International Labour Organization

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Research Brief

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Industrial symbiosis networks as part of a circular economy: Employment effects in some industrializing countries [1]

Key points

- Industrial symbiosis is a form of circular economy where exchanges of waste, by-products or other resources between enterprises generate competitive advantages.
- Industrial symbiosis networks can be either spontaneously created by private enterprises or established with the support of associations or public institutions.
- Industrial symbiosis does create employment. The quality of the jobs created, however, is not guaranteed.
- Besides making a small contribution to the transition to formality, another positive impact of industrial symbiosis networks is on job retention.
- Greater efforts are needed to fill the decent work deficits identified, in particular in the areas of gender equality and formalization, and to attain the SDGs, especially Goal 8.

Purpose

Industrial symbiosis networks as an expression of the circular economy can constitute a valuable contribution to developing economies' efforts to build a solid industrial sector in a sustainable manner. In many emerging economies in Latin America, such schemes have been set up and are on the rise.

The circular economy can be defined as a production and consumption model involving sharing, leasing, reusing, repairing, refurbishing and recycling materials and products (European Parliament, 2021), thereby minimizing waste. Industrial symbiosis is a form of circular economy where exchanges of waste, by-products or other resources between enterprises generate competitive advantages (Martin and Harris, 2018). A more detailed explanation is provided below, along with some examples of how industrial symbiosis can be applied. Most of the findings set out in this brief have been taken from country studies conducted in Argentina and Colombia under an ILO research project on industrial symbiosis.[2]

[1] This brief is authored by Sabrina De Gobbi, Technical Specialist, Research Department, International Labour Office.

[2] Information on Argentina and Colombia are entirely taken from Abriata and Masut (2021), and Rios and Rodrígues (2021).

Examples of industrial symbiosis have been recorded all over the world, including in Brazil, Mexico (Neves et al, 2020), Argentina, Colombia and Costa Rica.

In a comprehensive review of industrial symbiosis, Neves et al (2020) highlight the fact that while the positive environmental and economic impacts of the cases considered are examined in detail, the social dimension, including labour, remains neglected. Despite some industrial symbiosis initiatives being launched with the intention of creating jobs (E.G. Grangemouth in the United Kingdom and Dunkirk in France), the employment effects of industrial symbiosis networks in general have rarely been studied.

The purpose of the present brief is to examine the employment impacts of some industrial symbiosis schemes, from the perspectives of both quantity and quality (gender, informality, working time and wages). The characteristics of industrial symbiosis networks and their enabling environments will be presented, starting with some experiences from Argentina and Colombia. Lastly, recommendations will be made on policy measures to promote industrial symbiosis networks and improve the quality of the jobs they create.

Industrial symbiosis networks: What are they and how do they work?

Industrial symbiosis originated over 50 years ago in Kalundborg, Denmark. It is a subdiscipline of industrial ecology, an environmental framework according to which the industrial world can function as an ecosystem characterized by webs of interaction among companies (Lowe and Evans 1995). The Kalundborg case is described in Box 1.

▶ Box 1: Industrial symbiosis in Kalundborg: Origins and development

This network spontaneously originated and developed in the late 1960s. The goal was to reduce waste by finding alternative ways of using it to generate profit. Over time, the network's members realized that they were also generating environmental benefits. The five core partners are a coal power station, an oil refinery, a plasterboard factory, a pharmaceutical manufacturer, and the Kalundborg municipal authorities, which supply water and heating. These entities developed a network of exchanges between each other and with other smaller companies.

The power station provides steam to the refinery and to the city for heating and hot water; excess energy from the power plant is used for fish farming; the refinery supplies excess gas to the plasterboard factory; fly ash from the power station is used by a cement firm; sludge from pharmaceutical production and from the fish farm's water treatment plant is used as fertilizer. These are just some examples of the existing interactions.

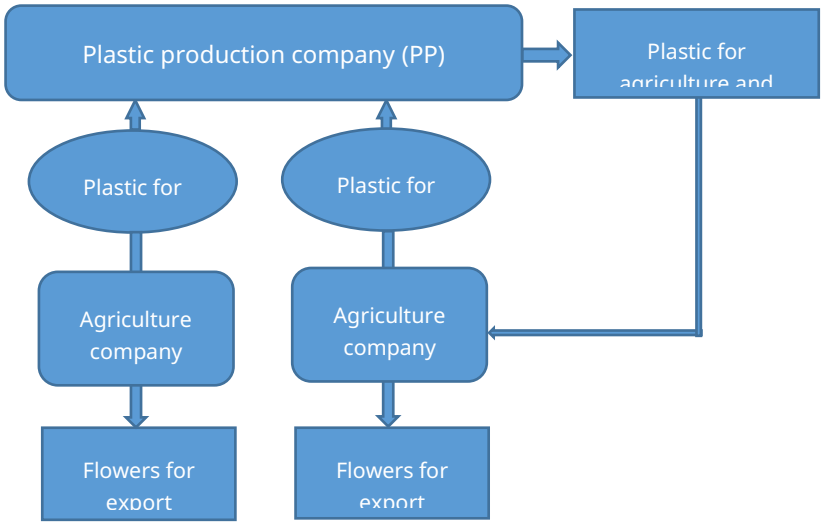
The network's evolution was not planned; it simply developed from one-to-one exchanges that made economic sense for pairs of participants.

Source: Lowe and Evans, 1995.

The characteristics of the Kalundborg network are reflected in the definition of industrial symbiosis proposed by Chertow (2000). Industrial symbiosis networks engage "traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products." (Ibid). Collaboration and geographic proximity between member enterprises are two key factors for setting up these schemes. They are typically established within the industrial and manufacturing sector, but often involve economic activities in other sectors (see Figure 1). Figure 1 gives an example of the companies involved in a small industrial symbiosis network; many more firms can be involved. Usually, a large company initiates the scheme, engaging other firms along its value chain.

▶ **Figure 1: An industrial symbiosis network from Colombia**

	PP	AG2	AG3
Economic sector	Manufacturing	Agriculture	Agriculture
Company size	Large	Large	Large
Percentage of female employees	40%	48%	49%



Source: Ríos and Rodrígues, 2021.
(Key: oval = wastes and by-products; rectangle = end products; rectangle with round corners= enterprise surveyed)

In the above example, AG2 and AG3 are enterprises from the agricultural sector which export flowers, while PP is a manufacturer of plastics for industrial and agricultural use. AG2 and AG3 give dismissed greenhouse cover plastics to PP. PP returns new black plastics to AG3 and pays the corresponding price for the received goods to AG2. Over a period of about 12 years, PP has developed exchanges of by-products, waste or other materials with some 25 firms.

Methodology

To study the employment impacts, primary and secondary data were considered. A total of five industrial symbiosis case studies were examined: three from Colombia and two from Argentina, where industrial symbiosis is applied to two complete value chains. Primary data were obtained through surveys completed by companies that are part of industrial symbiosis networks. Semi-structured interviews were conducted.

Different methodologies were applied in the two countries. In Colombia the method proposed by Martin and Harris (2018) was applied with some improvements. Three mechanisms were identified for job creation: (a) the development of new activities, such as waste collection, screening, classification and cleaning; (b) the generation of savings by reducing production costs; and (c) a production increase owing to the use of waste and by-products. In Argentina, employment multipliers were estimated. Direct, indirect and induced employment effects were assessed using data obtained from surveys and interviews conducted with enterprises, as well as information from secondary sources. An activity effect and a substitution effect were considered. This methodology shows that the additional jobs would have not been created without industrial symbiosis. Since this method is applied to the entire value chain, the employment effects are greater.

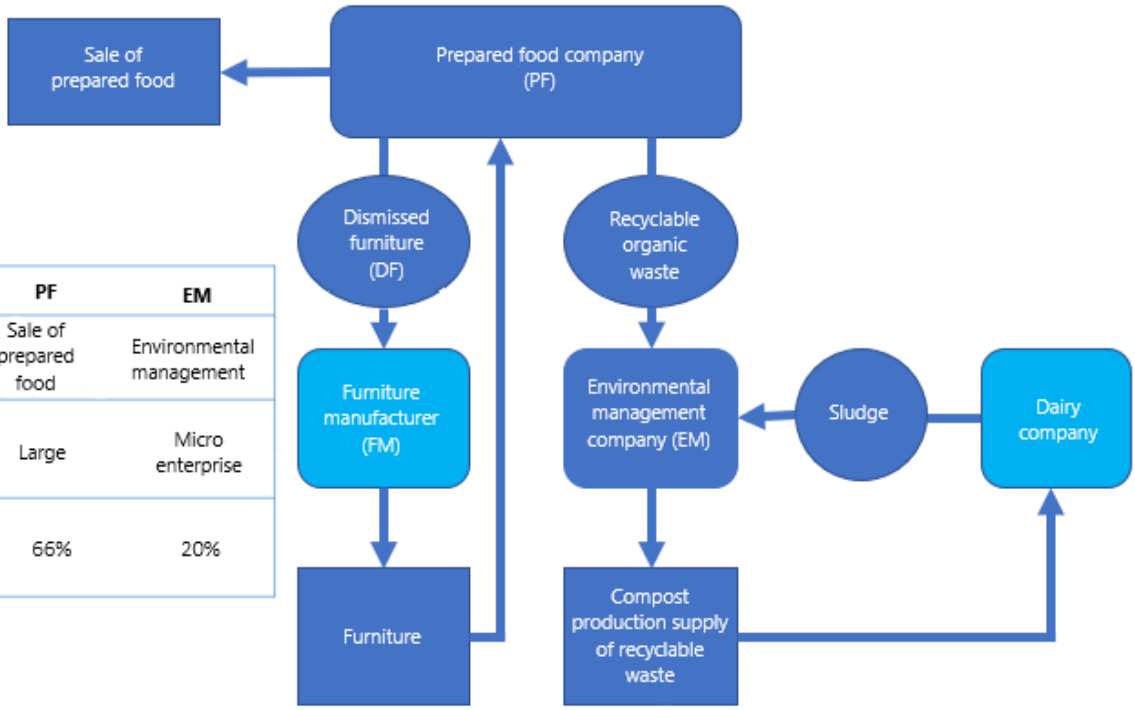
Quantitative employment impacts

Obtaining data on the impact of the circular economy on employment creation can be challenging, owing to the relative novelty of the concept. Furthermore, there are no databases containing statistical data on enterprises engaged in industrial symbiosis networks. Examining existing data on recycling activities in general may be helpful, since industrial symbiosis falls under that category. For Colombia, an estimate of firms engaged in recycling activities was calculated using data from the national household survey 2019 and the Annual Manufacturing Survey 2018. Of all manufacturing companies, only 8.5 per cent used wastes as inputs, and as little as 2.7 per cent traded waste products. It is therefore easy to conclude that few jobs are generated by recycling and industrial symbiosis in the manufacturing sector.

The analysis of industrial symbiosis networks in Colombia and Argentina included a clear assessment of the employment effects of such schemes, although on a very small scale. Enterprises from a variety of sectors ,not just manufacturing, were analysed.

In the case shown in Figure 1, 30 new jobs were created and 14 retained across the three enterprises. Considering the employment effects per firm as percentages of total jobs per company, new positions were created in PP and AG2, which are both large businesses, representing 2.5 per cent and 0.6 per cent of their total employment, respectively. The impact of industrial symbiosis can be much greater in small and microenterprises . Additional findings from the same study on Colombia revealed that in a microenterprise, three new jobs were created, which is 30 per cent of its total employment. Figure 2 shows this case, in which EM, an environmental management firm, is the growing microenterprise.

▶ **Figure 2: A Colombian industrial symbiosis network including a growing microenterprise**



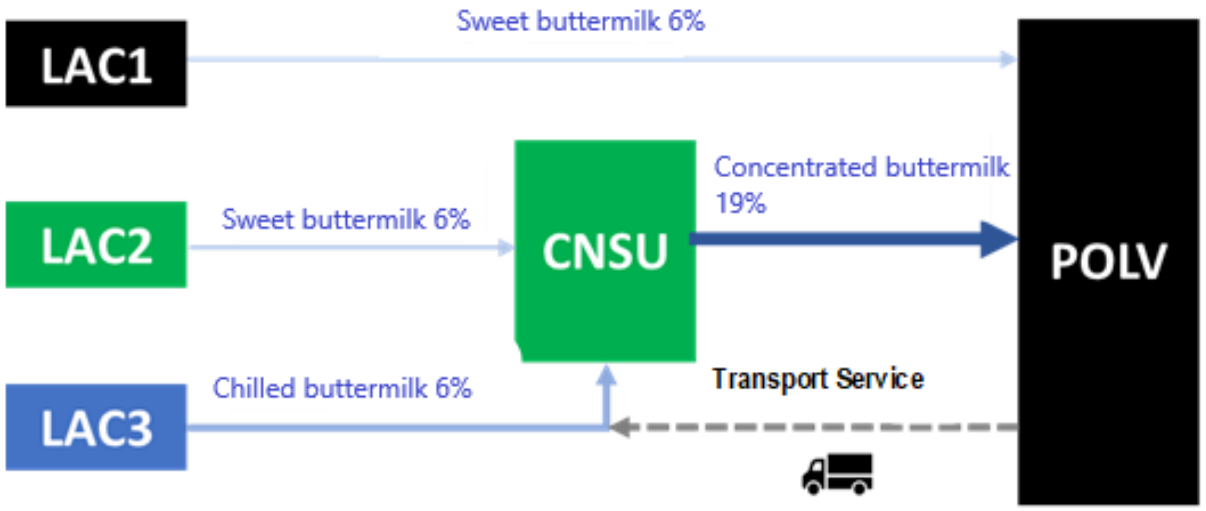
	PF	EM
Economic sector	Sale of prepared food	Environmental management
Company size	Large	Micro enterprise
Percentage of female employees	66%	20%

Source: Ríos and Rodrígues, 2021.
(Key: oval = wastes and by-products; rectangle = end products; dark blue rectangle with round corners = enterprise surveyed; light blue rectangle with round corners = enterprise not contacted).

In the case above, PF is the anchor enterprise in the industrial symbiosis network; it produces prepared food. It gives dismissed furniture from its points of sale to FM, a firm that utilizes the materials of the old fitments to make new furniture for PF. PF also gives organic waste and other dismissed recyclable materials, such as paper and glass, to EM, an environmental management microenterprise. Using the organic waste, EM produces compost, which is partly returned to PF for devolution to farm enterprises that are part of its value chain, including DC, a dairy company that needs compost to cultivate cattle pasture. The three jobs created in EM are for operational staff and production supervision.

In two industrial symbiosis networks in Argentina, employment multipliers were estimated across the entire value chains. Results showed much greater positive employment effects, since the entire value chain was taken into account. There was an overall increase in employment of 19 per cent in the case study on milk production and the value chain generated by buttermilk as a by-product, and 52 per cent in the case study on wood production and the value chain based on energy generation from wood wastes. Figure 3 shows the surveyed enterprises involved in the industrial symbiosis network for buttermilk production, while Figure 4 shows the surveyed firms in the wood production value chain analysed in the second Argentinean case study.

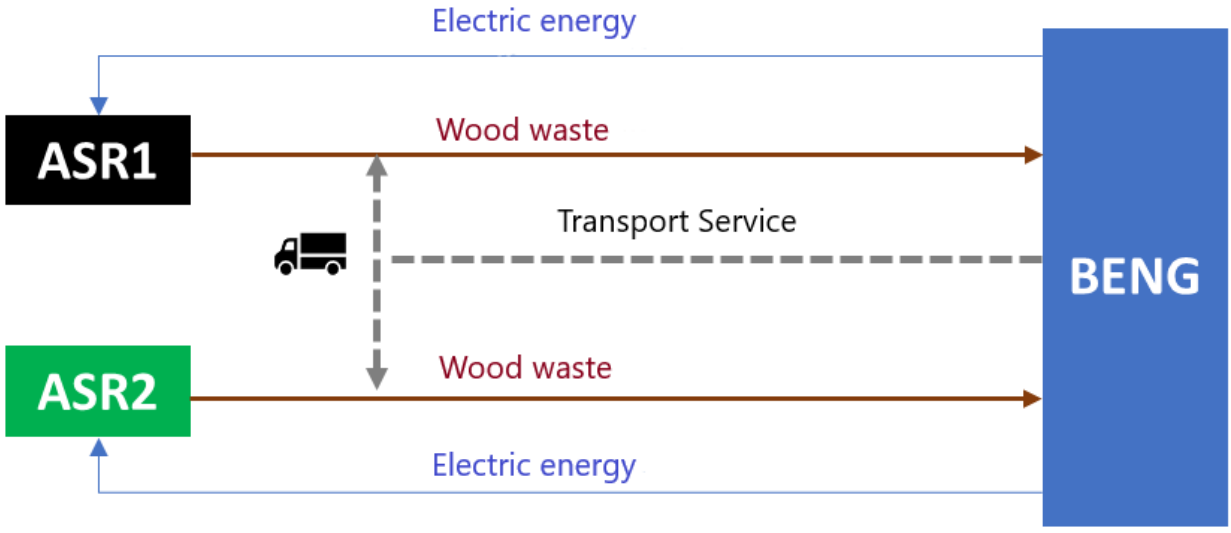
▶ **Figure 3: Industrial symbiosis network for buttermilk production in Argentina**



Source: Abriata and Masut, 2021.

The anchor enterprise in the example above is POLV, which produces buttermilk powder. The others are suppliers of by-products and milk waste to be treated for further use by POLV. Some of the companies provide liquid buttermilk or untreated buttermilk waste with 6 per cent solid matter (LAC1-3). In some instances, buttermilk waste must be chilled to be preserved. Three other firms (including CNSU) provide concentrated buttermilk at a 19 per cent concentration.

▶ **Figure 4: Industrial symbiosis network for wood and energy production in Argentina**



Source: Abriata and Masut, 2021.

The anchor enterprise in this case is BENG, the bioenergy firm. While there are at least 20 sawmills supplying wood wastes to BENG, only two were surveyed, ASR1 and ASR2. As much as 70 per cent of wood inputs from sawmills must be treated before being used by the bioenergy company; most sawmills have the equipment needed to do so. Transport companies are required to deliver the wood waste to BENG. BENG uses the treated wood waste to produce electricity, which is used by the sawmills.

The following table provides data on the direct, indirect and induced employment effects of the industrial symbiosis networks, since their inception, in the two value chains studied. The most striking difference is in the indirect impacts, which are much higher for the wood wastes and energy production value chain. This is mainly due to a significant increase in activities linked to wood waste treatment by sawmills, the manufacture of the specialist equipment required, and the transportation of wood and its by-products to BENG. Additional employment was generated also by the construction of the power plant and its machinery.

▶ Table 1: Direct, indirect and induced employment impacts in two industrial symbiosis networks in Argentina (%)

Value chain	Direct	Indirect	Induced	Overall impact
Buttermilk	19	20	19	19
Wood	44	67	50	52

Source: Abriata and Masut, 2021.

Qualitative employment impacts

Informal employment is widespread in the circular economy in Colombia. When looking at data from the national household survey conducted in 2019, if we use the category "self-employed and microbusinesses with fewer than 5 employees" as a proxy, informality accounts for 80.1 per cent of employment related to recycling and 86.6 per cent of jobs related to wastes trading. If we use the category "workers without a pension" as an indication of informality, the shares are 89.1 per cent and 89.3 per cent ,respectively.

The study conducted in Colombia shows positive effects of industrial symbiosis on enterprise formalization. In one case, a small informal business grew and formalized as a result of its involvement in an industrial symbiosis network. The number of employees with a decent, formal job increased, although on a very small scale.

Data from both Argentina and Colombia on women's employment in industrial symbiosis networks on the one hand, and recycling activities in general on the other, are rather disappointing. Starting from national data from Colombia, taken from the Annual Manufacturing Survey 2018, women account for 37 per cent of total employment in manufacturing firms, 27 per cent in enterprises using wastes as inputs, and 25 per cent in businesses trading wastes. These figures are taken from formal enterprises employing at least 10 people. A similar trend was recorded in the national household survey 2019, with women accounting for 24.8 per cent of workers in recycling activities and 27.9 per cent in wastes trading. The study by Ríos and Rodrígues (2021) does not provide any primary data on women's employment in industrial symbiosis networks. It is however to be noted that the companies involved in such schemes are sometimes from sectors other than manufacturing, where women's participation is higher, as depicted in the tables embedded in figures 1 and 2. Those tables show that, in most companies, especially those in the agriculture sector, the percentage of female employment per firm is over 37 per cent, which may suggest a higher level of women's participation in jobs created through industrial symbiosis.

In Argentina, women occupied only 26 per cent of the jobs created in the buttermilk value chain studied. In the wood industrial symbiosis scheme studied, the share of women in employment was even lower: 12 per cent. These percentages are lower than the proportion of women employed at the regional level, which is around 50 per cent of total employment in both spheres.

Formal employment in the two subsectors studied in Argentina is also lower than that recorded in the regional labour market, which is estimated at 63 per cent in the buttermilk industry and 38 per cent in the wood subsector. When looking at formal employment of women, shares are extremely low, at 11 per cent and 8 per cent, respectively. The scale of the informal economy and

the low employment levels for women are labour market issues that do not seem to be particularly alleviated by industrial symbiosis.

Besides making a small contribution to the transition to formality, another positive impact of industrial symbiosis networks is on job retention. Jobs are retained when new tasks resulting from industrial symbiosis-related activities can be performed by existing staff. These new assignments are often added to those already included in the regular functions of an employee, for example when he or she is responsible for environmental management. This can result in salary increases, although there is also a risk of overwork. A positive example was seen in Colombia, although there was only one case recorded, where additional tasks resulted in a significant increase in workload and a salary increase was granted.

Skills required

According to the enterprises studied, a wide range of skills were needed for the jobs created or retained. The labour force profiles required include operational staff for waste screening and classification, and professional specialists, such as environmental experts, engineers and digital developers to establish networks and make contacts with other firms. High- and low-skilled employees are needed. Research and innovation capacities are very important for identifying new by-products and outputs and finding ways to collaborate with other enterprises.

Availability of the abovementioned skills, needed for industrial symbiosis, was evident in the labour markets both in Argentina and Colombia. In Argentina, interdisciplinary management skills were identified as a capacity deficit. These should include, among others, some environmental knowledge to recognize the relevance of industrial symbiosis and the circular economy in general. Leadership in industrial symbiosis principles among managers was identified as a relevant skill in Colombia.

An enabling environment for industrial symbiosis networks

In the experience of Kalundborg (Denmark), the local government, enterprises and interested organizations joined forces towards the common goal of achieving economic development and technological innovation (Morales et al, 2019). According to our findings in Argentina and Colombia, industrial symbiosis networks can be either spontaneously created by private enterprises or established with the support of associations or public institutions.

In the case presented in Figure 1, the exchange between FP and AG2 originated from a spontaneous initiative by FP. The same company developed similar exchanges with several other firms along its value chain over a period of about 12 years. Two important factors that determined the spontaneous creation of an industrial symbiosis network in this case are strong corporate environmental responsibility, especially concerning the disposal of waste, and the perceived need to obtain international certification for meeting environmental standards, such as ISO14001. Findings from Argentina show additional explanations for why enterprises may spontaneously set up industrial symbiosis networks, including to solve a logistical problem and make savings in marginal costs.

When industrial symbiosis results from a spontaneous private initiative, exchanges occur between firms that are already connected by pre-existing commercial links or being part of the same value chain. When external entities are involved, firms can establish industrial symbiosis relations with unknown businesses.

Fourteen associations providing support for the creation of industrial symbiosis networks have been identified in Argentina. Some of them are linked to international organizations, such as the International Solid Waste Association or the World Business Council for Sustainable Development, while others are organized at the national or regional levels, such as the Argentinean Petrochemical Institute and sectoral chambers. Enterprises are encouraged by associations to establish linkages and create synergies through industrial symbiosis networks to increase revenue through the generation of a new activity, and improve their visibility and reputation.

In both Argentina and Colombia, Employers' organizations have supported and often been directly involved in facilitating the creation and development of industrial symbiosis networks. Unión Industrial Argentina actively participated in the establishment of one of the two cases studied, as described below. In Colombia, the National Business Association of Colombia assists firms that develop industrial symbiosis projects with RedES-CAR (see Box 2). Both national employers' organizations are involved in the establishment of eco-industrial parks in their respective countries.

Eco-industrial parks are conducive to the creation of industrial symbiosis networks as they offer geographic proximity and promote collaboration between the enterprises within them. UNIDO (2022) defines an eco-industrial park as "...a community of businesses located on a common property in which businesses seek to achieve enhanced environmental, economic and social performance through collaboration in managing environmental and resource issues".[3] Eco-industrial parks are also a good example of public and private support for industrial symbiosis. In both Argentina and in Colombia, industrial symbiosis networks are expected to be established in such parks. In Mexico, a large industrial symbiosis network was set up in the late 1990s in the Altamira Industrial Park (Morales et al, 2019).

The positive economic, environmental and employment effects of industrial symbiosis make legislation favouring its development highly desirable. In Argentina, there is no legal framework regulating the circular economy and industrial symbiosis. Nonetheless, at the Federal level, the Directorate for Sustainable Industry under the Ministry for Productive Development is responsible for the circular economy and thus far has organized several meetings and roundtables on the matter. At the regional and local levels, some public institutions are directly involved in the establishment of industrial symbiosis networks, including in the cases of the buttermilk value chain and the wood scheme presented above. In the former, the Ministry of Science and Technology, local entrepreneurs from La Pampa and Buenos Aires regions, and the Argentina Industrial Union employers' association worked together to find a solution to the problem of buttermilk waste. In the latter, reacting to an energy crisis in 2010, which had seriously hampered the operations of local enterprises, the provincial government of Corrientes started to plan the industrial symbiosis network in collaboration with the private sector. A forest-industrial park was established to group sawmills in a given area.

Elements of a national policy on the circular economy started to appear in Colombia in 2016. Industrial symbiosis was first mentioned in the Green Growth Policy, 2018. In 2019, with the adoption of the National Strategy for a Circular Economy, industrial symbiosis was explicitly promoted with fiscal incentives, training and technical support for enterprises to develop industrial symbiosis networks.

Technical support from research institutions and universities can be very useful (Morales et al, 2019) as shown in the case of RedES-CAR in Box 2 below.

▶ Box 2: Promoting industrial symbiosis in Colombia: the case of RedES-CAR

RedES-Car, the initiative of the Network of Sustainable Enterprises of the Cundinamarca Autonomous Regional Corporation was launched in 2013. It is led by the regional Authority of Cundinamarca, the principal environmental authority in the region, and is implemented in collaboration with the University of the Andes. Anchor enterprises are invited to participate in the design of industrial symbiosis projects. They are encouraged to involve smaller firms, which are part of their supply chain, in the programme. The public entity and the university present the main aspects and benefits of the programme to enterprises, which formalize their participation at no cost by signing a letter of agreement. A series of workshops are then organized in which companies design industrial symbiosis projects with technical assistance from the University. The implementation of the projects is verified by RedES-CAR six months later. As at 2021, 20 projects had been developed. The first were formulated in 2016 and their implementation started a year later.

Source: Ríos and Rodrígues, 2021.

Challenges to and remedies for creating an enabling environment

The research findings from Argentina and Colombia made it possible to identify some challenges and remedies to foster the creation and development of industrial symbiosis networks. The main findings in that regard are shown in Table 2 below. Remedies are recommendations for fostering an enabling environment for industrial symbiosis.

[3] As defined by UNIDO, eco-industrial parks and industrial symbiosis are synonymous.

▶ **Table 2: Industrial symbiosis networks: Challenges to and remedies for creating an enabling environment**

Challenge	Remedy
Financing measures within enterprises to adjust to a circular economy and to industrial symbiosis in particular. Investments to be made by firms receiving waste and by-products are especially burdensome.	Offer fiscal incentives to companies to compensate for the financial efforts that industrial symbiosis initially requires, in particular for receiving and processing waste and by-products.
Difficulties for enterprises to connect with one another in large and scarcely populated geographic areas.	Enact legislation to promote the establishment of eco-industrial parks to facilitate the creation of industrial symbiosis networks by grouping firms in a given area and favouring geographic proximity.
Reluctance among companies and some public institutions to set up industrial symbiosis networks as their positive effects are often unknown.	Ensure coordination between different local actors to make the benefits of industrial symbiosis clear to all. Disseminating the positive economic, environmental and employment impacts of industrial symbiosis is key to fostering its replication. This can be done through public forums and events. Training local public institutions and municipalities on the characteristics and benefits of industrial symbiosis is also important, so that they can take an active role in its promotion. They should also be trained in collecting data on the environmental, economic and employment impacts of industrial symbiosis networks.
Policy and regulatory frameworks unfavourable to industrial symbiosis.	Encourage the active participation of national public institutions in the establishment of industrial symbiosis networks to ensure favourable policy and regulatory frameworks. The adoption of extended producer responsibility legislation, where manufacturers are given financial and physical responsibility for the treatment or disposal of products, would also be helpful.
Difficulties for firms to identify by-products that can be exchanged or sold.	Involve knowledge institutions and universities in collecting information and data on waste and by-products and instructing enterprises that intend to join industrial symbiosis networks. Such institutions should gain companies' trust to encourage them to share data on their production and subsequently enjoy economic, environmental and employment gains.
Mutual mistrust of companies in sharing production data to identify more industrial symbiosis options.	Encourage employers' associations and local institutions and organizations to hold dialogue and technical meetings, through which enterprises can build mutual trust.
Reluctance or disengagement of employees.	Involve and train all employees, especially in small enterprises where usually only the owner is actively involved in planning industrial symbiosis activities. In large companies this could be done with the active support of trade unions.

Filling decent work deficits

In terms of the number of jobs created, the employment effects of industrial symbiosis are positive, in particular if the impacts on an entire value chain are taken into account. The quality of the jobs created, however, is not guaranteed. Some decent work deficits exist where industrial symbiosis schemes are in place; the existence of such networks does not necessarily result in significant improvements.

The informal economy is more widespread in developing countries than in the economically advanced States where industrial symbiosis originated, especially in the manufacturing sector, as illustrated by the findings from Colombia. While informal employment is not so prevalent

in the large Colombian enterprises shown in Figure 1 or those involved in the scheme described in Figure 2, it was significant in the two Argentinean value chains studied, which involved firms of all sizes, including micro- and small enterprises.

The occurrence of formalization mentioned with regard to the findings from Colombia could be replicated: in that instance, in order to become part of an industrial symbiosis network initiated by a large company, a microbusiness that was part of its supply chain had to be formalized. Since industrial symbiosis schemes need an anchor enterprise (normally a large firm with a significant supply chain) those enterprises have an opportunity to lead the formalization process. They must be aware of their role in that regard, and uphold high standards of corporate social responsibility.

The research findings do not suggest any solution for the gender gap identified, particularly in respect of the Argentinean industrial symbiosis cases studied. The low level of women's participation seems to reflect gender trends typical of the sector or sectors involved.

Next steps

The economic, environmental and employment effects of industrial symbiosis are perfectly in line with the principles of sustainable development and, more specifically, the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs). Industrial symbiosis fosters economic activities that are profitable and respectful of the environment. It also creates jobs, although there is scope to improve their quality.

In June 2021, the International Labour Conference adopted the global call to action for a human-centred recovery from the COVID-19 crisis that is inclusive, sustainable and resilient, which called for recovery strategies that are gender-responsive, with sustainable enterprises generating decent work. Furthermore, such strategies must foster supply chains that contribute to the sustainability of firms, including micro-, small and medium-sized businesses, and promote the transition to formality of jobs and enterprises.

Responding to the call for action, greater efforts are needed to fill the decent work deficits identified by our research findings on industrial symbiosis, in particular in the areas of gender equality and formalization, and to attain the SDGs, especially Goal 8.

The research conducted thus far does not provide sufficient information to formulate measures to adequately fill the decent work gaps identified. One or two additional country studies could be conducted, focusing on the quality of jobs generated by industrial symbiosis, to shed more light on remedies that have perhaps already been applied and could be replicated elsewhere. Further aspects of decent work could be considered, including occupational safety and health, social dialogue and unionization. Other dimensions could also be examined in greater depth, such as working time and wages. The ILO Call to Action also encourages engaging in research and data collection on the potential of the SDGs to generate decent work, including in the circular economy, as an integral part of the recovery process.

References

Abriata B.D. and Masut A. 2021. *Simbiosis industrial en empresas argentinas y su impacto en el empleo*. Research Department, International Labour Organization.

Chertow M.R. 2000. "Industrial symbiosis: literature and taxonomy". *Annual Review of Energy and the Environment*, Vol. 25: 313–337.

European Parliament. 2021. Circular economy: Definition, Importance and benefits.

Lowe E. A. and Evans L. K. 1995. "Industrial ecology and industrial ecosystems", *Journal of Cleaner Production*, Vol. 3, Issues 1–2: 47–53.

Martin M. and Harris S. 2018. "Prospecting the sustainability implications of an emerging industrial symbiosis network". *Resources, Conservation and Recycling,* Vol. 138: 246–256.

Morales M., Diemer A., Cervantes G., Carrillo-González G. 2019. "By-product synergy changes in the industrial symbiosis dynamics at the Altamira-Tampico industrial corridor: 20 years of industrial ecology in Mexico". *Resources, Conservation and Recycling*, Vol. 140: 235–245.

Neves A., Godina R., Azevedo S., Matias J. 2020. "A comprehensive review of industrial symbiosis". *Journal of Cleaner Production*, Vol. 247.

Ríos P. and Rodrígues E. 2021. *Las redes de simbiosis industrial y el empleo, el caso colombiano*. Research Department, International Labour Organization.

UNIDO. 2022. Eco-industrial parks.

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