FOSTERING INDUSTRIAL SYMBIOSIS FOR A SUSTAINABLE RESOURCE INTENSIVE INDUSTRY ACROSS THE EXTENDED CONSTRUCTION VALUE CHAIN

Life-cycle costing of new processes, materials, and products

Executive summary

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Authors: Sarah Broberg Viklund & Rickard Fornell (RISE)

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Introduction

Circular economy and industrial symbiosis (IS) aim to create a more sustainable and resource-efficient way of supplying products and services to the market. The FISSAC project addresses the resource-intensive industries of the construction value chain, to develop and demonstrate a zero waste approach using an industrial symbiosis model. Hence it is important to evaluate these new production systems from an environmental, social, and economic perspective in order to ensure their benefits from a sustainability perspective.

Life-Cycle Costing (LCC), which has been used in this project, is not as standardized as Life-Cycle Assessment (LCA). The term is used collectively to include many different types of analyses e.g. economic investments, risk analysis, and reliability. The common denominator of the analyses is that they analyse costs throughout the entire life cycle of the product or investment (Figure 1).

Figure 1 –Different steps of a product life cycle

LCC assessment can be done from different perspectives:

- *Consumer perspective* – information needed for decision making is connected to the use phase and end-of-life phase, e.g. price of product, quality, taxes, and labels on the product.
- *Manufacturer perspective* – information needed for decision making is mainly connected to the cost of production and the effects on e.g. maintenance, operational costs, and raw material costs.
- *Society perspective* – the LCC will impact e.g. taxes and subsidies, on pollution/emissions, regional infrastructure, and on waste treatment.

The LCC assessment in this task was performed from a manufacturer perspective, i.e. there is a focus on the profitability/feasibility for making the investments in this type of integrated IS networks.
Life-cycle cost analysis is conducted in five steps:

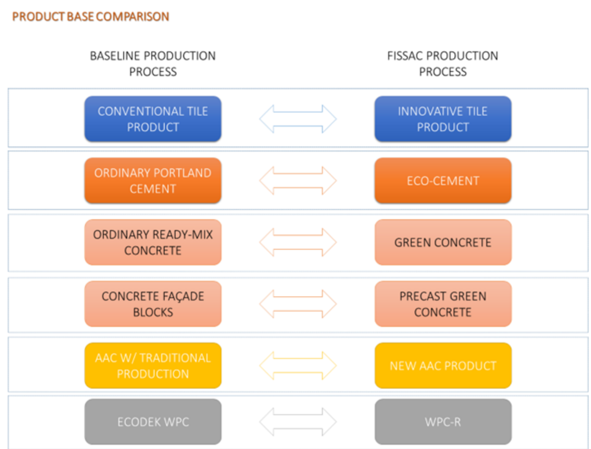
a. Problem definition
b. Methodology definition
c. Model development
d. Data collection
e. Results evaluation

As a part of the FISSAC project, a preliminary LCC screening was performed on a number of products that have been identified to have potential to use waste or by-product streams in an IS network. The aim of this preliminary LCC screening is to present a first evaluation of the economic sustainability of the products developed within the FISSAC project and make a preliminary assessment of the economic impact related to their entire life cycle. Expected results from this preliminary screening are mainly guidelines and aspects to consider in the continued work of the project. Recurring LCC assessments will be conducted during the project to continuously analyse and improve the processes and products addressed.

System boundaries

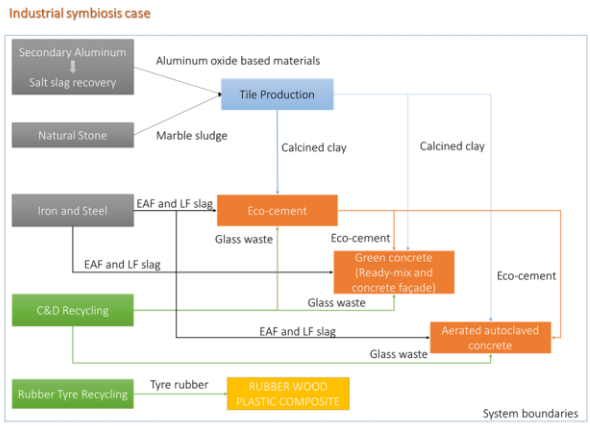
To enable comparisons on individual product- and production system basis, two different system boundaries were used. In the product-base comparison, each FISSAC innovative product was compared to a reference conventional product (Figure 2).

Figure 2 – System boundaries for product-based comparison



The second system boundary, the industrial symbiosis network, encloses and visualizes the different products and their connections when they are part of the same IS (Figure 3). The baseline for this comparison is conventional production routes for the baseline products. In this LCC analysis, the focus is upon the manufacturing process and mainly the changes made in order to implement an IS network.

Figure 3 – System boundaries for conceptual IS network



Both levels of comparisons consider the following foreground processes:

- Ceramic tile production (conventional and innovative tile production)
- Rubber wood plastic composite production (conventional and new composite floor)
- Cement manufacturing (Portland cement and eco-cement)
- Ready-mix concrete production (conventional and green ready-mix concreate)
- Aerated autoclaved concreate (AAC) production (conventional and green AAC)

Industrial symbiosis scenarios

Baseline scenarios involve the traditional industrial products described in the list above produced through conventional production processes. In FISSAC, the possible valorisation of industrial wastes in the form of secondary raw materials is reflected in different scenarios.

Two comparisons have been made. First the baseline products are compared with the new FISSAC products; innovative ceramic tiles, eco-cement, green concrete (conventional and AAC), and wood plastic composite. Second, at the industrial symbiosis case an eco-industrial park is conceptualised to manufacture the FISSAC products.

The project aims to establish applicability of a new conceptual IS network of the mentioned eco-products through valorisation of the industrial waste streams presented in the following sections. Data required for the LCC assessment on e.g. investment costs, manufacturing costs, and waste disposal is based on information collected from e.g. manufacturers involved in FISSAC and databases.

Ceramic tiles

The generic ceramic tile manufacturing process consists of a number of steps:

- Raw material preparation, milling, & spray drying: mixing components, wet milling the mixture, spray drying to obtain required moisture content;
- Pressing: tile forming through mechanical compression;
- Drying: to reduce the moisture content;
- Glazing and decoration: applying one or more coats on the tile;
- Firing: to create desired properties in the tile.

For the industrial symbiosis case two alternative raw materials for ceramic tile production, arising from natural stone slurry and aluminum waste slag, are investigated.

Wood plastic composite

Wood plastic composite (WPC) is a hybrid material composed of a mixture of natural wood fibers and plastic polymers. Wood fibers from e.g. wood, peanut hulls and bamboo are mixed with waste plastic at high temperature. The mixture is then molded into the finished product. A number of additives can be added to achieve desired properties. The studied process is virtually waste-free since excess materials from production can be re-granulated and fed back into the production process.

Rubber crumbs are added in the materials mix for WPC in the industrial symbiosis case.

Cement

Seven main steps constitute the cement manufacturing process:

- Crushing/grounding;
- Pre-homogenization (mixing of raw materials to required composition) and raw meal production (the mixture is milled into “raw meal);
- Preheating: reducing moisture content;
- Precalcining: decomposition of limestone to lime;
- Clinker production (the meal is melted into clinker in a kiln, cooling, and storing;
- Blending: the clinker is mixed with other minerals;
- Cement grinding: the mixture is ground into a powder.

Calcined clay from tile production and glass waste from construction and demolition recycling are new raw materials used in the industrial symbiosis case of eco-cement production.

Concrete

The properties of concrete are determined by modifying the proportions of the main ingredients. Concrete is produced by mixing together various ingredients. Main ingredients are: aggregate (a mixture of large chunks of materials, such as limestone, and finer materials, such as sand), cement (used as a binding material), water, chemical admixtures (to achieve varied properties), reinforcement (to increase the tensile strength), and mineral mixtures (use of by-products from industries).

For the production of green concrete, eco-cement, glass waste from construction and demolition recycling, and EAF slag from iron and steel production are used as raw materials.

Aerated autoclaved concrete (AAC)

AAC, also named cellular concrete, is one example of lightweight concrete. Four steps constitute the production process: mixing (cement & fine aggregates), addition of water, expansion (expansion agent added to the mix to increase the paste's volume), and reaction (a chemical reaction causes forming of air bubbles resulting in increased paste volume).

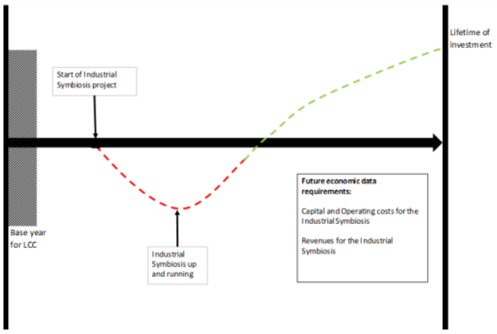
As for green concrete production, eco-cement and EAF slag from iron and steel production are used as raw materials in the production of green AAC. Additionally LF slag from the iron and steel industry is added.

The conceptual FISSAC eco-industrial park including the material flows described above are illustrated in Figure 3.

Life-cycle costing model and assessment method

The LCC analysis in FISSAC was made using product-based comparisons. The results of this comparative analysis should be able to reveal the potential feasibility of making investments in IS compared to business as usual (Figure 4).

Figure 4 – An example the effect of an investment in IS compared to business as usual



Due to its wider scope, full-cost accounting (FCA) was considered suitable for the LCC analysis and a net present value (NPV) based assessment approach was adopted under the scope of FCA. The LCC analysis in the overall FISSAC project will cover costs for investments, replacement, operation and maintenance, and end-of life costs. However, this first LCC screening does not contain such a comprehensive analysis, as necessary data is not available at such an early stage of the FISSAC project.

Conclusion

The purpose of this preliminary screening LCC was to point out the way for forthcoming developments in the project and the LCC assessments later on in the project.

At such an early stage of the project, where a conceptual eco-industrial park are studied with innovative FISSAC products, much of the information needed to perform a comprehensive LCC analysis according to the five steps presented in this report is missing. Therefore the focus of this executive summary is on the first three steps, step a, b, and c. These steps are presented throughout this report.

a. Problem definition: The problem has been clearly defined in coherent with the LCA, the system boundaries have been set and the purpose of the study explained.
b. Methodology definition: The methodology has been selected.
c. Model development: A model for LCC analysis has been developed.

In the continued work of the FISSAC project, the recommendation, based on this work, is thus to focus on the two last steps, step d and e; data collection and results evaluation. Since these two steps depend on each other, an improvement in data collection will also lead to an improved analysis of the results. Data collection is therefore the key to an improvement in the economic analysis and consequently the evaluation of the conceptual eco-industrial park.