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

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

Executive summary

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D3.1 Life-cycle assessment of new processes, materials, and products
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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 IS 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.

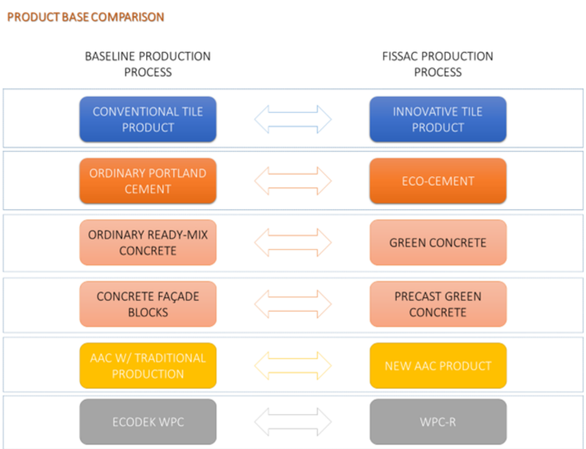
Life-Cycle Assessment (LCA), which has been used in this project, has become one of the major methods to assess environmental performance of products and services. LCA accounts for all flows of energy and material across the system boundary, and allocates the environmental impact and resource use between different outputs in multifunctional processes. Thereby LCA ensures a good overview of the environmental performance of a product or service.

The aim of the preliminary screening LCA that is presented here was to outline the environmental profile of the new processes and products developed within the project and make a preliminary assessment of the environmental impact related to their entire life cycle, i.e. production, application, recycling/disposal. Recurring LCA analyses will be conducted during the project to continuously analyse and improve the processes and products addressed.

System boundaries

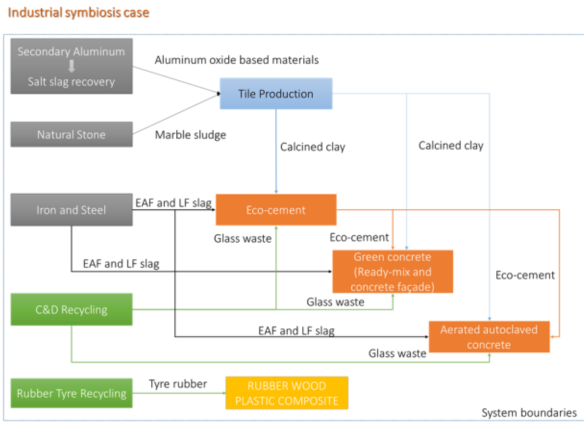
To enable comparisons on individual product- and production system basis, two different system boundaries were used. In the product-base comparison, the system boundary was drawn around the reference conventional products and the corresponding FISSAC innovative products (Figure 1).

Figure 1 – System boundaries for product-based comparison



The second system boundary, the industrial symbiosis network, encloses and visualizes the different products and their connections in the IS case (Figure 2). The baseline for this comparison is conventional production routes for the baseline products.

Figure 2 – 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 concreate production (conventional and green ready-mix concreate)
- Aerated autoclaved concreate (AAC) production (conventional and green AAC)

Background processes:

- Iron and steel production
- Secondary aluminum
- Natural stone processing
- Electricity generation
- Natural gas supply
- Diesel supply
- Road transport
- Raw material acquisition processes (limestone, sand, aggregate quarrying etc.)

Industrial symbiosis scenarios

Baseline scenarios involve the traditional industrial products previously described, 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.

Through the use of LCA methodology and software the environmental impacts from the production of the different products have been identified and quantified for the different scenarios. Data required for the LCA analyses on quantities, input and output in the different productions and life-cycle steps are based on information received from e.g. the manufacturers involved in FISSAC or previous scientific studies.

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 IS 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 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.

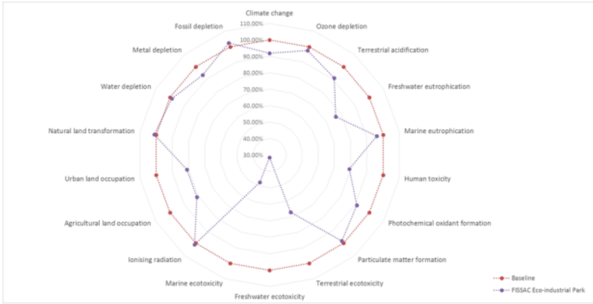
The conceptual FISSAC eco-industrial park including the material flows described above are illustrated in Figure 2.

Conclusion

Since this task presents the preliminary screening LCA the quality and quantity of data used are not complete. Such screening can give insight on what to be aware of in the continued developing of a product or system, but cannot give detailed results of their environmental performance. Consequently, the conclusions drawn are of a more general character and the focus of this task is rather to point out important aspects to consider during the further work within the FISSAC project. As the FISSAC project progresses, LCA analyses will be essential to give further and more detailed feedback on how the IS systems should be designed in order to deliver environmental gains.

On the industrial symbiosis level the results indicate that the overall environmental impact from the conceptual FISSAC eco-industrial park is lower than the baseline scenario (Figure 3). However, for several of the impact categories the differences are too small to draw any conclusions.

Figure 3 Comparison of overall impacts of a baseline production system and conceptual FISSAC eco-industrial park.



In the product-based scenario assessment not all individual products showed environmental benefits. This deterioration can however be offset by reduction of environmental impact by other production processes by using multi-sectorial synergies or logistics optimization in an eco-industrial park.

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