# Including Environmental Impact Considerations in the Business Model Innovation Process for Industrial Symbiosis

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*Published in:*
Proceedings of the 7th International Conference on New Business Models

*Publication date:*
2022

*Document Version*
Publisher's PDF, also known as Version of record

# Including Environmental Impact Considerations in the Business Model Innovation Process for Industrial Symbiosis

## The GAIA model

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## Extended abstract

### Introduction

Industrial symbiosis (IS) is a collective approach for an exchange, sharing, or transaction of excess resources (including materials, energy, and water) between organizations of traditionally separate industries (Chertow, 2000). Considered a means of realizing a circular economy (Sommer, 2020), the concept has received increasing attention in research in recent years (Mallawaarachchi *et al.*, 2020; Vahidzadeh *et al.*, 2021). IS can be seen as a way of improving the sustainability of individual companies' business models, as well as a way of creating collaborative business models (see e.g. Albino and Fraccascia, 2015) that are widely considered an archetype of circular business models in themselves (Bocken *et al.*, 2014; Phi *et al.*, 2020).

### Problem formulation

There are a variety of tools that practitioners can use during the IS development process. Much of the focus within the research field centres on the technical dimensions of IS, including digital tools (Kosmol and Leyh, 2019), process integration and mathematical optimization methods (Lawal *et al.*, 2021), as well as other methods assisting with ideation, concept development, and implementation.

For the assessment of environmental impacts, calculations using life cycle assessment (LCA) methods have been presented in several publications (Daddi, Nucci and Iraldo, 2017; Martin and Harris, 2018; Løkke *et al.*, 2020).

These calculations are, however, quite complex. Considering the time, competencies, and resources needed, LCA is perhaps more appropriate for expert use, and less suitable for practitioner use throughout the IS development process. There is currently no middle ground between a principle-based estimation, such as reuse being considered more advantageous than recycling, and conducting LCAs. This research aims to address this gap by presenting a practical tool for incorporating environmental impact considerations into the IS development process.

# Methods

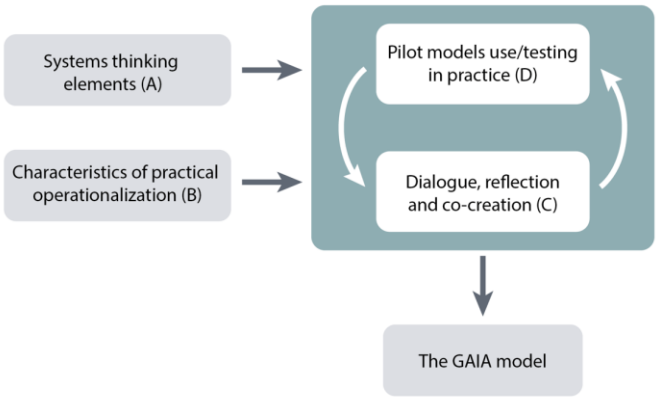


*Figure 11: The process of building and testing the GAIA model.*

During an IS facilitation project, the project team engaged in an iterative and co-creating process to develop a tool for pre-LCA environmental impact considerations.

## Systems thinking elements (A)

The model for Green Business Development through Industrial Symbiosis, hereafter `The GAIA model'[30], incorporated literature on systems thinking, both on a conceptual level and regarding the methods for mapping and analysing environmental impacts (Kørnøv, Lyhne, Nors, *et al.*, 2020). The three key concepts the model building process relied upon were: interdependency, feedback, and adaptation. The system modelling framework in consequential LCA formed the foundation for the model. With the question in focus being *"how will flows change in response to decisions?"* (Weidema *et al.*, 2018, p. 308), impacts of a decision within one system on a wider system were analysed.

## Characteristics of practical operationalization (B)

[30] To highlight both the analogy with nature that the concept of IS emerged through and the systems thinking principles that underlie our developed model, the name was inspired by the GAIA hypothesis. This hypothesis states that living organisms interact with their surroundings to form a synergistic and self-regulating and complex system (Lovelock and Margulis, 1974).

Inspired by the work of Alter (2011) and his recommendations for practitioner tools, the model was built with the intention to help: businesses *"organize and explore their own understanding"; "provide guidance"*; develop an understanding *"regardless of whether technical experts are available";* reduce the need for *"extensive data or new data collection"* (p. 1-2). In addition to *"typical business terminology"* (p. 1) being included in the model, the model was also designed to resemble the structure of the BM canvas (Osterwalder and Pigneur, 2010), which many practitioners are familiar with.

### Dialogue, reflection, and co-creation (C)

The elements from systems thinking and Alter's characteristics listed above were the building blocks for the authors' iterative process, anchored in dialogue, reflection, and co-creation of the model. The authors' experience and expertise within LCA, sustainability science, and business development was then used to develop an initial model of GAIA. Next, participatory action research involved working and co-creating with companies to explore the environmental impacts of BMs during the innovation process via use of the initial model. Special attention was paid to the relations and interactions between researchers (i.e., the authors) and the corporate representatives, as well as their potential implication regarding the validity and reliability of the study (Kørnøv *et al.*, 2016).

### Pilot models use and test in practice (D)

The use and test of the GAIA model in practice was an integrated element of an IS facilitation project in Aalborg, Denmark, with a focus on small and medium-sized enterprises. In total, 42 business model innovation processes were undertaken, spanning 16 different industrial symbioses in collaboration with 24 companies (Kørnøv, Lyhne, Schlüter, *et al.*, 2020). Informal feedback on the model was given during the collaboration. While the model was tested on all symbioses, its usability is highlighted in the present abstract through its application to two selected cases.

## Results

The GAIA model acts as a tool for considering the impacts of closing resource loops through an IS collaboration. The model is adopted at points in the process, where ideas regarding the potential application of excess resources emerge. Throughout the process of IS development, the tool is then populated by each party participating in the symbiosis.

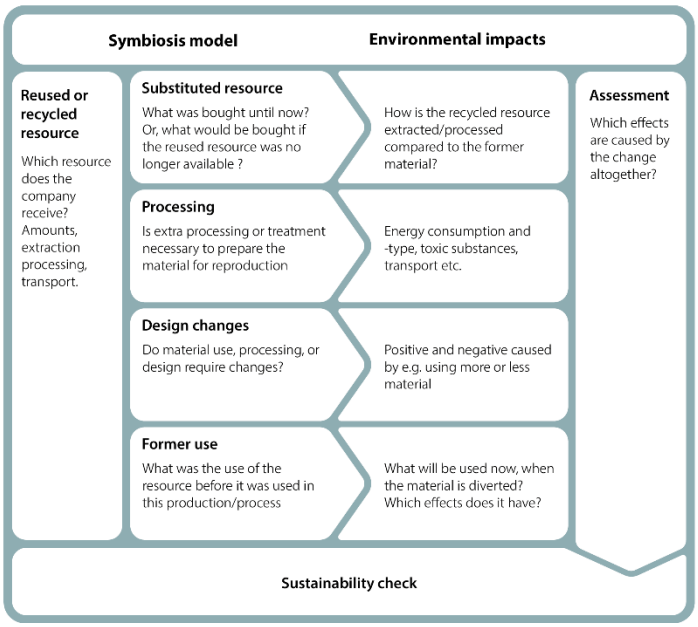


*Figure 12: The GAIA-model (Kørnøv, Lyhne, Nors, et al., 2020).*

The effects of using the GAIA model are exemplified through the following two symbioses:

**Case 1. Symbiosis between steel companies in an industrial area for the recycling of plastic sheets**

Minor plastic waste fractions, comprising corrugated polypropylene sheets, are used as a protective layer separating steel plates and sent for incineration at a local waste-to-energy plant. A shared logistical solution was designed to enable the collection of the fractions from multiple sites and their transport to a recycling facility.

**Case 2. Symbiosis between farms within the region for the recycling of agricultural foil**

Agricultural foils (agri-foils) comprise high-density polyethylene sheets primarily used to protect crops. The foil is rolled into bales up to 1km in length following use and sent for local incineration, with minor quantities recycled abroad. The IS concept describes a collection and recycling model for these fractions.

The application of GAIA to these cases highlighted several important interconnections and feedback mechanisms, and further illustrated the need for an adaptive system when implementing and assessing circular business models:

## Impacts

Local recycling and re-entry into the system will not only substitute another, possibly virgin, material, but will also help reduce the environmental impacts of transporting virgin plastic from a plastic producing company further afield (case 1 and 2). However, the sustainability of the business

model depends on how the newly collected waste plastic is recycled and what material it substitutes within the system.

## Feedback loop

A local logistical solution for both plastic types may reduce the economic barrier among companies within the area, thus positively impacting the sustainability of the wider system (case 1 and 2).

## Burden shifting

As plastic is diverted from local incineration plants, it is replaced by coal in the local energy system, which negatively impacts the sustainability of the business model. However, as the share of renewable energy in the energy system increases, the sustainability of the BM will improve. Another potential burden shifting occurs when multiple phases of processing results in increased energy and water consumption, both impacting the sustainability of the business model.

## Adaptations

The collected agri-foil must be cleaned before it is recycled. One adaptation identified by the use of the GAIA model, is that the weight of the foil can be minimised by rinsing the agri-foils on-site prior to collection, which helps to reduce the burden on fuel consumption during transportation to the recycling facility. Another adaptation relates to the fact that the foil requires further processing at a facility. Presently, there are no sites in Denmark which can recycle 1 km long agri-foil sheets. Thus, capital investment in new technology, additional staff, and the adaption of existing policies are needed.

## Conclusions

The uses of the GAIA model showed that a practical tool based on systems thinking and the consequential LCA paradigm can support the IS development process and give users a better understanding of environmental impacts, where feedback loops, burden shifting, and potential adaptations are considered.

Future research avenues lay in a better integration of the industrial symbiosis and circular business model concept and in the development of systems thinking principles for circular business models more generally.

# Keywords

Industrial symbiosis, circular economy, business model, environmental impact, systems thinking tool

**Acknowledgements.** This research has not been supported by external research funding. However, the research idea and content has been inspired by participation in the EU-supported project ‘Sustainable Synergies’, for which Aalborg University was the operator and which was funded by

the National Operational Program for the European Regional Development Fund, 2014–2020. We thank Anton Møller for the design of the graphics.

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