targeted application as for their principle competing solutions.

4) Sustainability assessment using the methods LCA, LCC and LCWE

This step is the application of the three previous steps. The new system is compared to conventional solutions (as benchmark) regarding environmental, economic and societal aspects.

5) Decision support

The outcome of 4) serves as a basis for decision support, which production route performs best or where are the weak points in the specific routes. Here the main drivers and the biggest optimisation potentials are identified and derived.

Conclusions

This report presents the current stage of sustainability assessment within the BASE project. The work is currently in progress; open questions will be answered and will be followed by first quantitative results. LCA modelling of biotechnological production process is ongoing in parallel with technical development as well as the LCA modelling of applications and their principle competitors. Further adaptations of the applications and the functional units have to be done in parallel with technical development.
For the holistic view of the production process of biopeptides and their proposed application data collection for LCC and LCWE is in progress. Weak point analysis will identify main drivers of environmental and economic impacts.
An approach how to assess totally new developed technical material attributes/features, e.g. self healing surface due to self assembling properties, has to be discussed and set up.

References:

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