Business Value of Industrial Symbiosis

A comprehensive assessment with focus on synergies between Econova, Holmen Paper Braviken, Tekniska Verken and Holmen Timber

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Contents

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Summary

Industrial symbiosis (IS) involves resource management collaborations among multiple actors that are often from diverse backgrounds and geographically concentrated. The concept creates economic, environmental and social value by making improved use of otherwise wasted or underutilised resources and by developing products, services and utilities that are more sustainable. As such, IS offers a good potential to contribute to more circular and bio-based economies. Nevertheless, the practical employment of the concept remains inadequate.

The business value created by IS has a key influence on management decisions to develop and maintain synergistic relations. Despite its importance, business value of IS is seldom assessed, and existing assessments often focus only on reduction of input purchase and waste management costs and new revenues from the sales of residuals. Although IS has a strong potential to improve business performance in multiple additional ways, these are not considered adequately. Thus, business value of IS is often underestimated and this may be contributing to the limited support given to the concept from business and policy makers.

Our aim in this study was to create improved knowledge of the business value of IS and thereby stimulate further support for the concept. In order to meet our objectives, we first reviewed relevant literature from diverse fields and identified different ways by which IS could create business value. We grouped the diverse range of factors into five categories, namely: cost reduction; risk reduction; revenues, products and markets; stakeholder relations, and learning and innovation. We then used this framework in order to systematically capture diverse business value contributions of operational synergies between Econova, Holmen Paper, Tekniska Verken Linköping, and Holmen Timber. The main synergies we focused on involved the use of fiber sludge from paper making in gardening soil products and the use of bottom- and fly-ash in industrial work surface construction.

Despite the data limitations we faced, we identified significant cost saving and revenue generation benefits that are also common in other studies in the area. Going over and beyond, we found evidence of business value offered in diverse and numerous additional ways. These include, but are not limited to: reduction of operational, input supply, market and regulatory risks; development of new products that allow access to new markets; improving the image of the company for business partners, financiers, shareholders (and if on-going efforts succeed, soon for customers), and; improving innovation capabilities that stimulate operational efficiency and new product and service developments. Such comprehensive assessment with multiple new business value elements was certainly effective in increasing the recognition of the business value of IS within the studied companies. We strongly believe that further refinement of our approach (for example, in order to quantitatively assess risk reduction contributions) and its wider application to other cases should be supported, as this will better inform both businesses and policy makers about the significance of business value IS does or can create and thereby secure their increased interest and support.

1 Introduction

Industrial symbiosis (IS) refers to collaborative processes for resource management, where multiple actors from diverse sectors collectively identify and develop innovative solutions that create environmental, business and development value[1]. In recent years, there is a growing interest in the concept, in recognition of its potential to contribute to the development of more circular- and bio-based economies[2].

The business value created by IS has a key influence on management decisions regarding the development and maintenance of synergistic relations. Despite their importance, studies on the business value of industrial symbiosis remain limited and majority of these, almost exclusively, focus on reduction of input purchase and waste management costs and new revenues from the sales of by-products[3]. Although, industrial symbiosis, and other relevant, literature highlight a much wider set of business value potentials–albeit in a scattered way–these are inadequately taken into consideration in relevant assessments. Such studies only provide a partial picture of the business value industrial symbiosis actually creates and therefore may result in securing sub-optimal support both from businesses and policy makers. Our aim in this study was to help fill this gap by attempting to create improved knowledge of the business value of IS. In order to do this, we focused on operational synergies involving resource exchanges and collaborations between Econova AB, Holmen Paper Braviken AB, Tekniska Verken AB, and Holmen Timber AB. Our objectives were to:

- Identify different ways by which IS can potentially create business value?
- Identify and analyse business value created for the studied companies through their operational synergies.

1.1 Method and limitations

In order to reach our aim, we first conducted a thorough literature review–focusing mainly on IS but also other relevant fields such as corporate environmental management and inter-organisational management–and identified a wide spectrum of means by which IS can create business value. We then clustered these into five main groups related to: cost reduction; risk reduction; revenues, products and markets; stakeholder relations, and; learning and innovation. Afterwards, we determined the data requirements of assessing performance within these categories and developed data sheets and interview guides to assist the data collection. As our desktop research only provided a limited part of the required data, we relied on company representatives as our main source of data. In all four companies, we had half-day sessions with group discussions and plant walk-arounds, during which time we discussed different aspects related to company operations and synergistic relations in focus. We compounded these with semi-structured interviews with relevant managers from all companies. We processed the data quantitatively and qualitatively as needed to assess and identify business value created and to form our findings.

We were only able to access part of the data we hoped for to perform all the assessments we had in mind. This was particularly limiting for the quantitative assessments we intended. Relatedly, some of the parameters we wanted to quantify, we were only able to assess qualitatively. For some of the qualitative areas information was also inadequate. Such limitations emerged due toa combination of data/information not being readily available and informants having limited time

[1] (Mirata et al. 2017)
[2] (Gustafsson et al. 2011; Johnsen et al. 2015; European Commission and Directorate-General for Research and Innovation 2012)
[3] (Chertow and Lombardi 2005; Jacobsen 2006; Van Berkel et al. 2009)

and/or inadequate interest in our study. In order to assist future assessments the parties may choose to perform if the data gaps can be filled, we developed templates that may aid future assessments.

2 Overview of the case companies and studied synergies

This study focused on four companies and their synergistic relationships. A brief overview of the companies is provided below.

Econova AB was founded in 1959 as a road construction company for the forest industry. It expanded its business in the 1970's and started to recycle bark to create soil. Over the years the company has diversified its recycling activities and its products. Today the company profiles itself as an environmental integrator – taking care of material traditionally seen as waste and transform it into a valuable resource. Gardening soil, wood fuels, cover material for landfills and hard surface material are some of their recycled products. Company's operations in Braviken, just outside Norrköping, produces around 60 000 t/y (~ 120 000 m^3/y) of gardening soil.

Holmen Paper Braviken AB is part of the Holmen group and produces printing paper for magazines, books, catalogues and newspapers through thermo-mechanical pulping of virgin wood fibers. In 2016, they produced 520 000 tonnes of paper using which 1.15 M m^3 of wood. In recent years, the company has been shifting its production towards higher-grade speciality printing papers with lower-weight and higher durability.

Tekniska Verken AB is a publicly owned utility company delivering electricity, district heating and broadband, to water, waste management and biogas to the region of Östergötland and serving 230 000 customers. The electricity and district heating are produced in a CHP plant fuelled with household waste and biomass, leaving ash as a waste. In 2016 TV has incinerated just below 570 000 tonnes of industrial and household waste, which generated around 120 000 and 18 500 tonnes of bottom- and fly-ash, respectively. The majority of fly ash was sent to Norway for backfilling. Following processing for metal recovery, the bottom ash is used as construction material or for landfill covering or is landfilled.

Holmen Timber AB is a sawmill located close to the Holmen Paper mill and produces different sawn timber products. The plant became operational in 2012 and in 2016 produced 440 000 m^3 of sawn goods from 1.1 Million m^3 of raw wood. Both figures are expected to increase by about 30% when the mill reaches its full capacity.

In our study we focused on the following synergistic relations.

2.1 Fiber mulch production from fiber-rich sludge

The wastewater treatment operations of Holmen Paper (HP) generate a fiber-rich sludge. After dewatering, about a quarter of this sludge is combusted on-site by HP to meet the energy demands of the paper mill, as well as neighboring sawmill since 2012[4]. The remaining part is considered waste, and needs to be handled as such. Since 1977 this fraction has been handled by Econova, who composts the sludge and uses the resulting fiber mulch, referred to as "fibermull", as an additive in the production of gardening soil. Econova performs composting and mixing operations on a land adjacent to the paper mill, which is owned by HP. The amount of sludge generation has decreased over the years–both due to reduced overall production and due to

[4] The energy synergy between the paper mill and the saw mill constitutes another synergy, but this was not investigated in this study as the focus was kept on those involving material exchanges and where Econova has an active role.

product and process modifications in the mill. During the time of this study, Econova was processing about 45 000 t/y sludge, producing approximately 41 000 m³/y of fiber mulch.

2.2 Waste wood as fuel

Another synergistic relation, that is relatively understudied in this exercise, includes the provision of waste wood as fuel to Holmen Paper by Econova. Such waste wood not only substitutes fuel-oil needed, but also provides a better fuel mix and allows increased utilisation of internally produced by-products as fuel.

2.3 Industrial work-surface construction using bottom ash

Bottom ash arising from combustion of bio-fuels and household waste has hydraulic characteristics, allowing its use as a binding material. Taking advantage of such characteristics, Econova launched a new product called Econova's Cement-stabilised Ash (Econovas cementstabiliserande aska) referred to as ECA. It is a working surface constructed by mixing bottom ash, cement and course gravel and is considered to offer benefits when used in industrial areas with tough operational conditions (such as heavy loads and vehicles, high abrasion on the surface an so forth). ECA is particularly applicable for Waste treatment plants, recycling plants and other heavy duty applications where heavy trucks go for different applications. Every square meter of ECA surface produced, uses approximately 375 kg of ash[5], and in the process substitutes an equal amount of cement. In 2016. 1 125 tonnes of fly-ash and 5 250 tonnes of bottom as was valorised as ECA and used for the construction of industrial work surfaces for Holmen Braviken Sawmill. .

3 Business value of industrial symbiosis

Following a review of industrial symbiosis[6] and other relevant literature (from strategic environmental management and inter-organisational management fields)[7] we identified a wide range of dynamics by which IS can create business value. While also including the commonly assessed factors of cost reduction and revenue generation, our list includes a number of additional factors to be considered. We clustered these under the heading of: cost reduction; risk reduction; revenues, markets and products; stakeholder relations, and; learning and innovation. These categories and some of their important sup-components are shown in Figure 1. Our findings from studied cases within different categories are summarised below:

3.1 Cost reduction

Industrial symbiosis can influence costs, among others, by providing cheaper input supply and waste management options; by affecting investment requirements, and by impacting operational complexity and efficiency, and by reducing transportation and logistics needs. Studied synergistic relations have considerable cost implications.

[5] Approximately 25 cm of ash is used in ECA surface construction and ash has a density of 1.5 t/m³.
[6] (Chertow and Lombardi 2005; Jacobsen 2006; van Beers et al. 2007; Van Berkel et al. 2009; Domenech and Davies 2011; Short et al. 2014; Iacondini et al. 2015; Yuan and Shi 2009; Veleva et al. 2015; Paquin et al. 2015; Iacobescu et al. 2016; Sharib and Halog 2017; Mirata et al. 2017; Mirata 2005)
[7] (Hart et al. 2003; Forest Reinhardt 2000; Renato J. Orsato 2006; Dyer and Singh 1998; Boons et al. 2013)

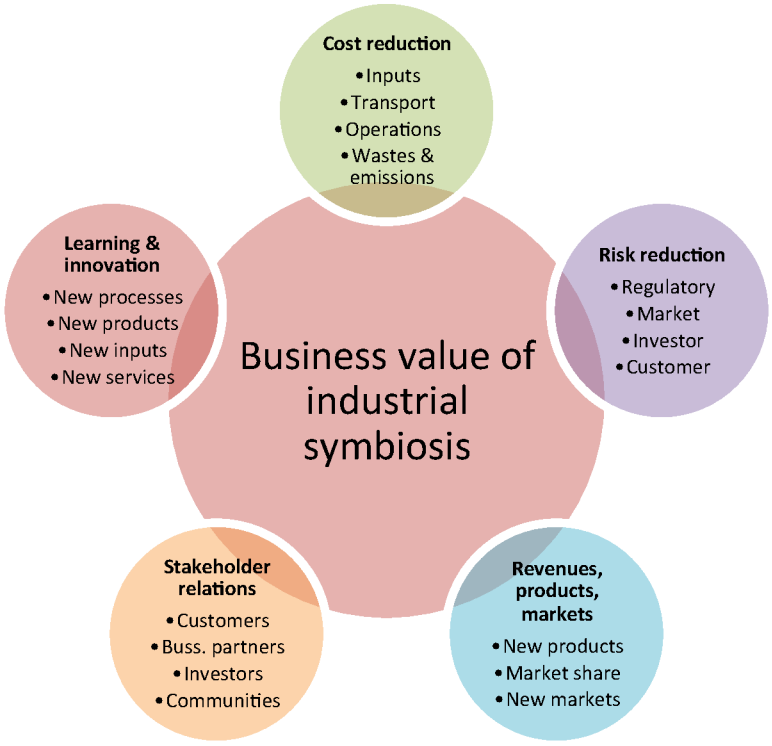

Figure 1: Dimensions of business value creation by industrial symbiosis.

By having Econova to compost the fiber-sludge into a soil additive, HP is able to avoid alternative waste management options–such as usage as surface cover (in roadside embarkments and in landfill areas), alternative composting, or incineration–that are significantly costlier. Current dynamic's cost is 3.6 and 7 times lower, as compared to costs of next feasible option and incineration–resulting in annual savings in excess of 8 and 19 M SEK, respectively[8]. HP also recognises that partnership with Econova enhances its operational efficiency and thereby reduces associated costs. This is linked to the fact that the company does not need to (within limits) worry about volume and quantity fluctuations with the sludge or apply any complex and/or costly treatment(s) to it. For example, another Holmen plant performing similar production in Hallstavik has decided to compost the sludge in their own capacity, which required sizeable investments and continuously requires operational resources. Lastly, by using wood-waste derived fuel supplied by Econova, HP is able to use an increased proportion of internally produced bark and sludge as fuel, in the process reducing both energy and waste management costs. These were not possible to quantify within the scope of this study.

Further operational flexibility and cost reduction benefits are provided to Holmen Paper by the preservation of space in own landfills. Even before 2005, when landfilling of fiber sludge would have been an attractive possibility, the sludge was handled for mulch production. As a result, it is estimated that the company has preserved more than 1.3 M[9] m^3 of landfill space, which can now be used for other wastes (e.g. ash) whose external management appears to become increasingly

[8] Calculation based on annual sludge amount of 45 000 tonnes, and cost of alternative composting and incineration being 180 and 430 SEK/tonne higher, respectively, than current practice.
[9] This is an educated estimate, and is not based on real historic data.

problematic and/or costly[10]. Having used the landfill space sparingly also helps company to delay the final covering costs, estimated to be between 20 to 30 M SEK.

Tekniska Verken also saves bottom-ash handling costs, when the material is valorised in the construction of ECA surfaces. For the time being, bottom ash is primarily used for the construction of roads and other permanent structures on TV's site, but this activity is expected to last only for another five to six years. Afterwards, the least costly alternative would be to use ash for similar applications but externally. This option would entail a cost that is more than twice[11] the cost of taking the ECA route. When the landfill-covering market is saturated and landfilling remains as the most feasible alternative, valorising ash as ECA will avoid costs that are at least 5 times higher.

Econova also derives significant cost benefits from synergies. Thanks to its desirable characteristics–such as better water holding structure, higher pH value, and higher organic content–using fiber mulch in soil products reduces the need for virgin and more expensive inputs–most notably peat, but also chalk and fertilisers. These substitutions provided at least 3 M SEK cost savings in 2016[12]. This corresponds to approximately18% reduction in material costs and 10% reduction in total production costs. It is important to note that currently Econova sources an important share of its peat needs from its own marshland, which is expected to remain productive for another four to five years. However, the process of harvesting peat is unpredictable and depending on dry weather conditions during a short harvest season; so for those years when own production is not optimum, cost savings are likely to be higher. Upon depletion of this marshland, the company will need to meet its peat needs from the market at a higher cost and by then fiber mulch use will enable at least 5.6 M SEK/y savings, resulting in 29% and 18% reductions in material and total operational costs, respectively[13] . Also worth noting is that Econova is working on new by-product synergy potentials with actors outside the scope of this study, which holds the potential for reducing the company's costs for lime inputs by more than 50%[14].

Additional benefits are provided to Econova due to improved operational stability and efficiency. One reason is that fiber mulch is a better input for soil production. Externally sourced peat comes in different structure in each delivery and requires operational adjustments to ensure product specifications. Fiber mulch characteristics, on the other hand, show little variations over time. Moreover, thanks to close communication between the companies, Econova receives timely information regarding changes impacting the sludge and can take necessary measures to reduce disruptions. This improves production efficiency and costs. Ability to perform operations on Holmen's land also allows Econova to significantly reduce its logistics costs for material transfer and equipment mobility, the latter of which allows the company to offer competitive services to the nearby Holmen Timber mill.

Having ECA working surfaces also provide cost savings to Tekniska Verken, Holmen Timber and Econova (operating on Holmen Paper's land). The development cost of the surface is around three times cheaper than concrete and comparable to asphalt, but due to its superior structural stability expected to last longer than asphalt. Relatedly, its use reduces development and maintenance costs. Its use, on the other hand, eliminates contamination from bare ground and this improves product (in the case of Econova and Holmen Timber) and fuel qualities (in the

[10] The author recognizes that this dynamic implies saved capacity for an option that is low on the sustainable waste management hierarchy. Nevertheless, having such preserved capacity does constitute a business advantage under currently prevailing conditions.
[11] More precisely, such alternative will entail a cost 2.3 times higher, if the ash is handled in Häradsudden landfill site and if the ECA application was to take place in Braviken.
[12] Based on the highly conservative assumption that all the fiber mulch substitutes peat sourced from company's own marshland, which has a lower cost. Chalk and fertilizer cost reductions are estimations by company representatives.
[13] Provided that production volumes and peat market prices remain at the same level as 2016.
[14] Although lime purchas does not represent a large cost for the company, 50% reduction is substantial.

case of Tekniska Verken) by eliminating contamination from bare soil. Operational ease and costs in all companies are also improved as heavy vehicles can operate more easily and using less fuel on ECA surfaces. Moreover, better work environments are provided to the employees[15].

3.2 Risk reduction

Symbiotic relationships can reduce risks related to supply-, operations-, market-, product-, and regulations. Examples of these were encountered in studied cases including the following:

To start with Econova, use of fiber mulch helps the company to reduce the supply risk with peat, which will become higher once company's own marshland is depleted and supply will become more dependent on external and further-away providers. Fiber mulch also helps mitigating regulatory and market related risks. In some other countries, such as Germany, there are regulations that prohibit the use of peat in commercial gardening soil. Furthermore, at international climate meetings it has been stated that the mixing in of peat is not acceptable if the soil is to be labelled with any eco-label. If these attitudes were to spread to Sweden and the regulation made peat use harder, Econova will have a front-runner's advantage in the market, as they already have necessary knowledge and operational expertise in place.

For Holmen Paper, the partnership with Econova helps address a critical operational risk, linked to reliable and cost-efficient handling of a waste stream that arises continuously in large quantities and with fluctuating quantitative and qualitative characteristics. Composting of this waste stream by Econova, therefore, enable operational stability and continuity that are both critical. As stated, alternative treatment options are costly and/or are difficult and require more strict management of sludge properties. Thus, the long-term partnership with Econova eliminates a potentially critical operational bottleneck.

Similarly, for Tekniska Verken, which produces large quantities of ash, finding productive uses for ash outside their own operations is very important. To this end, using ash as a component in ECA represents a good opportunity to help address future business bottlenecks. Both Holmen and Tekniska Verken also hold that the trend with ever tightening environmental regulations is likely to persist and within such a landscape handling of waste streams through Econova's productive approaches help reduce regulatory risks.

However, there are also dynamics that affect the risk profiles adversely. For example, as we established above, fiber mulch is becoming increasingly important for Econova. However, over recent years sludge quantities displayed a decreasing trend– influenced primarily by the changes in printing paper market but also due to product changes and internal optimization developments in Holmen Paper. As sludge is a by-product whose characteristics are governed by changes on main products and production processes and for which there is no dedicated optimization effort, it is more susceptible to fluctuations. However, both companies believe that sludge quantities are likely to remain the same and may even increase slightly and the handling fee is also expected to remain at a comparable level. There is also a regulatory risk regarding the bottom ash being classified as hazardous waste in the EU, which may limit its availability for ECA applications. The uncertainty regarding the long-term immobilization of pollutants contained in the ECA also gives rise to inter-connected product and regulatory risks, resulting in decreased acceptance from clients and regulators, in times caused by lengthy permitting procedures. This risk is particularly relevant for Tekniska Verken, where ash quantities are already high and are expected to increase further.

[15] ECA surfaces have not been in use long enough to provide reliable information on the maintenance needs. Furthermore, companies were not able to provide a reliable estimate of reduced machinery operation costs, or the worth of improved product and fuel characteristics, linked to improved surface characteristics. Therefore, savings connected to ECA are not possible to estimate at this stage.

3.3 New revenues, products and markets

For Econova, symbiotic relations have resulted in two successful new products (fiber mulch from sludge, and ECA from bottom ash) creating new revenues. In addition, fiber mulch use allows Econova to generate additional income by selling the peat–that would otherwise be used in own production–to the market. Additional extra revenues generated through these two dynamics are estimated to be in the vicinity of 3.5 M SEK in 2016). It is also held that both of these products also offer distinct environmental–and in the case of ECA, safety[16]–qualities. However, so far it was not possible to successfully create a differentiated product, as the companies using such material do not value the environmental and safety features enough to pay a premium. The experimental "100% recycled soil" product launched in 2016 at a premium price, saw lower demand than expectations. However, it received "the gardening product of the year" award, and thereby raised company's profile in the market. Current lack of customer demand is considered to be due to a combination of limited knowledge and interest in the quality of the contents of the soil products and price taking a priority in purchasing decisions. Econova recognises that by better informing key customer segments and raising their awareness of the positive values provided by secondary resource use, this dynamic can be favourably influenced[17]. Holmen Paper and Tekniska Verken also acknowledge that they have limited active environmental branding efforts, leaving a potential market opportunity untapped.

Its partnership with Econova also provides additional benefits to Holmen Paper. These arise partly from the renting of land and partly from the use of waste-wood "Returträ" derived fuel supplied by Econova, which increases the availability of wood residues that can be sold at a higher price in the market.

3.4 Stakeholder relations and image

As illuminated above, all companies acknowledge that their synergistic relations have a potential to improve company reputation, which is inadequately utilised today. Companies like Tekniska Verken are concerned that such marketing can be perceived as greenwash, as the amount of waste valorised through the synergies is only a fraction of the total. In addition, and as also illuminated earlier, companies highlight that external stakeholders generally lack awareness of industrial symbiosis and its benefits and this limits their ability to use their symbiotic practices for improved image. Nevertheless, industrial symbiosis is seen as a timely concept around which there is increasing awareness and interest. Therefore, the companies believe that their established practices will be increasingly important for creating additional reputational value.

Of the companies studied, Holmen Paper and Econova appear to derive most reputational value from their synergistic relations, although none of them have any active initiative to this end. Holmen paper, for example, faces an increasing demand from customers and rating agencies to provide environmental information, including on waste management. Ability to report a productive use for sludge is well-aligned with and supports HP's image of being a company with strong sustainability performance (The Holmen Group is a Global 100 member). Econova, on the other hand, is increasingly recognized as a good partner which can effectively create higher utility from waste products. This is manifested by the fact that the company is involved in an increasing number of dialogues and negotiations with diverse actors for creating value from secondary resources.

Top level management of all involved companies also recognise industrial symbiosis as strategically important and creating shareholder value.

[16] Asphalt is prone to generating toxic fumes in case of fire exposure; whereas ECA is free from such risks.
[17] By the time this report was prepared, a workshop aimed at raising customer awareness was already planned.

3.5 Collaboration enabled learning and innovation

Last, but certainly not least, the synergistic relations stimulate closer collaboration, provide valuable learning, and enhance innovative capabilities. For Holmen Paper, for example, its relationship with Econova provides useful ideas and knowledge in areas which are non-core and therefore limited internal resources are allocated for improvement. Over the years, Holmen Paper received a number of improvements ideas from Econova and by implementing some of these realised cost savings and operational improvements.

Synergistic relations also enhance innovative capabilities of companies, as it allows them to tackle problems of common concern with a richer set of knowledge and competencies. This results in the generation of new ideas and supports their development potential. Within the flow of this project, two such outcomes was realised during one of the project meetings. Here project partners brainstormed around alternative uses of bottom ash, identified a new possibility, and elaborated on relevant courses of action for its further development. Similarly, in the same event the possibility of utilising digestate from biogas production as fertiliser in soil products was identified. The dialogue initiated by then is on-going, and currently focuses on possibilities of pelletising digestate, which will enable its use as a fertiliser substitute.

Collaborative relationships also provide the actors with additional benefits. For example, for a company like Econova who works with residues, it is important to have a continuum of projects where residual materials can be revalorized. To this end, Econova has received important business benefits by gaining access to new clients thanks to positive references provided by Holmen Paper.

4 Concluding remarks

Although becoming gradually more common, industrial symbioses remain under-developed and have a large potential for scaling-up. As the concept presents a major shift from the traditional industrial model and entails higher complexity, it receives limited interest from business decision makers and sometimes also faces reluctance. In such a situation, properly capturing and communicating the business value industrial symbiosis has a strong potential to secure increased interest and support. In this study we attempted this, by moving beyond input and waste management cost reduction and additional sales of by-products and by systematically searching for evidence for business value created by industrial symbiosis in multiple dimensions. Despite the data limitations, we were able to demonstrate that, in addition to considerable cost savings and new revenues, industrial symbiosis offered meaningful contributions related to: operations, regulatory, input-supply and market related risk reduction; new products development and access to markets; improved image towards, and relations with key stakeholders, and; improved innovation capabilities. These we believe, can be at least as important and their consideration certainly provides a more complete picture of the business value IS provides. Our findings already facilitated increased recognition of the benefits of IS within the companies who were involved in the study. We strongly encourage further refinement of our approach and its wider utilisation in other cases for more comprehensive assessments of the business value IS does or can create. We believe that the improved knowledge created this way will be effective in securing increased interest and support for IS, both from business leaders and from policy makers. This will help accelerate progress towards more circular and bio-based economies.

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