International Labour Organization

Industrial symbiosis and productivity

The employment effects in developing countries

Edited by
Maria Sabrina De Gobbi

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Two of the case studies, Argentina and South Africa, present analytical work from partner countries of the Partnership for Action on Green Economy (PAGE), an interagency programme that brings together the expertise of five UN agencies – UNEP, UNDP, ILO, UNIDO and UNITAR – to support countries in an integrated and holistic manner in their green economic transition. Thanks is given for the additional financial contribution and technical support that were provided by PAGE in this context. Last but not least, appreciation is due to the authors of the chapters that make up this volume, without whom its preparation would not have been possible.

▶ Abbreviations

GDP	gross domestic product
IS	industrial symbiosis
NGO	non-governmental organization
R&D	research and development
SME	small and medium-sized enterprise
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

Introduction

How can we achieve social justice, preventing climate change, preserving natural resources and reducing poverty? To what extent can decent jobs be created through a sustainable economic model such as a circular economy and, more specifically, industrial symbiosis? These are the overarching questions addressed in the present volume.

This book explores the social dimension of a circular economy, taking into consideration a specific form of it called "industrial symbiosis" (IS). It considers the effects on employment of enterprises' recycling activities and describes the impacts on jobs of a sustainable development model based on sustainable production and consumption patterns.

IS is a business-to-business model in which companies behave in a way that simulates a web of interactions like those that are typical of a natural ecosystem. The waste or by-products of a firm become inputs for the production of another enterprise. How do workers – women and men alike – fit into such a scheme? What is the human component of a circular economy model such as IS? And how do such models function in developing countries?

The economic and environmental effects of IS have been thoroughly studied, whereas there is a knowledge gap on its employment impacts. This is the research gap that the present volume seeks to fill, considering both the quantitative and the qualitative effects on employment. Furthermore, IS is a sustainable economic model that can frequently be found in advanced economies, but not so much in developing countries. Less developed and emerging economies will be the focus of this book.

This volume contains the results of a research project implemented by the ILO under the technical supervision of Senior Economist Maria Sabrina De Gobbi. The project was conducted over a period of five years, from 2020 to 2024, and covered six countries from Africa and Latin America. The main specific research questions that were addressed are:

- What are the quantitative and qualitative employment effects of IS networks?
- What are the barriers to and enablers of positive employment results in IS?
- What specific skills (if any) are needed in jobs created through IS?
- What actions can the private sector and national and local governments take to further promote employment creation through IS?

To address these research questions, the experiences of two developing regions of the world were explored using technical inputs from national consultants. Benin, South Africa and the United Republic of Tanzania were the countries selected for the African continent, while Argentina, Colombia and Costa Rica were chosen for Latin America. Since 2020 six country studies have been conducted and published; these reports are extended versions of the country chapters in this volume.

Maria Sabrina De Gobbi, the initiator of the above-mentioned research project and editor of this book, has over 25 years of experience at the ILO, where she has worked mainly as an economist, focusing especially on developing countries. She holds advanced university degrees covering various fields, including economics, law and environmental management. The team of national consultants who co-authored chapters in this volume include experts in different areas to address all technical aspects of the issues examined. These specialists comprise economists and statisticians Bruno Dante Abriata, Calixte Adjallala, Gaston Gnonhoué, Ariel Masut, Paola Ríos, Esmeralda Rodríguez and Riaan Rossouw; environmental management experts Luis Valerio Pérez, Amani George Rweyendela and William John Mwegoha; industrial engineer Roberto Quirós Vargas; chemical engineer Lucía Rodríguez Delgado; agro-economist engineer Gaston Agossou; and circular economy expert Kiera Crowe Pettersson.

This book presents original primary and secondary data showing clearly the positive employment effects of IS. Direct jobs are measured through primary data, while indirect and induced jobs are additionally assessed using secondary data and employment multipliers. Field surveys, semi-structured interviews and site visits were the main research instruments with which primary data were collected. Secondary data, national and international literature, and published and unpublished materials were also consulted. The origins and characteristics of IS are described, as well as the mechanisms through which employment can be created. A conducive institutional framework is highlighted, with a specific focus on developing countries.

The volume starts in Chapter 1 with a review of relevant literature to set the background against which the main issues for the six featured countries will be addressed. Chapter 2 on Colombia focuses on direct jobs created and retained in some national IS networks. Chapter 3 on the United Republic of Tanzania presents a sectoral approach to IS in the sugar industry; it also provides some information on the quality of the employment that IS generates. In the following chapter on Costa Rica (Chapter 4), measurement of direct jobs created and retained is extended to small firms along the supply chain of anchor enterprises; some data on the quality of jobs in small firms along the value chain of anchor companies are described, complementing those presented in the preceding chapter. Chapter 5 on Benin focuses on informal workers, while Chapter 6 on Argentina and Chapter 7 on South Africa assess direct, indirect and induced employment using employment multipliers. The case of South Africa adds information on informal workers, completing the data presented in the chapter on Benin. Chapter 8 replicates the structure of the first chapter, providing an examination of emerging issues through the prism of conclusions drawn from the six country studies. A final Conclusions section rounds off the book, setting out the policy implications of the main findings presented in the preceding chapters and offering some policy recommendations.

Decent work, productivity and industrial symbiosis:

Literature review and methodology

1

Maria Sabrina
De Gobbi

1.1. The circular economy model

The present volume focuses on the employment effects of industrial symbiosis (IS), which is a form of circular economy. A circular economy is a sustainable economic model, where products and materials are reused, remanufactured, recycled or recovered. The resources of which products and materials are made are preserved, and waste is minimized or avoided. This very same scheme allows the prevention or reduction of greenhouse gas emissions (Castro de Hallgren et al. 2021; UNEP 2019).

From the 1960s, the circular economy became characterized by terms beginning with the letter R, such as Reduce, Reuse and Recycle, to which others were later added, such as Repair, Rethink, Refuse, Redesign, Refurbish, Recover, Remanufacture and Repurpose (Morseletto 2023). The following "4 Rs" are often used: reuse, remanufacture, recycle and recover (Castro de Hallgren et al. 2021).

A circular economy is an alternative approach to the "take–make–waste" linear model according to which, after being used, a product is discarded and becomes waste. A linear economy also involves the depletion of scarce or non-renewable resources. Sustainable Development Goal (SDG) 12 is about ensuring sustainable consumption and production patterns, and a circular economy falls within this framework. By relying on an efficient use of resources minimizing waste, circular economy practices and behaviours are crucial to the achievement of sustainable development.

SDG 8 promotes "sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all". Target 8.4 urges a progressive improvement in global resource efficiency and the achievement of economic growth without environmental degradation, while target 8.5 calls for productive employment and decent work for all, including for young people and persons with disabilities, and equal pay for work of equal value. The scope of the research that is the focus of the present volume lies in the connection between SDG 12 and targets 8.4 and 8.5 within the framework of a sustainable development circular economic model.

Furthermore, in 2023 the International Labour Conference adopted a Resolution concerning a just transition towards environmentally sustainable economies and societies for all, where governments, in consultation with employers' and workers' organizations, are invited to adopt and implement industrial policies towards a circular economy (ILO 2023). A solid basis for this Resolution is provided by paragraph 9 of the ILO Just Transition Guidelines, which posits that governments, employers and workers are agents of change towards social justice and sustainable development; this they can achieve "by fostering sustainable enterprises and decent work for all" (ILO 2015).

The business and financial sector has an important role to play in promoting and supporting a circular economy (UNEP 2019). The focus of this book, industrial symbiosis, is a circular economic model where the business community plays a pivotal role. It occurs when enterprises adopt specific behaviours aimed at collaborating with other companies, often (though not necessarily) within the same value chain.

Morseletto (2023) suggests that circularity is chosen when there are economic benefits, convenience, service improvements or competitive advantages. Environmental benefits are also considered, but economic and financial aspects prevail. The implementation of circular models depends upon investments, expertise, coordination and changes in the entire value chain. This is why linear schemes, which are supposedly less demanding, are often preferred.

The social dimension, and in particular the labour effects, of the circular economy are often neglected. These impacts are nonetheless encouraging. The ILO estimates that a net total of 7–8 million new jobs will be created globally by 2030 as a result of policies and changes associated with the circular economy (ILO 2018). The Organisation for Economic Co-operation and Development (OECD) anticipates a less strong impact, with policies promoting resource efficiency and a circular economy generating a marginal net gain of 1.8 million new jobs by 2040 (OECD 2020). A study focusing on Chile, Colombia, Mexico and Peru in Latin America shows that the effects of the circular economy on gross domestic product (GDP) and employment are positive and increasing over time (Rodríguez et al. 2023).

Despite the positive quantitative impact of circular activities on employment, some decent work deficits have been recorded with respect to the quality of jobs. Work in the circular economy is often of poor quality, involving temporary, flexible or informal employment with limited or no social dialogue or social protection (ILO, Circle Economy and World Bank 2023). In particular, in some low-income countries circular activities are necessity-driven and occur largely in the informal economy, where working conditions are poor (Korsunova et al. 2022). This is especially so in the case of waste pickers, or those who collect, sort and recycle all kinds of waste, including hazardous products and materials. Korsunova et al. (2022) posit that it is not clear how the circular economy, which is anchored

in technological innovation and engineering production models in formal systems, can offer opportunities to informal workers, bringing them social justice and leading to improvements in their living and working conditions. The same authors express the need for more research on existing linkages between informal circular economy practices and formal systems. This volume also seeks to shed some light on this particular aspect.

There is scant information available on the social and economic effects of the circular economy in developing countries compared with advanced economies. A recent report reveals that 84 per cent of the studies on this topic focus on the global North (ILO, Circle Economy and World Bank 2023). This volume contributes to rebalancing the situation by focusing on developing countries.

1.2. Industrial symbiosis

Industrial symbiosis (IS) is a subfield of industrial ecology, a discipline based on 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). It is believed that the human effects on the environment can be reduced by applying lessons learned from natural ecosystems. Industrial ecology uses a system-scale approach as in biological ecosystems, but often refers to engineering and business models (Deutz and Lyons 2015).

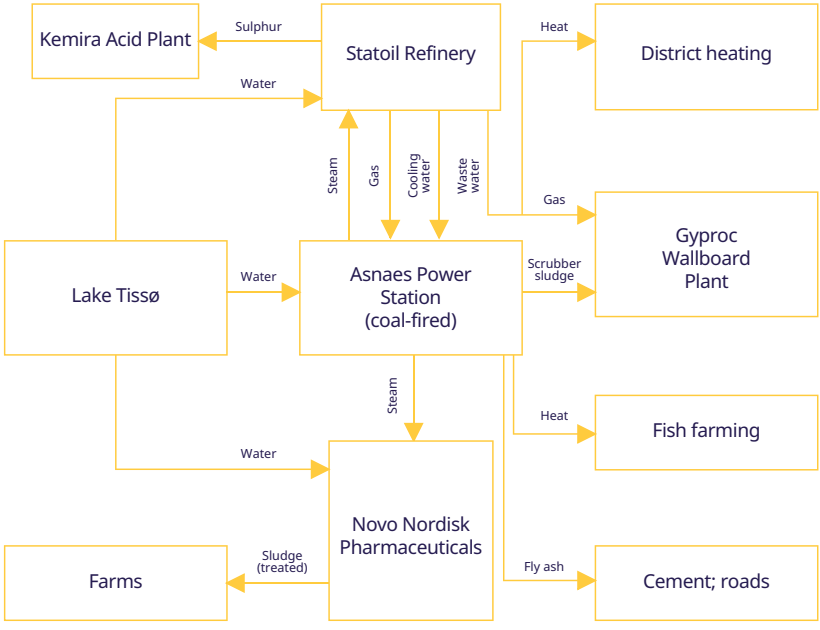
IS refers to the relationship in nature in which two unrelated species exchange energy, materials or information in a way that is mutually beneficial. In the industrial world, separate enterprises work together for a mutual benefit that is greater than the sum of individual benefits that each firm could obtain by acting on its own. According to a subsequent definition, IS "engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products" (Chertow 2000).

In our research, the following simpler definition is adopted: "Companies that use by-products or waste from other companies" (Neves et al. 2020). It is a "business-to-business" model and does not deal with the recycling of municipal waste (Buda and Ricz 2023). It involves reuse and recycling of waste and by-products, including the treatment of such products to make them suitable as inputs in the production processes of the receiving company. Exchanges between firms entail a mutual benefit or advantage, as is the case in an IS relationship in nature.

IS is a different notion from supply chain integration (that is, vertical integrated systems in supply chains). The latter approach has the objective of achieving sustainability but is based on a linear model involving material flows from suppliers to customers. IS focuses on linkages across industries instead, and functions according to circularity principles. Only in recent years have attempts been made to explore the possibility of including circularity in vertical supply chain systems (Bimpizas-Pinis, Calzolari and Genovese 2022; Del Giudice et al. 2021).

The first case of an IS network was realized in Kalundborg, Denmark. This network originated spontaneously on the initiative of some private companies and developed in the 1960s (Johnsen et al. 2015). The goal was to reduce waste by finding alternative ways of using it to generate profit. Only in the late 1980s did the network's members realize that they were also generating environmental benefits. The five initial core partners were a coal-fired 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 one another and with other smaller companies, including local farmers.

▶ **Figure 1.1. Industrial symbiosis at Kalundborg, Denmark**



Source: Chertow (2000).

In the early 1990s Schwarz and Steininger (1997) mapped the Styria region in Austria. Starting from a basic goods company which was both a supplier and a recipient of waste, they identified a "recycling network" involving more than 50 facilities. The Styria example shows that recycling networks may often exist even if they are not recognized as such. Similar findings are presented in Chapter 6, where the mapping conducted by the authors disclosed the existence of over 15 IS networks in Argentina.

Geographical proximity is often mentioned as a key element of IS, which is why the eco-industrial park (where a community of businesses grouped in a specific common property try to improve their environmental, economic and social performance through collaboration in the management of the environment and resources) is sometimes seen as an exemplar or paradigm case (UNIDO, n.d.). The spatial dimension of IS considers the locational advantages linked to inputs and transport costs (Chertow 2000). However, IS also occurs between distant enterprises (Neves et al. 2020; Johnsen et al. 2015), as is seen in the case of the United Republic of Tanzania (Chapter 3) and in sparsely populated countries and regions such as Australia (Deutz and Lyons 2015) and Argentina (Chapter 6).

Interest in industrial ecology and IS originated in various industrialized countries in North America and Europe. It extended to emerging economies, such as China, India, South Africa and the Republic of Korea, in the early 2000s. In more recent years, the focus has increasingly included developing countries, particularly in Asia (Neves et al. 2020; Boom-Cárcamo and Peñabaena-Niebles 2022). Deutz and Lyons (2015) report that the nuances of developing countries' contexts have not been sufficiently taken into account and that economic, social and cultural differences should be carefully considered. In less developed economies, IS should be implemented in different ways (Olayide 2015; Boom-Cárcamo and Peñabaena-Niebles 2022). The present volume focuses on developing regions of the world and seeks to adapt and extend the notion of IS to developing contexts where agriculture prevails. It tries to fill the knowledge gap on alternative applications of this sustainable economic model, such as the Songhaï Centre in Benin (Chapter 5).

One key element of IS which persists in any geographical or economic situation is the engagement of the private sector. The motivation usually lies in economic advantages, such as increased competitiveness and efficiency (Schwarz and Steininger 1997; Johnsen et al. 2015; Neves et al. 2020) and improved resource productivity (Chertow 2000). Schwarz and Steininger (1997) posit that, to be successful, recycling networks require intercompany dialogue based on common terminology, open information exchanges, and, if necessary, the creation of an information system to facilitate coordination. The same authors point out that informal contacts between employees of the enterprises involved are beneficial. Workers' participation is therefore important.

Industrialization is key for economic development and is the basis of IS, which focuses on the manufacturing sector and the transformation of materials into products. However, many other sectors can be involved in IS, including agro-based industries such as agriculture with crops and raising and breeding of animals (Neves et al. 2020; Boom-Cárcamo and Peñabaena-Niebles 2022), which are more significant in the economies of emerging and developing countries.

Power plants, in particular, seem to have the capacity to generate IS linkages with other companies. The literature provides several examples of IS networks anchored around this type of activity (Neves et al. 2020), including the industrial forest park in Argentina described in Chapter 6.

In a comprehensive review of IS, 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. According to these authors, social impacts are difficult to quantify (see also Johnsen et al. 2015). Despite some IS initiatives being launched with the intention of creating jobs (for instance, Grangemouth in the United Kingdom of Great Britain and Northern Ireland and Dunkirk in France), the employment effects of IS networks in general have rarely been studied. This volume seeks to fill this research gap.

As noted above, much of the literature on IS case studies focuses on Europe and Asia. By contrast, the examples described in this book are centred in Africa and Latin America, where IS does indeed occur but is much less understood. One barrier to the dissemination of findings on IS networks in these two continents that is often encountered is the different languages used: Spanish in most parts of Latin America and French in parts of Africa. This volume tries to overcome this obstacle by including short versions in English of reports that were previously published in Spanish or French.

1.3. Genesis of industrial symbiosis networks

The literature on industrial symbiosis (IS) describes three models by which IS networks are created: (i) self-organization or serendipitous network processes; (ii) facilitation by individuals or organizations; and (iii) top-down planning. These categories often overlap in practice (Paquin and Howard-Grenville 2012; Johnsen et al. 2015).

In the first model, entrepreneurs spontaneously collaborate to gain economic benefits. Exchanges are aimed at reducing costs, increasing revenues or expanding one's own business. At the very beginning, the members of an IS network may not be conscious of the symbiotic nature of their exchanges; they become aware only over time. These networks are often initiated by an anchor enterprise involving partner companies along its supply or value chain (Neves et al. 2019).

In the second model, an organization or a leader brings interested firms together, providing experience, knowledge and contacts that such enterprises do not have.

In the third model, external actors identify enterprises to facilitate exchanges among them. In this case, coordinators play a pivotal role in making connections, setting IS networks' goals and structures, and decision-making. Public authorities may be involved in management bodies, providing facilities and funding (Johnsen et al. 2015). Policies initiated by governments are often the origin of this type of IS network; one good example of such networks is eco-industrial parks (Bacudio et al. 2016). In the realm of advanced economies, IS has been explicitly promoted in public plans and policies. The European Commission made adjustments to the European waste management regulations; in the United Kingdom a National Industrial Symbiosis Project was prepared; and the Republic of Korea's national strategic plan includes IS (He et al. 2020).

Self-organized networks tend to be longer-lasting and more resilient as they build on previously existing cultural and social ties (Paquin and Howard-Grenville 2012).

1.4. Employment-creating mechanisms

Industrial symbiosis (IS) can generate and retain direct and indirect jobs. Work in solid waste and recyclables collection, materials processing, and scrap material businesses is, for instance, a source of direct employment. Examples of indirect jobs are those created in upstream and downstream activities linked to solid waste management, manufacturing of recyclables, and the construction of waste management facilities. An additional type of employment is that of induced employment, which stems from direct and indirect workers' economic activities and spending (Liu et al. 2020).

Structural changes linked to IS may generate or retain jobs, and may also destroy them. New employment is created as new products or technologies are introduced. Jobs can be retained when employees are shifted from obsolete production processes to cleaner systems, and they can be lost when, for example, certain packaging materials are no longer used (Sulich and Soloducho-Pelc 2022).

This volume focuses on employment creation, considering the net balance between new jobs and jobs that are destroyed. Some employment-generating mechanisms are identified as follows:

Cost reduction and increased competitiveness. Thanks to IS, costs for waste management and disposal are reduced. Moreover, by-products and waste are often cheaper inputs than virgin materials, which can lead to further cost reduction (Chertow and Lombardi 2005; Boom-Cárcamo and Peñabaena-Niebles 2022). Enterprise competitiveness is enhanced and revenues increase. Savings and higher returns for enterprises that are engaged in IS activities can be used to recruit new employees.

Development of new economic activities. The reutilization of waste and by-products can result in new business opportunities, new product lines and new jobs (Johnsen et al. 2015).

Research and innovation. IS requires new technology stemming from research and innovation. This is another area where jobs can be created (Lombardi et al. 2012; Boom-Cárcamo and Peñabaena-Niebles 2022).

Creation of indirect employment. IS builds on the collaboration between enterprises. New jobs may be generated for specialized consulting services to set up IS activities, for the identification of IS linkages between firms, for transport and logistics for the exchange of by-products and waste, and for new machinery to treat waste and by-products (Boom-Cárcamo and Peñabaena-Niebles 2022; Oughton et al. 2022).

1.5. Industrial symbiosis in Africa

Industrial symbiosis (IS) requires small asset investments compared with other green transition models. It represents, therefore, a viable solution for the African region, which is poorer than other continents. It is also a good mechanism to increase productivity through efficient use of resources in a region that has very large amounts of unutilized materials in the form of waste (Buda and Ricz 2023).

In African countries, smallholder farming is widespread, and applications of IS can be found in this sector, as illustrated by the case of Benin in this volume (Chapter 5). Another example is Konia in Liberia, where a community development project on integrated farming was started by a missionary group supported by the University of Michigan; the project resulted in increased productivity and reduced waste (Alfaro and Miller 2013). In this continent, more than elsewhere, it is believed that the establishment of IS schemes requires external stimuli, from international agencies such as the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP), or from universities and non-governmental organizations (NGOs) from the global North. Specific programmes in Benin, Liberia, South Africa and the United Republic of Tanzania are described as illustrations of IS initiatives started and supported by external actors (Olayide 2015). However, the case of the United Republic of Tanzania in this volume (Chapter 3) shows that, by mapping the industrial landscape, even in Africa IS networks that are spontaneously created by the private sector can be uncovered. Spontaneously created IS networks have also been identified in Uganda (Buda and Ricz 2023).

Other African countries where IS has been explored or implemented in different forms include Algeria, Egypt, Ghana, Kenya, Mauritius, Morocco (Neves et al. 2020) and Zimbabwe. Some States, such as Kenya, South Africa, the United Republic of Tanzania and Uganda, have adopted policy and legal frameworks which favour IS. This is a valid element to foster the development of this type of circular economy (Buda and Ricz 2023; Oni et al. 2022; Circle Economy Foundation 2021, 2022b). Other countries, such as Benin, passed legislation on waste management in the 1990s where the circular economy is not mentioned (Circle Economy Foundation 2022a).

1.6. Industrial symbiosis in Latin America

The higher industrialization level of Latin America compared with Africa has favoured the creation of large industrial symbiosis (IS) networks taking the form of eco-industrial parks, as in the case of the Altamira project in Mexico, which started in 1997 (Morales et al. 2019). UNIDO is supporting the creation of eco-industrial parks in several countries, including Argentina, the Plurinational State of Bolivia, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Panama and Paraguay (Muyulema-Allaica et al. 2023).

There is scant literature on IS in Latin American countries. Ostina-Mateus et al. (2023) report that IS is an "underdeveloped" theme in the region. Neves et al. (2020) report cases in Brazil and Mexico. The three country studies on Latin America presented in this volume clearly indicate that IS networks exist, some of which were spontaneously established by the private sector (see Chapters 2, 4 and 6).

There is a more vibrant policy dialogue on the circular economy and IS in this region than in Africa. As the relevant chapters of this book illustrate, strategies and policies have recently been adopted in Argentina, Colombia and Costa Rica. Ecuador (Primicias 2021) and Peru (Tenajeros and Dick 2020) are also developing national plans and strategies to foster the creation of IS networks.

Tangible implementation elements for IS development can also be found in the region. Specialized consulting firms have been set up to facilitate exchanges of waste and by-products between companies, as seen in the case of Argentina (Chapter 6). In Ecuador the national government has established an online platform to favour contacts and exchanges between enterprises (Simbiosis Industrial Ecuador, n.d.).

1.7. Informal employment

As mentioned in section 1.1, industrial symbiosis (IS) is generally anchored in formal engineering and business models, which usually involve large enterprises and formal employment. Nevertheless, IS networks can engage very small or micro firms that operate in the informal economy, and can even extend their reach to informal waste pickers. It is especially in this realm of the circular economy that decent work deficits are recorded.

In their research in Argentina and Brazil, Gutberlet and Carenzo (2020) posit that waste picking is women-dominated work. Wittmer (2021) describes research conducted in an Indian city, where she reaches a similar conclusion and adds that waste picking requires little formal education and allows flexible working hours around household and caring activities. Ogando, Roever and Rogan (2017), in their study covering sub-Saharan Africa and Latin America, express a different view, stating that the gender dimension of waste picking is not clear and that the gender composition differs depending on the specific context.

Ibáñez-Forés et al. (2019) focus on the social dimension of the management of municipal solid waste and conclude that informal waste pickers are formalized through the creation of associations or cooperatives. This finding will be taken into account in some cases of IS described in this book, giving due consideration to the fact that IS does not deal with the recycling of municipal waste as it is a business-to-business model (Buda and Ricz 2023).

Launched in 2008, the International Alliance of Waste Pickers is a union of waste pickers across 34 countries. Supported by Women in Informal Employment: Globalizing and Organizing (WIEGO), this movement fights for better working conditions for its members (International Alliance of Waste Pickers 2024).

This volume seeks to identify linkages through which IS can be used to formalize either microenterprises or individual workers. Information in this regard is provided in each of the following chapters, either directly in the case of the chapters on Benin and South Africa, or indirectly in all the other country-specific chapters. General conclusions are presented in the final chapter on emerging themes.

1.8. Barriers to and enablers of industrial symbiosis and productivity

Many scholars focus on the challenges and drivers of industrial symbiosis (IS) (including, among others, Yang et al. 2022; Sellitto et al. 2021; Morales et al. 2019; Neves et al. 2019; Lombardi 2017; Bacudio et al. 2016; Golev, Corder and Giurco 2015; Johnsen et al. 2015; Schwarz and Steininger 1997). Several authors identify five categories of obstacles or drivers (economic, technical, organizational, social and policy/institutional), as presented in table 1.1.

Table 1.1. Barriers to and enablers of industrial symbiosis and productivity

Category	Barrier/enabler
Economic	Additional revenues or net cost reduction in purchase of virgin materials, waste management and disposal, operations, transport and transactions
	Availability of funding for necessary capital investments
	Vibrant market for products obtained through recycling
	Costs linked to environmental damage and climate effects not reflected in market prices
	Contribution to competitive advantage
Technical	Quality, quantity and regular flow of by-products and waste received and released
	Availability of technologies allowing synergies
	Geographical position
	Presence of anchor enterprise
	Availability of infrastructure

Organizational	Knowledge about IS
	Management support to IS
	Availability of time and resources, including staff
	Organizational culture
	Reluctance to change
	Reluctance to share information
	Employees' involvement
	Knowledge of firms that could be IS partners
	Innovation and research capacity
Social	Communication and negotiation capacity
	Common objective and vision
	Presence of trust fostering social relations
	Commitment to social responsibility
	Safety issues on human health and the environment
Policy/institutional	Environmental standards and policy
	More or less favourable legal and regulatory requirements
	Taxation, fines, subsidies and credit availability favouring or hindering IS
	Presence or absence of IS strategies
	Research incentives
	Support and presence of universities and research centres

Note: It is assumed that each obstacle has a corresponding enabler (and vice versa) and hence that the description of one leads to an understanding of the other.

Source: Yang et al. 2022; Sellitto et al. 2021; Neves et al. 2019; Morales et al. 2019; Lombardi 2017; Bacudio et al. 2016; Golev, Corder and Giurco 2015; Johnsen et al. 2015; Schwarz and Steininger 1997.

Neves et al. (2019) posit that the presence of a favourable policy and regulatory framework is one of the most important drivers of IS. Equally relevant are economic incentives.

In an attempt to prioritize challenges and drivers of IS in emerging and developing countries, it may be useful to consider that Sellitto et al. (2021), analysing barriers in an IS network in Brazil, identify some technical, economic and organizational obstacles in terms of excessive processing, logistical costs, lack of research and risk of discontinuity. Drivers include new products, cost reductions, increased revenues and favourable legal requirements.

Starting from an analysis of an eco-industrial park in the Philippines, Bacudio et al. (2016) conclude that the most significant barrier is top management support, without which goals motivating employees to innovate and put forward new ideas are not established. Top management is responsible for setting up policies, procedures and funds for IS, and has a major impact on collaboration with other firms and on awareness of IS principles. The organization of seminars, focus group discussions and training on IS is another set of activities that should be prioritized.

Yang et al. (2022) assess barriers to IS by studying a large chemical industry-dominated IS network in China. Technological barriers are ranked as the most significant. More specifically, "Technology of extending industrial chain", "Recycling technology" and "Evaluation technique" are the three most important impediments in this category; extending recycling and recovery to the whole value chain is considered much more relevant than the two other technological barriers. The category of economic barriers comes next, where "Product added value", "Cost" and "Investment" are the most relevant obstacles; achieving the added value of raw chemical materials by extending the value chain is key to enhancing the IS network under consideration. Cost is also very important as, in some cases, recycling entails a production process that is too expensive and not financially sustainable without subsidies.

1.9. Skills for industrial symbiosis and productivity

The implementation of a circular economy model requires specific skills. Skills development is key for a just transition and a productive green transformation with decent work. It is to be noted that no information seems to be available on the skills required by industrial symbiosis (IS) specifically.

ILO (2021) posits that core skills will play a pivotal role in industrial green restructuring. Environmental awareness and respect, together with a willingness to learn about sustainable development, are just a starting point for a just transition to a green economy. The core skills for a sustainable environment include improving efficiency and preventing waste, teamwork, adaptability, strategic thinking and leadership, negotiation, communication, analytical and innovative thinking, basic digital skills, and literacy. Technological innovation, which is very important in IS, requires learning to learn, which is the ability to pursue learning of new skills and knowledge for continuous improvement.

ILO (2019) estimates that the shift towards a circular economy will mostly affect male-dominated medium-skill occupations, with workers moving away from extractive industries towards waste management and reprocessing of materials. Retail trade and research and development are other sectors where new jobs will be created. High net growth levels are expected in occupations such as workers in electrical and electronic trades, workers in metal, machinery and related trades, science and engineering professionals and associates, and refuse workers.

Skills for employability in growing industries in a circular economy are soft skills, including communication, teamwork, problem-solving, numeracy, and information technology (IT) literacy skills. Some soft skills, such as leadership and presentation skills, are also important for emerging high-skill occupations. Besides these soft skills, there are semi-technical skills (such as scheduling, budgeting, and sales and marketing) and technical skills (such as engineering and plumbing) that are transferable and can be used in a circular economy model (ILO 2019).

Circle Economy (2021) suggests that lifelong learning for upskilling seems to be a valid solution that many industries have already adopted to fill skills gaps linked to the circular economy. Companies provide vocational education and training and offer on-the-job training to their employees. According to the same source, interdisciplinarity is another characteristic of work in a circular economy, where employees who can valorize materials across sectors are needed. Interdisciplinary learning is likely to lead to new qualifications for multi-skilled workers.

1.10. Methodology

The selection of the six countries that are the focus of this book was made according to the following criteria:

- they should be located in either Latin America or Africa, which are regions where little is known about industrial symbiosis (IS);
- interest should be shown by national stakeholders, in particular governments and employers;
- information on existing IS networks should be available; and
- support from ILO field offices should be available.

Both quantitative and qualitative methods were employed, using both primary and secondary data sources.

A review of national literature and documents was the starting point for each of the country studies. Secondary data were used, in particular to estimate employment multipliers in the cases of Argentina and South Africa, where input–output tables from national sources were used. National household and enterprise surveys were also consulted.

The core findings for each country case are based on primary data derived from structured, and more often semi-structured, questionnaires and interviews conducted with managers of enterprises and key informants, including representatives of government institutions, specialized agencies and academia. Purposive and snowball sampling was used. To obtain more information on the quality of jobs, it was sometimes possible to interview employees, including from the informal economy, as in the cases of Benin and South Africa.

The methodology described in Martins and Harris (2018) was considered to measure direct jobs created and retained. This methodology was used for the country studies of Benin, Colombia, Costa Rica and the United Republic of Tanzania.

Kühnen and Hahn (2018) and Ibáñez-Forés et al. (2019) provided sets of indicators to measure employment effects as well as measurement approaches. The indicators considered in the country studies presented in this volume include (among others) number of jobs created or retained with gender disaggregation, type of jobs created (formal, informal, temporary, etc.), wages, working hours, occupational safety and health at work, work accidents and other information on the quality of jobs, skills needed in jobs deriving from IS, and number of new enterprises.

The impact of IS on direct, indirect and induced jobs was assessed following a methodology based on employment multipliers as described in Abriata and Masut (2021).

The methodologies adopted in the six country cases are different, in part because secondary data for input–output analysis were lacking in some cases. However, the different methodologies used allow employment impacts to be examined from distinctive viewpoints.

1.11. Brief overview of chapters

The series of country studies starts with Colombia (Chapter 2), which is the first case study in chronological order, as it was commissioned in 2020 and completed in early 2021. The number of direct jobs created and retained through industrial symbiosis (IS) was measured, and for the first time it was possible to determine that IS has a positive quantitative effect on employment in developing countries. The Colombian experience also shows that IS networks can be either spontaneously created or set up with technical support, for instance from a local public authority or a university (or both). This country has a circular economy policy that includes the promotion of IS, which is a powerful enabler of IS development.

The case of the United Republic of Tanzania, presented in Chapter 3, illustrates the experience of IS in the sugar sector. The sectoral approach adopted confirms the positive quantitative employment effects of IS. Direct jobs created are considered, and due attention is also given to the quality of work, which is decent in the large formal enterprises considered.

The experience of Costa Rica is described in Chapter 4. The measurement of direct jobs created and retained is extended to small firms along the supply chain of anchor enterprises, confirming the positive quantitative impact of IS on labour. For the first time, it was possible to survey employees. The results show that the quality of jobs created and linked to IS is also decent in the formal small firms along the supply chain of large anchor companies.

The first three country case studies indicate that some employment formalization occurs through the establishment of small and micro firms, without which large enterprises would not be prepared to deal with informal workers or units.

The case of Benin described in Chapter 5 focuses on informal workers. This case study examines IS in the agro-based zero-waste model of the Songhaï Centre. Survey findings indicate that IS has no impact on the formalization of employees or enterprises. It is, however, to be noted that the large majority of small enterprises in the agriculture sector in the country are informal. Skills acquisition is a positive effect of IS on informal workers.

Chapter 6, on Argentina, introduces a methodology to measure direct, indirect and induced jobs along a value chain by estimating employment multipliers. The positive employment impacts of IS on the quantity of jobs created is confirmed in this case. It appears that IS has no positive effect on the formalization of indirect labour generated through IS.

Chapter 7, the final country study, presents the case of South Africa. The methodology used for Argentina is replicated and positive quantitative effects on direct, indirect and induced employment are confirmed. The South African case goes into greater depth on formalization through surveys of informal workers. Once more, IS does not seem to have any impact on this dimension of labour. As in the case of Benin, informal workers acquire new skills as a result of IS programmes but do not become formalized.

Finally, Chapter 8 draws detailed conclusions on emerging themes from the six country experiences. Starting from the literature review presented in this chapter, it describes research findings that add new information, filling knowledge gaps in particular on the different forms and characteristics of IS in emerging economies and on its employment effects.

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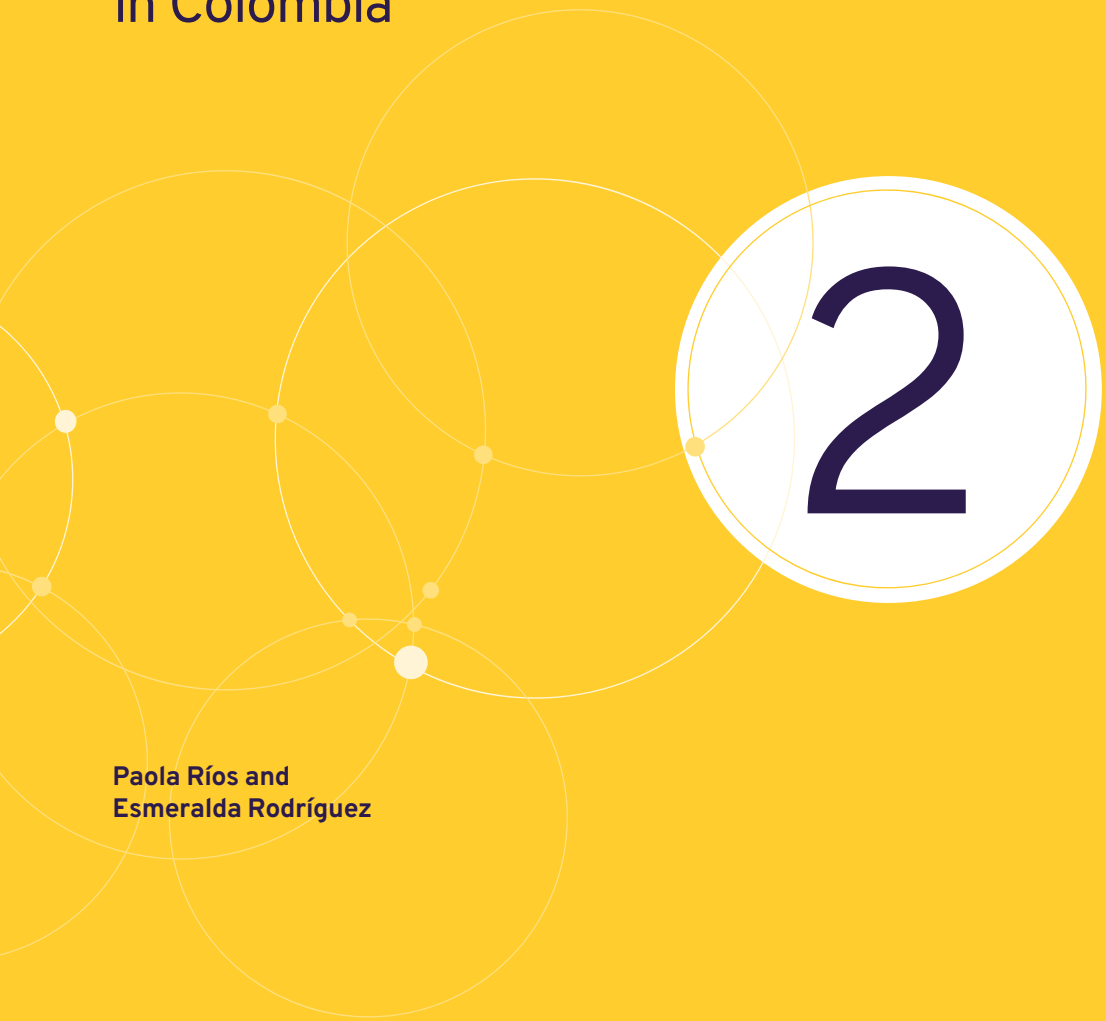
Industrial symbiosis networks and productive employment

in Colombia



Paola Ríos and
Esmeralda Rodríguez

2.1. The development of industrial symbiosis in Colombia

The term "circular economy" was used for the first time in Colombia when the National Policy for the Integral Management of Solid Waste, established in document CONPES 3874, was introduced in 2016 (DNP 2016). In terms of the development of solid waste management, this policy was proposed as the initial starting point from which to advance towards the circular economy.

In 2018, through document CONPES 3934, the Green Growth Policy was created (DNP 2018). In this, four lines of action were proposed, defining a road map towards the transition to a circular economy. It should be noted that this document contains few references to the topic of industrial symbiosis (IS); it is mentioned only as a line of action to be tackled by the Ministry of Commerce, Industry and Tourism, which is to oversee the development and implementation of four IS pilot projects between 2022 and 2025.

Subsequently, in June 2019, the Government of President Iván Duque launched the National Strategy for Circular Economy (Government of Colombia 2019). In this strategy, IS is promoted, and sustainable value or supply chains and eco-efficient industrial parks are used as vehicles for the promotion of IS activities. Within its circular economy management mechanisms, the strategy includes incentives for companies and ventures. These include training, technical support and tax benefits for companies that develop circular economy projects such as IS. Another mechanism in which IS is explicitly mentioned is "communication and citizen culture", which seeks to raise awareness among productive sectors with a view to their shifting towards sustainability and competitiveness through (for example) the adoption of IS.

▶ 2.1.1. Job creation

The 2018 Green Growth Policy mentions that there is a lack of statistical data that would make it possible to estimate the number of green jobs (DNP 2018). Therefore, one of its lines of action is to improve the quantity and quality of information available on green jobs. The National Administrative Department of Statistics (DANE) estimated that in 2018 there were 79,187 green jobs, basing its calculation on the sum of economic and environmental activities and associated transactions (DANE 2020a). Finally, the 2019 National Strategy for the Circular Economy addresses the issue of jobs created as a result of the emergence of new business models and markets, based on improved use of the economy's natural resources (Government of Colombia 2019).

▶ 2.1.2. Programmes to promote and strengthen industrial symbiosis in Colombia

Public–private partnerships have been created in recent years within the framework of public policy actions seeking to promote IS. Two of the most relevant strategies for the implementation of IS in the country are the UNIDO Global Eco-Industrial Parks programme and the RedES-CAR programme. In both cases, collective learning and technical support have been used to establish or strengthen IS networks in Colombia. The main characteristics of the RedES-CAR programme are described below.

The RedES-CAR strategy, launched in 2013, is led by the Regional Autonomous Corporation of Cundinamarca (CAR) and the Universidad de los Andes.[1] CAR is the highest environmental authority in one of the areas with the greatest industrial development in the country. The Cundinamarca region includes the country's capital, Bogotá, where the Universidad de los Andes, one of Colombia's most recognized private universities, is located.

At its start, the purpose of the RedES-CAR programme was to "strengthen the production performance of small and medium-sized companies in supply chains" (van Hoof et al. 2016). Its creation was a response to what was stated in the National Policy on Sustainable Production and Consumption of 2010 and to the need of the environmental authority to improve the environmental conduct of small and medium-sized enterprises (SMEs) (van Hoof and Duque-Hernández 2020).

1 RedES = Red de Empresas Sostenibles (Network of Sustainable Businesses); CAR = Corporación Autónoma Regional de Cundinamarca (Regional Autonomous Corporation of Cundinamarca).

The operation of the programme begins with the search for anchor companies that are motivated to participate and that in turn invite their SME suppliers to be part of cleaner production and IS dissemination programmes.[2]

CAR and the Universidad de los Andes are responsible for explaining the main characteristics of the programme and its benefits. Subsequently, companies decide to participate by signing a letter of intent to do so, voluntarily and at no cost. The next phase consists of workshops that allow companies to design cleaner production and IS projects. The workshops culminate in the presentation of the final projects. Finally, the implementation of the projects is verified six months later (van Hoof and Duque-Hernández 2020).

Currently, the programme targets four areas for change: cleaner production, IS, comprehensive water management, and CAR granting Environmental Recognition for Sustainable Companies (RACES). In addition, RedES-CAR is responsible for involving other sectors of academia in the process: it has trained other universities with a view to transforming them into service centres that disseminate the programme's methodology in cleaner production and IS and that are also able to provide support to companies in the development of their circular economy projects (van Hoof and Duque-Hernández 2020). Currently, four universities are part of this initiative: Universidad Javeriana, Universidad El Bosque, Universidad Piloto de Colombia and Corporación Universitaria Minuto de Dios.

It should be noted that the success of RedES-CAR is based on the joint work of public, private and academic institutions. Thanks to the programme, an alliance has been created between these three sectors, which has enabled the participation of various actors who manage to align their interests and increase the benefits obtained (van Hoof et al. 2016). The role of academia is particularly important since it functions as a bridge between the public sector and the private sector. Through workshops and support in the formulation of company projects, trust is established between these three groups.

The majority of anchor enterprises belong to the food and beverage industry, followed by associations of industrial or agricultural producers (van Hoof and Duque-Hernández 2020). Of the first 20 IS projects designed through RedES-CAR, 17 involve by-product exchange, 2 involve shared services, and 1 involves joint bio-sludge management (Park, Duque-Hernández and Díaz-Posada 2018).

2 Anchor companies are required to operate within the jurisdiction of CAR.

▶ 2.1.3. Characteristics of industrial symbiosis networks in Colombia

In the case of RedES-CAR, project development began in 2016, with implementation starting a year later. The eco-industrial parks are in the initial stage of implementation. This does not mean that Colombian companies were not participating in IS networks previously, but rather that there was no record of these cooperative processes.

Apart from the companies involved in RedES-CAR, there is currently no administrative record or questionnaire that allows the characteristics of IS networks in Colombia to be examined. However, with the aim of estimating the number of companies that are potentially involved in IS networks where waste and by-products are exchanged, data from the Great Integrated Household Survey (GEIH) and the Annual Manufacturing Survey (EAM) were explored.

A review of the type of companies that are part of RedES-CAR revealed that manufacturing companies and those whose main activity consists of the recovery of materials and waste were active participants within the networks. For this reason, manufacturing industries that use waste as raw material and industries that commercialize this waste were identified. This was possible through EAM analysis. On the other hand, the GEIH made it possible to identify the characteristics of workers who are in the materials recovery industry.

Taking into account that the EAM examines only formal and established institutions (they must have annual income of more than 500 million Colombian pesos and at least ten employees), the analysis of GEIH microdata was also considered, whereby workers in the materials recovery industry can be identified without the constraint of company size.

In order to identify which companies in the 2018 EAM use waste as raw material and which produce waste for commercial purposes, the results of the indicator developed by DANE (2020a), "Consumption of waste products by manufacturing industry", were considered. The document describes which products are taken into account according to the Central Product Classification V2 A.C. These products include, for example, cocoa husks, iron scrap, coal slag, glass waste and paper waste. Taking these definitions into account, some characteristics of the enterprises were found.

In thousands of tonnes, in 2018 cocoa husk was the most used raw material from waste (926), followed by scrap iron (732), paper and cardboard waste (713), glass waste (616) and scrap steel (547) (DANE 2020a).[3]

3 The quantities do not reflect their economic value or their representativeness in the production chain. However, the type of waste that is used as raw material is shown.

Companies that use waste as raw material represent 8.5 per cent of all industrial establishments in Colombia. Table 2.1 shows the percentage of all establishments using waste as raw material represented by each industry. Food and beverage product manufacture is the industry with the highest percentage (32.83 per cent), followed by manufacture of other non-metallic mineral products (14.16 per cent) and manufacture of rubber and plastic products (11.14 per cent).

Table 2.1. Breakdown of companies using waste as raw materials by industry, national total, 2018 (percentage)

Industry	%
Manufacture of food and beverage products	32.83
Manufacture of other non-metallic mineral products	14.16
Manufacture of rubber and plastic products	11.14
Coking; manufacture of petroleum-refining products; fuel-blending activity; manufacture of chemical substances and products	8.58
Manufacture of basic metallurgical products	7.53
Manufacture of machinery and equipment not elsewhere classified	4.97
Manufacture of paper, cardboard, and paper and cardboard products	4.82
Manufacture of products made from metal, except machinery and equipment	4.22
Tanning and retanning of leather; shoe manufacture; manufacture of travel items, suitcases, handbags and similar; manufacture of saddlery and harness articles; dressing and dyeing of fur	3.16
Manufacture of textile products and clothing manufacture	1.66
Manufacture of computer, electronic and optical products; manufacture of electrical appliances and equipment	1.51
Other manufacturing industries and specialized installation; maintenance and repair of machinery and equipment	1.51
Manufacture of pharmaceutical products, medicinal chemical substances, and botanical products for pharmaceutical use	1.36
Manufacture of furniture, mattresses and bed frames	1.36
Manufacture of motor vehicles, trailers and semi-trailers	1.20
Total	100.00

Note: Industry categories are based on ISIC V4 (International Standard Industrial Classification of All Economic Activities, Revision 4).

Source: Drafted by the authors based on the 2018 EAM.

With respect to companies that commercialize waste, it was apparent that only 2.7 per cent of the industry in Colombia carries out this activity. Table 2.2 shows the percentage of all companies that commercialize waste represented by each industry. In a similar way to companies that use waste, it is the food and beverage production sector that has the greatest percentage of companies that sell waste, accounting for more than half of all such establishments (62.5 per cent). Table 2.2 also shows that there are fewer sectors involved in commercializing waste than there are in using it (table 2.1).

▶ **Table 2.2. Breakdown of companies commercializing waste by industry, national total, 2018** (percentage)

Industry	%
Manufacture of food and beverage products	62.5
Manufacture of rubber and plastic products	11.5
Manufacture of products made from metal, except machinery and equipment	6.3
Manufacture of paper, cardboard, and paper and cardboard products	5.7
Manufacture of textile products and clothing manufacture	2.6
Tanning and retanning of leather; shoe manufacture; manufacture of travel items, suitcases, handbags and similar; manufacture of saddlery and harness items; dressing and dyeing of fur	2.6
Manufacture of basic metallurgical products	2.6
Coking; manufacture of petroleum-refining products; fuel-blending activity; manufacture of chemical substances and products	1.6
Manufacture of other non-metallic mineral products	1.6
Manufacture of electrical appliances and equipment	1.6
Manufacture of machinery and equipment not elsewhere classified; manufacture of motor vehicles, trailers and semi-trailers	1.6
Total	100.0

Note: Categories are based on CIIU V4 (DANE 2020b).

Source: Drafted by the authors based on the 2018 EAM.

In addition to the type of sectors that participate in the use and commercialization of waste, it is also important to understand the size of the companies that carry out these activities and some characteristics of their workers. Table 2.3 shows average values for certain characteristics of the companies that use and commercialize waste. In addition, these values are compared with the characteristics of the entire industry.

Table 2.3. Characteristics of employees in companies using waste as raw material and in those commercializing it, national total, 2018

Variable	Industrial establishments that use waste as raw material	Industrial establishments that commercialize waste	All establishments
Number of employees	123.29 (210.16)	217.03 (300.02)	89.62 (158.95)
Percentage of women	27% (0.20)	25% (0.15)	37% (0.24)
Percentage of professionals	10% (0.13)	13% (0.15)	11% (0.14)
Percentage of direct temporary employees	19% (0.34)	20% (0.33)	22% (0.33)
Percentage of employees on indefinite contract	67% (0.37)	64% (0.34)	65% (0.35)
Number of establishments	664	192	7 791

Note: The values shown are averages; standard deviations are shown in parentheses.
Source: Drafted by the authors based on the 2018 EAM.

The information in table 2.3 demonstrates that establishments that use waste as raw material are generally smaller than those that produce and commercialize waste. The average percentages of professional employees, direct temporary employees and indefinite-term employees are very similar for the three groups studied. Regarding the percentage of women, there is a difference of 10 percentage points between the average percentage of women across all establishments and those that use waste, and 12 percentage points compared with those that commercialize waste.

In addition, information from household surveys can be used to identify another sector that has a high probability of IS network participation: materials recovery. Table 2.4 contains information about the number of jobs in this sector, the participation of women and the informality rate. Here, the materials recovery sector is compared with a sector that is traditionally informal – the trade in waste, refuse and scrap metal.

▶ **Table 2.4. Characteristics of employees in materials recovery and in wholesale trade of waste, refuse and scrap metal, national total, 2019**

Industry	Materials recovery	Trade in waste, refuse and scrap metal
Percentage of women	24.81%	27.88%
Rate of informality (defined by company size)[1]	80.12%	86.65%
Rate of informality (defined by pension affiliation)[2]	89.07%	89.26%
Number of jobs	36 251	78 609

Note: [1] According to this definition, workers are considered informal if they are part of companies with fewer than five workers or if they are independent and perform unskilled activities. [2] According to this definition, an informal worker is one who does not contribute to a pension fund.

Source: Drafted by the authors based on the 2019 GEIH.

The materials recovery sector includes activities such as processing of plastic or rubber waste and its conversion into granules, and processing of oils, fats, food and beverage waste and their conversion into secondary raw materials, among other mechanical or chemical transformation processes (DANE 2020b). According to information from the GEIH, 36,251 people worked in this sector. Table 2.4 reports that 24.81 per cent of these workers are women and that high rates of informality prevail (80.12 per cent). This last indicator is explained by the size of the companies, which tend to be very small. When these characteristics are compared with the waste, refuse and scrap metal trade sector, it is observed that there is a

slightly lower participation of women in the materials recovery sector and that, with respect to the informality rate, when defined by company size, it is higher for the waste trading sector. However, the informality rate, when defined by pension affiliation, is very similar in both sectors.

IS networks may involve activities that go beyond those described in this section. For example, activities such as energy use, synergies with other sectors besides industry, services and shared spaces are outside the scope of the figures that have been reported here. However, some conclusions can be drawn from the available data. Specifically, it can be concluded that a low percentage of industrial establishments participate in waste utilization activities and in waste processing and commercialization activities. However, two sectors stand out in these processes: manufacturers of food and beverage products and rubber and plastic manufacturers. It was also evident that activities such as materials recovery are concentrated in small companies. On the other hand, the low participation of women in the workforce of these sectors is very similar to the participation level seen in Colombia's industrial sectors as a whole (see table 2.3).

2.2. Methodology

Given the lack of a registry or other source of consolidated information on the companies that are part of the industrial symbiosis (IS) networks, the decision was made to collect primary data that would make it possible to identify the effects of IS on employment.

This primary information comes from two sources. In the first instance, information was obtained from companies that form part of three IS network case studies. The second source draws on interviews with key respondents. When using case studies, there are limitations on the extent to which generalizations can be made from the conclusions derived. However, these case studies make it possible to conduct an in-depth analysis of how IS processes affect employment-related factors. In the case of interviews, while key respondents may have a perception bias, their input nevertheless provides a general overview that complements the findings of the case studies.

Most previous analyses of the social indicators of IS networks are based on case studies. For this study, the RedES-CAR value chains were used as a reference. Given that most of the projects developed in RedES-CAR concern by-product and waste transactions, this type of IS was taken into account in the selection of cases. To choose case studies, a decision was made to contact the anchor enterprises or organizations in the 2017, 2018 and 2019 value chains. Identifying the companies and the contacts within them was made possible by information published by RedES-CAR

on its web page. Specifically, four anchor enterprises from the food and beverage sector were contacted, in addition to one from the cosmetics sector, one from the construction sector and one from the agro-industrial sector. Likewise, contact was made with businesses associated with the anchor enterprises. However, information was obtained only from those that agreed to participate in the study. In total, seven companies were contacted.

At the end of the exercise, information was captured from one network for each of the chains for the years 2017, 2018 and 2019. The information was gathered through telephone-assisted surveys conducted with IS project managers. The objective of these surveys was to obtain information that would provide greater clarity on the functioning of IS projects and to identify how these could represent changes within the companies that ultimately led to the hiring of more personnel or the assignment of new activities within the companies.

For the second source of primary information, semi-structured interviews were carried out with representatives from RedES-CAR, UNIDO, the Colombian Ministry of Environment and the National Planning Department (DNP) and with coordinators of the Cauca Free Zone.[4]

2.3. Company survey results

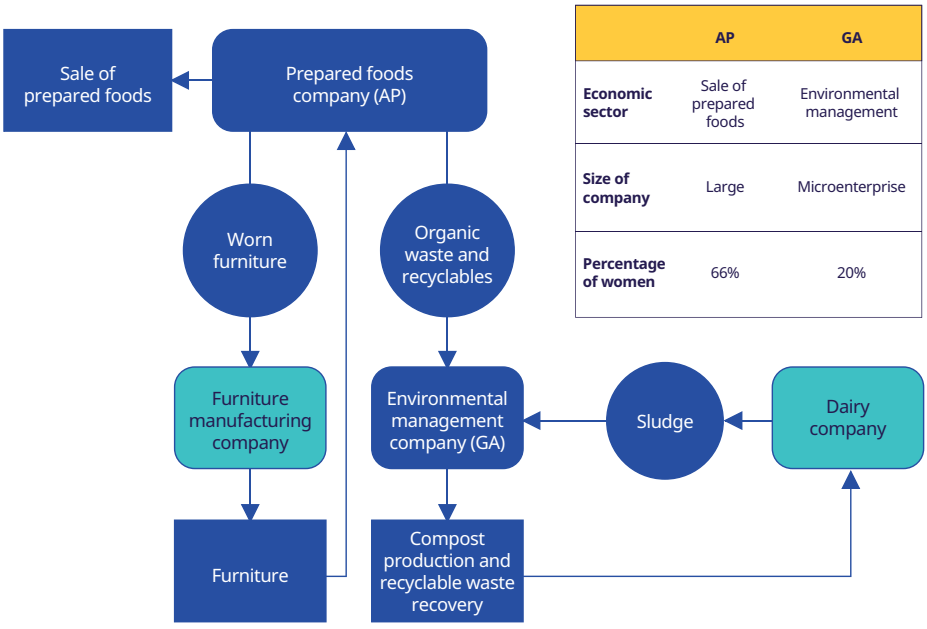
For the three case studies that were taken into account, a strategy was devised to describe the industrial symbiosis (IS) process, along with some characteristics of the companies consulted. In each case, the number of new jobs created from IS networks, the creative sources of these jobs, the types of jobs created, and the number of jobs retained are presented. This last indicator is understood as the number of workers who, thanks to the IS process, are carrying out new activities. Finally, some answers to open questions given by the companies surveyed about the effects of IS on employment and the existence of qualified personnel in the Colombian labour market are presented together.

4 For further details on the methodology used in this country study and on the study more broadly, see Ríos and Rodríguez (2021).

2.3.1. Case study 1

The first case study concerns an anchor enterprise that has been participating in the RedES-CAR programme since it began in 2013. Figure 2.1 illustrates the composition of the network.

Figure 2.1. Composition of the industrial symbiosis network in case study 1



	AP	GA
Economic sector	Sale of prepared foods	Environmental management
Size of company	Large	Microenterprise
Percentage of women	66%	20%

Note: The circles represent the waste or by-products of the companies, while the boxes with square corners represent their final products. The blue boxes with rounded corners represent organizations that are part of the network and were surveyed; the turquoise boxes with rounded corners represent organizations that could not be contacted for the study.

Source: Drafted by the authors.

Some characteristics of the companies involved are shown in figure 2.1, including the economic sector, the size of the company, the percentage of women in the company, and the exchange and conversion of waste in production processes. The anchor company, whose main activity is sale of prepared foods (AP), delivers worn-out furniture used at points of sale to another company, which reuses the furniture materials and creates new furniture, which is used again by AP. At the same time, AP delivers its organic and recyclable waste, such as paper, cardboard and glass, to an environmental management company (GA). GA produces compost with the organic material. Some of this compost is returned to AP, which delivers it to farmers who are part of its value chain.[5] However, the compost usually goes to a dairy company, which uses it to fertilize the soil for its livestock. This company also generates sludge or industrial water, which is processed by GA.

Table 2.5 indicates the transformative processes that took place within the companies thanks to the IS network. In AP's case, supplies such as furniture were acquired. AP told us that existing suppliers were replaced, and savings of nearly 40 per cent were generated by acquisition of furniture through the network, in comparison to the previous method of acquisition. This network began in 2018 and its economic impact is still relatively small.[6]

5 This process is not shown in figure 2.1 as it does not occur frequently, and when it does occur, it involves only small quantities.

6 In 2019 the furniture used was 58 point-of-sale chairs, 32 office chairs, 23 pieces of furniture and 30 waste-sorting bins.

Table 2.5. Results of case study 1

Company	AP	GA
Input acquisition	Yes	No
Production increase	No	–
Generation of savings	Yes = furniture Spending = usable organic waste	Yes
New income generation	No	Yes
Jobs created	–	3
Job creation mechanisms	–	Savings, new activities, new income
Type of workers hired	–	Operational staff, supervisors of production activities
Job retention	–	4

Source: Drafted by the authors.

IS did not result in the direct generation or retention of jobs within AP. However, effects were apparent in other companies that provide services to AP. For example, the furniture manufacturing company hires people in vulnerable conditions, and AP has an inclusive hiring policy that allows these types of companies to participate in its value chain. Likewise, the potential effect on employment in the company GA, which is in charge of the waste transportation, sorting and disposal process, was mentioned in the questionnaire. This was corroborated through analysis of the effects on GA. The questionnaire revealed that GA's participation in the IS chain with AP and the dairy company resulted in additional income, new activities generated within the company, and savings; and thanks to these, three additional jobs were created for operational personnel and production activity supervisors, and four jobs were retained.

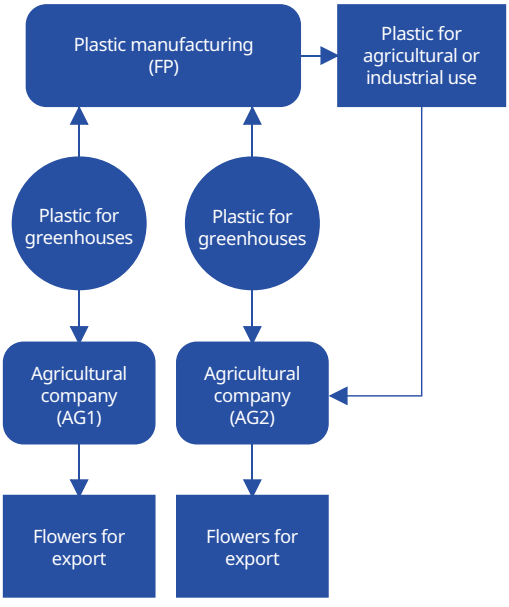
Regarding future prospects, the two companies indicated that network expansion might be possible over the next five years. AP indicated that it plans to expand its Bogota-based recyclables and organics recovery operation to other cities. For GA, there are opportunities for expansion as it manages to integrate more companies into its processes and to collaborate with more networks of recyclers. GA also indicated that in the coming years it could increase its workforce thanks to the network and that to do so it would require personnel in the areas of engineering, innovation and digital development.

▶ 2.3.2. Case study 2

The second case study comprises three companies. The anchor enterprise that was contacted is an organization in the manufacturing sector, and through this, two companies in the agricultural sector were contacted. Figure 2.2 shows the make-up of the IS network, which has been in operation since 2018.

▶ Figure 2.2. Composition of the IS network in case study 2

	FP	AG1	AG2
Economic sector	Manufacturing	Agriculture	Agriculture
Size of company	Large	Large	Large
Percentage of women	40%	48%	49%



Note: The circles represent the waste or by-products of the companies, while the boxes with square corners represent their final products. The boxes with rounded corners represent organizations that are part of the network.

Source: Drafted by the authors.

As can be seen in figure 2.2, all the companies that are part of this network are large. The two agricultural companies AG1 and AG2 export flowers, while the manufacturing company FP makes plastic for agricultural and industrial use. Regarding waste transactions, AG1 and AG2 deliver used greenhouse cover plastic to FP; in exchange, FP gives back plastic for agricultural use to AG2, while it pays AG1 for its waste plastic. An interesting aspect of FP's experience is that it has been carrying out IS projects since 2008 and joined the RedES-CAR initiative only in 2018. FP conducts transactions with approximately 25 companies and already exchanged plastics with AG1 before joining the RedES-CAR programme. It became acquainted with AG2 during the programme.

Table 2.6 shows the various changes that occurred within companies when they joined the IS network. While FP and AG2 acquired inputs, AG1 did not, since it only receives money from FP in exchange for greenhouse plastic. Only FP experienced an increase in production, which was partly due to the fact that it carries out exchanges with many companies, as mentioned previously. Also, as was reported in the interview, FP has had to increase its lines of production over the years; initially, it had only one, but it currently has three.

Table 2.6. Results of case study 2

Company	FP	AG1	AG2
Input acquisition	Yes	No	Yes
Production increase	Yes	–	–
Generation of savings	Yes	Yes	Yes
New income generation	Yes	Yes	Yes
Jobs created	10	20	–
Job creation mechanisms	Input acquisition, savings, new activities, new income	Savings, new activities, new income	–
Type of workers hired	Machine supervisors, operational staff	Labour for classification and sorting of waste	–
Job retention	12	–	2

Source: Drafted by the authors.

The three companies commented on savings generated as a result of being part of the IS network. AG2 experienced savings thanks to FP, and vice versa. However, AG1 experienced savings with other companies by which it is supplied with paper, cardboard and packaging (these other companies were not considered in this case study). Regarding the generation of new income thanks to the commercialization of by-products and waste, the three companies reported having acquired new income. In the case of AG1 and AG2, this was generated through FP, while FP obtained its income from other companies.

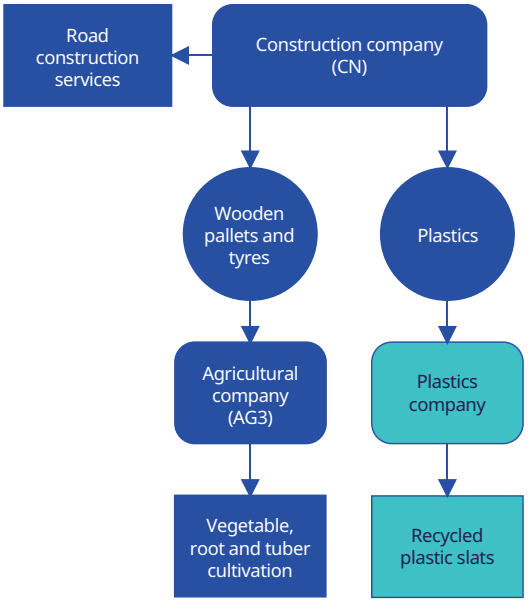
With respect to job creation, approximately ten jobs were created in FP through IS and via several mechanisms: input acquisition, generation of savings, new activity development (for example, collection, classification, cleaning and processing of materials) and new income. In the case of AG1, approximately 20 jobs were created; these were created through generation of savings, new income and new activity development. In the case of AG2, no jobs were created. At the same time, 12 jobs were retained in FP, and two in AG2.

Finally, when the coordinators were asked about their perspective on the future with respect to company capacity to increase the number of new jobs thanks to IS networks, the FP and AG1 coordinators responded yes, while the AG2 coordinator said no. This is because FP and AG1 believe that their networks can expand over five years, while AG2 does not know if this is possible in its case.

▸ 2.3.3. Case study 3

The third and final case study is made up of two companies. This IS network dates back to 2019 and is therefore the most recent of those studied. As can be seen in figure 2.3, the company CN is a large company in the construction sector, while AG3 is a microenterprise that grows root and other vegetables. In this IS network, CN delivers wooden pallets and tyres to AG3. These materials are used in crop beds, although both companies commented that this waste is only delivered seasonally. At the same time, CN delivers plastics to a company that produces recycled plastic slats for the construction of homes. This company, however, was not contacted since it is not part of RedES-CAR and only came to be known through the questionnaire.

Figure 2.3. Composition of the industrial symbiosis network in case study 3



	CN	AG3
Economic sector	Construction	Agriculture
Size of company	Large	Microenterprise
Percentage of women	18%	40%

Note: The circles represent the waste or by-products of the companies, while the boxes with square corners represent their final products. The blue boxes with rounded corners represent organizations that are part of the network; the turquoise box with rounded corners represents an organization that could not be contacted for the study.

Source: Drafted by the authors.

Table 2.7 shows how companies transform as part of IS networks. Only AG3 acquired inputs; neither company experienced an increase in production. Both companies reported savings. CN experienced savings as it avoided paying for waste to be sent to landfill with both AG3 and the plastics company. At the same time, AG3 generated savings by not having to pay for receipt of the pallets and tyres.

▶ Table 2.7. Results of case study 3

Company	CN	AG3
Input acquisition	No	Yes
Production increase	–	No
Generation of savings	Yes	Yes
New income generation	Yes	No
Jobs created	–	–
Job retention	10	–

Source: Drafted by the authors.

Only CN experienced income generation. It reported that it had generated new income thanks to the commercialization of other types of waste with companies that are not included in this network. Neither company experienced job creation. CN managed to retain ten jobs because, as part of the IS network, some of its current employees had to perform new activities and therefore additional work was created for them. The CN coordinator explained that this retention of jobs occurred when CN was working with the plastics company. As an example, the coordinator spoke of the work to develop campaigns to collect plastic with the company's workers and their families, in addition to campaigns that were carried out in several schools.

Finally, in answer to the question of whether the company might be able to create new jobs within five years thanks to the IS network, both coordinators were of the view that this would not be possible. This is possibly due to the type of waste they work with. In CN's case, new personnel were not required for plastic collection, which can be carried out with the company's existing workers. This encourages job retention but not job creation.

2.3.4. Review of the three case studies

The overall review of the three case studies reveals that IS processes have the capacity to generate employment. Three of the companies surveyed reported the creation of new jobs. This occurred in two large companies and in one microenterprise, and a total of 33 jobs were created. For FP, which is a large company, the ten jobs created represent 2.5 per cent of its total employees. In AG1, the 20 jobs created represent only 0.6 per cent of its total employees. In GA, the microenterprise, the three jobs created represent 30 per cent of its total employees. These data show that the capacity for job creation varies depending on the IS processes and the types of companies that participate. For example, in small companies in the environmental management sector, the number of jobs generated as a result of IS is considerable; however, in large agricultural and plastics companies, the number of jobs created is, proportionately, very small. On the other hand, the common denominator within the companies that created jobs is that the IS processes jointly allowed them to create income, generate savings, and increase the number of activities within the companies.

In other cases, where income and savings were generated but there was no significant change in the company's internal processes, direct employment generation was not identified. However, it should be noted that, given the magnitude of the economic resources derived from IS, a company may be able to carry out plans to expand its personnel using these additional resources, which may thus generate job creation indirectly. Another mechanism that was found is acquisition of inputs. This must be accompanied by an increase in production because if, for example, an existing input supplier is replaced, there will be no significant change and the staff in the company will not be affected.

That said, the results of the survey also show that there was job retention resulting from IS. Of the companies surveyed, four reported job retention. In each case, jobs were retained because, in joining an IS network, some of the current employees had to perform new activities and additional work was therefore created for them. In total, the retention of 28 jobs was reported. In some cases, as in the companies CN and FP, activities related to IS form part of the responsibilities of workers in environmental management and do not represent an additional workload. In other cases, such as the company AG2, when new IS-related activities represent a considerable addition to the workload, there is an increase in workers' salaries.

In the company questionnaire, IS project coordinators from each of the companies surveyed were asked some open questions. Regarding job creation, all of them were of the view that IS was a means through which new jobs could be created. When asked their views on how jobs could be created, one mechanism mentioned was the creation of new lines of business and business creation. CN, for example, mentioned a company that works with recycled plastic ribbons for construction and explained how this company was created from its involvement in IS.

Another mechanism mentioned was the new activities that emerge in companies that belong to an IS network. These new activities, which include the sorting and classification of waste and the transformation of waste into by-products, require new labour that was not previously needed by the company. Finally, the topic of industrial innovation was mentioned. This relates to the adoption by companies of new technologies, including specialized recycling machines and the workers needed to operate them.

The company managers and coordinators were also asked what type of workers they believed would be required to expand their IS networks. The answers included operational personnel, personnel for the sorting and classification of waste, environmental professionals, and digital developers who would enhance the creation of networks and facilitate contact between companies. Several of the coordinators agreed that both skilled and unskilled labour would be needed. In addition, six of the seven respondents were of the view that these kinds of workers are available in the Colombian labour market.

The questionnaire also included a question asking for clarification of the role of RedES-CAR in the operation of these networks. The companies that developed their IS projects after joining RedES-CAR highlighted the support available to help develop their projects and pointed to the awareness-raising work carried out in the programme. In the case of companies that already had IS processes in place prior to entering the programme, the main role of RedES-CAR was identified as opening up a space to meet new companies, expanding networks and, above all, providing an opportunity to learn about the concept of IS from an academic point of view. This was important because, prior to joining the programme, these companies had developed their IS projects in a more intuitive way and, in some cases, without a clear methodology or follow-up processes.

Taking the above into account, it is evident that IS processes can sometimes occur as a result of a company's own initiative, without the intervention of a third party, and that some companies have been creating their own networks in this way. One of the factors that allows the emergence of IS initiatives is that they place value on environmental responsibility, specifically regarding the management of waste that is generated in their plants. Another factor that was observed is that the pursuit of international accreditation by companies can also be a gateway for companies to start the IS process. Such was the case with the company FP. On the other hand, the creation of IS networks prior to RedES-CAR occurred in companies from various sectors that initially had only a commercial relationship, as was the case with FP and AG1. In such cases, it is more likely for waste transactions to occur without the influence of an external agent. However, there are other companies, such as CN and AG3, which are from completely different sectors and had no prior relationship whatsoever before they joined the RedES-CAR programme. In these cases, an IS network could not have been generated had it not been for the existence of the programme.

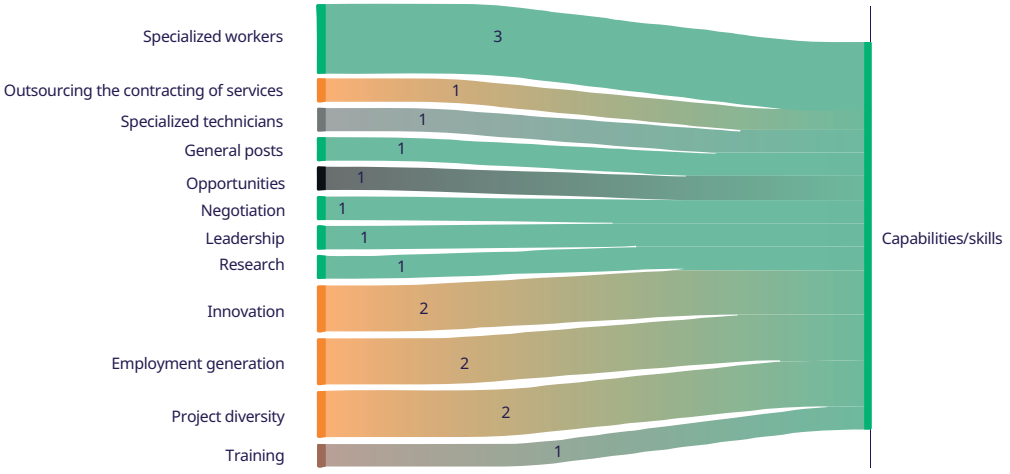
2.4. Results and analysis of the interviews

2.4.1. Skills for industrial symbiosis

Key respondents were asked about the type of skills that would be required for the jobs created in the industrial symbiosis (IS) processes and about the availability of workers with such skills in the Colombian market. The respondents agreed that the required skills depend on the type of projects being developed. In certain cases, specialized workers will be required – for instance, for the design of industrial waste plants. Likewise, the respondents agreed that the relevant skills were generally available in the Colombian labour market, although they reiterated that the particular skills required depend on the type of IS project.

Figure 2.4 shows the skills and competencies required of workers that were mentioned during the interviews. Some competencies raised in the interviews include innovation, research, negotiation skills and leadership by decision-makers within companies. On this point, three respondents highlighted the importance of involving not only the technical part of the company, but also those who make up the company's senior project management team.

▶ Figure 2.4. Competencies and skills required for jobs created by industrial symbiosis



Note: The numbers represent the number of times a given theme was raised in the interviews; related themes are shown in similar colours.

Source: Drafted by the authors.

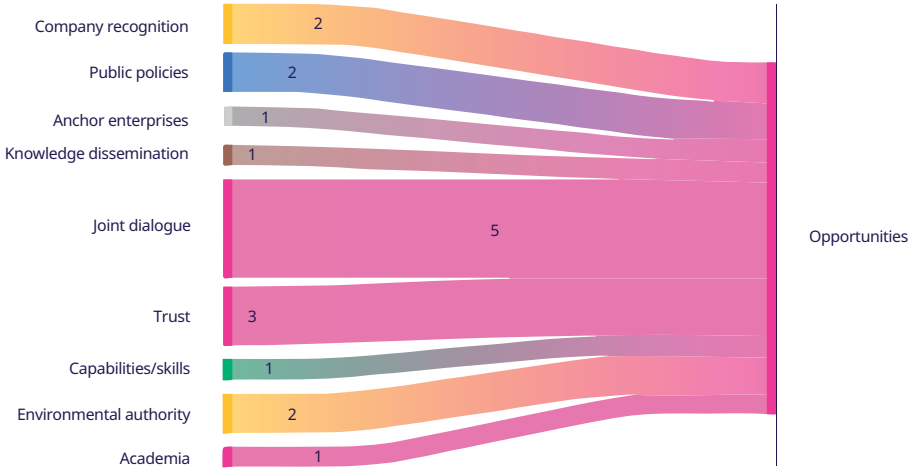
▶ 2.4.2. Industrial symbiosis development opportunities

Key respondents were also asked about opportunities to promote IS networks in Colombia (figure 2.5). The opportunities identified include:

- the existence of anchor enterprises;
- the creation of spaces of trust between companies;
- joint dialogue between companies to identify opportunities for IS strategies;
- the presence of academia and an environmental authority in the development of projects;
- the existence of public policies;

- the dissemination of knowledge through training;
- the development of capabilities and competencies of company workers who are part of IS projects; and
- recognition for companies that develop IS projects.

Figure 2.5. Development opportunities for industrial symbiosis



Note: The numbers represent the number of times a given theme was raised in the interviews; related themes are shown in similar colours.

Source: Drafted by the authors.

The creation of spaces for joint dialogue between companies was the IS development opportunity most often raised by respondents. They mentioned that companies exchange information about their waste in training workshops and try to establish how they can achieve mutual benefits. In one case, a lack of communication meant that two companies – although they were neighbours and within the same free zone – had not recognized that they could conduct a mutually beneficial exchange.

Another factor that was mentioned several times by the key respondents was the building of trust between companies. For example, RedES-CAR has facilitated relations in such a way – especially with respect to academia – that companies now feel comfortable talking about their production processes, thereby allowing these waste and by-product transactions to take place.

In the interview with RedES-CAR, the role of the CAR environmental authority was highlighted. Not only does it promote sustainable development in the companies under its control, but in order to further promote these projects, CAR has also begun to recognize sustainable companies, bestowing a distinction (in the form of a RACES award) on those that have developed cleaner production and IS projects. This distinction does not provide any economic benefit, but it enhances a company's reputation.

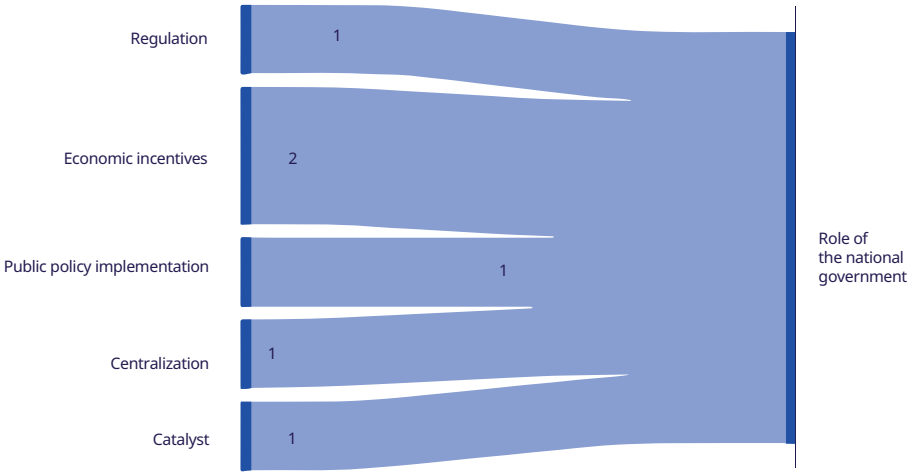
▶ 2.4.3. Challenges for the development of industrial symbiosis

Challenges identified by key respondents were financing, feasibility and economic incentives. Financing was the challenge mentioned most often. It can be costly for companies to adopt circular economy and IS strategies, which is why economic incentives are required to facilitate these processes and to enable new companies to join the country's manufacturing sector, which is still small. Similarly, another aspect deemed important was the existence of legislation to promote the creation of eco-industrial parks. Actors playing a significant role in overcoming these challenges include both national and local governments and academia.

▶ 2.4.4. Role of the national government

Key respondents were asked how they viewed the role of the national government in promoting job creation through IS (figure 2.6). The role most often mentioned was that of providing economic incentives. It was believed that the government can provide tax incentives to companies participating in these projects, which are working to reduce their level of waste and rely on technological innovation to do so.

Figure 2.6. Role of the national government in promoting industrial symbiosis



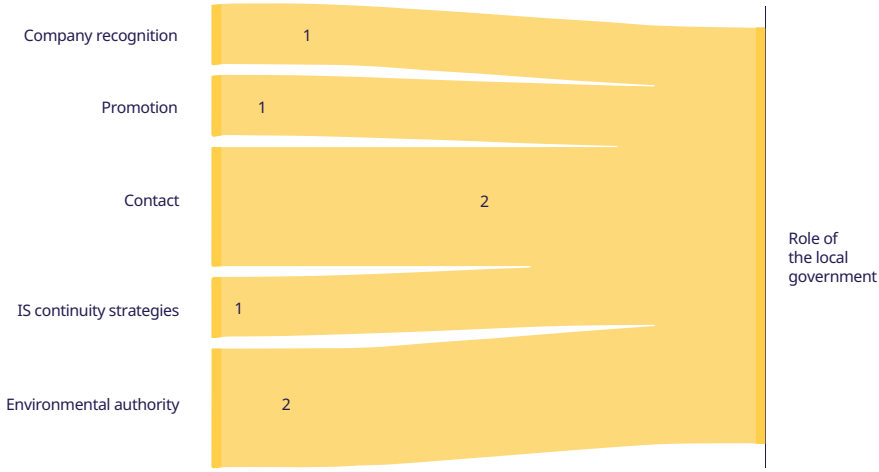
Note: The numbers represent the number of times a given theme was raised in the interviews.
Source: Drafted by the authors.

At the same time, it was commented that government institutions could play a centralizing role in terms of benefits, contacts and information. The government could set up a work team dedicated specifically to IS, to inform people about existing opportunities and to provide information and technical assistance. Other government roles, such as implementing public policies and acting as a catalyst and regulator, were also emphasized.

2.4.5. Role of the local government

It was explained by key informants that the local government is a perfect point of contact between civil society and the private sector, serving as a shared platform where these actors can meet companies of the free zone or industrial parks and discuss how a project can be developed together (figure 2.7). Additionally, the local government is in a position to communicate with the national government and to scale the needs of its region. These characteristics of local governments are key to their capacity to promote and develop IS strategies across different parts of the country.

▶ Figure 2.7. Role of the local government in developing and promoting IS projects



Note: The numbers represent the number of times a given theme was raised in the interviews.
Source: Drafted by the authors.

Another important role played by the local government, connected to its role as interlocutor, is that of promoter. As local governments are in contact with both companies and people in the community, they are in a good position to promote IS. The regional authority CAR has been able to guide and facilitate IS strategies. In addition, there were comments on the role of the local government in maintaining continuity in IS strategies. There is a challenge here: to ensure that IS initiatives continue to be promoted and that they endure and evolve over time. It is this continuity that allows IS processes to gradually unfold, creating employment as they do so.

▶ 2.4.6. National government initiatives to promote industrial symbiosis

Consultations with national government sectors revealed that their efforts with respect to IS are focused on supporting the UNIDO Eco-Industrial Parks Programme. Indirectly, another initiative that could encourage IS development is government efforts to promote green businesses. This strategy involves creating a portfolio of green businesses at the national level, promoting these businesses and supporting their improvement plans,

thereby enabling them to enhance their levels of social responsibility. One green business line is recovery and treatment of waste. The promotion of SMEs operating in this line and the existence of the portfolio can encourage the establishment of IS networks, since companies that want to make better use of their waste can use the portfolio to contact possible associates.

The interviews confirmed that there are no other strategies specifically aimed at promoting IS in Colombia, beyond those already identified by UNIDO and RedES-CAR.

2.5. Conclusions

- Jobs are created within companies as a result of their participation in industrial symbiosis (IS) networks. Three of the companies surveyed reported the creation of new jobs. This occurred in two large companies and in a microenterprise whose main activity is materials and waste recovery. Thirty-three jobs were created in total.
- The number of jobs created through IS is of particular importance for small companies, but not for large ones.
- The mechanisms through which employment was created were: development of new activities related to sorting and classification of waste; generation of savings; generation of new income; acquisition of inputs; development of new activities not previously planned within companies; growth of SMEs; creation of companies; and development of new lines of business.
- IS allows for job retention. Of the seven companies surveyed, four reported job retention. In total, the retention of 28 jobs was reported.
- For IS, leadership and negotiation skills were predominantly highlighted, since these are necessary to establish contact with other companies and reach mutually beneficial agreements. Likewise, research, innovation and adaptation to change were mentioned.
- To promote IS, the national government can give tax incentives to companies that are developing this type of strategy.
- The government could create in some of its entities an office dedicated specifically to IS, and thus centralize in a more concrete way the benefits, contacts, information or technical assistance relevant to this issue.

- Local governments can be a channel of communication with the national government; they could also create a space for the private sector to meet with civil society to discuss projects that enhance IS in the region.
- Local governments can act to promote IS since they have the ability to communicate more closely with companies and people in their community.
- The private sector does not exclusively require the intervention of third parties for IS processes to occur; however, third-party support can enhance these processes through network expansion, measurement of indicators and project monitoring.
- A relevant actor that can convene and create bridges between initiatives and companies is the National Association of Entrepreneurs of Colombia (ANDI), which currently supports the Eco-Industrial Parks project and can strategically create a bridge between companies and the project.
- The participation of industries in waste recovery and commercialization processes is low.
- IS can encourage the creation of value chains between large and small companies, with a view to the development and formalization of the latter.

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Direct productive employment in industrial symbiosis

in the Tanzanian sugar sector

3

Amani George Rweyendela and William John Mwegoha

3.1. Industrial symbiosis in the sugar industry

Ongoing political debates have focused on sustainable industrialization as an economic growth strategy to solve the United Republic of Tanzania's persistently high unemployment and poverty rates (Kamat et al. 2019; Kinyondo, Newman and Tarp 2016). The sugar industry is considered a strategic sector for generating employment opportunities in the country and a significant component of industrial and agricultural policies (Sulle 2017). As a result, much policy attention is paid to this sector.

The sugar industry produces huge amounts and varieties of waste and by-products that can be utilized to produce various secondary products through industrial symbiosis (IS). Gopinath et al. (2018) set out a number of waste valorization pathways for achieving optimal resource utilization and zero waste in the sugar industry. The examples below describe some of the main valorization routes (Gopinath et al. 2018; Rweyendela and Mwegoha 2021; Veana et al. 2014; Zhu et al. 2008):

- **Energy industry.** Bagasse from sugar mills can be burned in cogeneration boilers to generate electricity, which can then be distributed to sugar mills and nearby communities. It can also be used to produce biofuels via pyrolysis. In addition to sugarcane bagasse, sugarcane straw (including cane stubble, tops and leaves) can also be used in cogeneration boilers.

- **Construction industry.** Residual bagasse ash has many applications in the construction industry. It can be used as an inert filler or supplementary cementitious material in cement production to enhance the durability and mechanical properties of cement. It can also be used to produce alkali-activated binders and unburnt bricks, as fine aggregates. Carbonation filter mud can be used for similar purposes.

- **Chemical and beverage industry.** Molasses produced in sugar refineries is widely used as a feedstock in distilleries for producing industrial ethanol/alcohol.
- **Pulp and paper industry.** Bagasse from sugar mills can be used in pulp and paper mills to make paper.
- **Fertilizer industry.** Press (filter) mud from the carbonation process and molasses from alcohol factories can be processed to make compound fertilizers.
- **Food industry.** Sugarcane bagasse and molasses can be used in the food industry to produce invertase, a key enzyme in the manufacture of sweeteners.

Only three studies have been reported to date that focus on characterizing the physical manifestations of Tanzanian IS networks, the underlying factors, and the economic and environmental benefits (Rweyendela and Kombe 2021a, 2021b; Rweyendela and Mwegoha 2021). In this context, the current study contributes to filling this knowledge gap by investigating the employment effects of IS in the country, with a particular focus on the sugar sector.

3.1.1. Overview of the Tanzanian sugar industry

Sugarcane development in what is now the United Republic of Tanzania began in the early 1920s, when the Tanganyika Planting Company factory was established in Moshi, and large-scale commercial sugar production started in the 1960s (Sulle and Dancer 2019). Since its privatization between 1998 and 2001, the industry has grown steadily in terms of cane production area, capital investment and revenue earned (Sulle 2017). In recognition of the social, economic and political importance of this sector, the Government of the United Republic of Tanzania has implemented three main policy measures to improve the business environment: the enactment of the Sugar Industry Act of 2001 and the establishment of the Sugar Board of Tanzania and the National Sugar Institute. The Sugar Board of Tanzania is mandated to regulate the industry, while the National Sugar Institute was established to develop the requisite labour force for the sugar sector. Overall, these policy initiatives are designed to encourage the development of the sector with a view to maximizing its numerous socio-economic and environmental benefits.

The construction of new facilities and the extension of current ones are supporting the expansion of the sector. There are currently seven sugar factories in the country, one of which is still under construction. Table 3.1 outlines the operational sugar factories, as well as the one that is currently being built.

Table 3.1. Overview of sugar projects in the United Republic of Tanzania

Manufacturer	Region	Year established	Installed/ planned capacity (tonnes per annum)
Bagamoyo Sugar	Pwani	2022	30–35 000
Kagera Sugar	Kagera	1982	105 000
Kilombero Sugar Company	Morogoro	1961	130 000
Manyara Sugar Company	Manyara	2003	8 000
Mkulazi Holding Company	Morogoro	Under construction	250 000
Mtibwa Sugar Estates	Morogoro	1973	50 000
Tanganyika Planting Company	Kilimanjaro	1930	100 000

Source: Asoko Insight (2022); Sulle (2017).

▶ 3.2. Methodology

An exploratory research design was applied, using case studies and qualitative research approaches as deemed appropriate. Because each case is a complex entity situated in its own context (Stake 2005), a multi-case study approach was necessary to illuminate contextual variations and similarities (Barratt, Choi and Li 2011; Stake 2005).

Research participants, both sugar enterprises and individuals, were sampled purposefully (Benoot, Hannes and Bilsen 2016). The final sample depended on the individual's or company's willingness and availability to participate in the research. For the survey, the target personnel were those with first-hand information on industrial processes, waste management and human resources, including process and production engineers, environmental managers, and human resource managers and officers. The research team targeted diverse key informants, including managers of enterprises, representatives of employers' organizations, government officials, academics, and experts in labour and industrial waste management. Key informants were sought for the qualitative interviews. The initial respondents were identified through the research team's personal and professional networks, and a snowballing technique was employed to identify additional respondents (Jalali and Wohlin 2012). The final sample comprised 14 respondents.

Data collection was carried out in two phases. The first phase involved mapping physical flows within the sugar companies. The aim of this phase was to survey the current state of industrial symbiosis (IS) activity in terms of physical energy and material flows and associated employment aspects. The overall methodological approach used was material flow analysis, a popular methodology used in industrial ecology to account for a system's physical flows and estimate the derived social, environmental and economic indicators (Brunner and Rechberger 2004; Sendra, Gabarrell and Vicent 2007). The empirical task involved characterizing the industrial processes, major inputs, major outputs and derived employment indicators. Access to the companies was gained through official requests. To ensure anonymity and confidentiality, each firm was given a code name.

The research team collected data through three main techniques:

- physical site observation: site visits to locate plants, industrial processes, and resource stocks and flows;
- document review: a review of websites and other corporate documents to identify relevant information; and
- surveys of staff and managers of enterprises using a questionnaire.

The second phase involved examining the perceptions and lived experiences of key actors. Here, emphasis was placed on capturing key actors' perceptions, opinions and experiences of the employment effects of IS activity. Data were collected through semi-structured, in-depth interviews with key informants using an interview guide.

The interview and survey data were analysed both qualitatively and quantitatively. The basic characteristics of IS activity and employment effects were summarized with descriptive statistics, using count data and percentages.[1]

The findings of the current study must be interpreted in the light of several limitations. First, we narrowed the scope of the analysis to focus only on direct jobs during the operational phase in order to produce more credible results. It should be noted that additional direct and indirect jobs are created during the planning, construction and installation phases. It is also important to acknowledge that the case study findings may not be generalizable to a larger population. Lastly, while IS networks are typically dynamic and evolutionary, the analysis presented here is based on data collected at a certain time. Consequently, important evolutionary features could not be captured. Therefore, further research focused on varied sectoral and geopolitical contexts is required to strengthen the qualitative and quantitative evidence on the topic, especially research that captures indirect and induced jobs and performs longitudinal analyses.

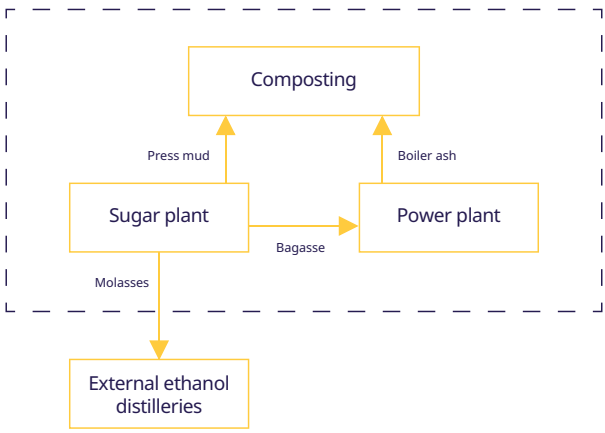
1 For further details on the methodology used in this country study and on the study more broadly, see Rweyendela and Mwegoha (2023).

3.3. Forms of industrial symbiosis and associated productive employment effects

3.3.1. Case study 1: Alpha Sugar Company

Analysis of Alpha Sugar Company revealed that, internally, only one main industrial symbiosis (IS) exchange occurs – namely, the use of sugar factory bagasse as a feedstock for a 20-megawatt internal power plant (figure 3.1). The generated electricity meets the company's energy needs, with the excess complementing the national grid. The internal applications include industrial activity, irrigation, office power and employee quotas. A portion of the molasses is sold to outside distilleries, while the remainder is used as animal feed by the company's employees and the local villages.

Figure 3.1. Material flow model for Alpha Sugar Company



Source: Drafted by the authors.

During peak season, the company employs approximately 1,900 people. IS operations have directly created approximately 88 jobs across various occupations, as summarized in table 3.2. This equates to approximately 4.6 per cent of the overall workforce.

Table 3.2. Characteristics of employees in companies using waste as raw material and in those commercializing it, national total, 2018

Occupational group (official title)	Tasks and duties performed	No. of jobs (2022)	Experience requirement	Educational requirement	Skills requirement	Women employed	Working contract
Boiler operators	Operate the boiler	9	2 years	Certificate	Boiler operations	0	Permanent
Engineers	Conduct operational tests; inspect and maintain systems	9	3 years	Bachelor's degree	Mechanical and water resources engineering	0	Permanent
Laboratory scientists	Collect samples; conduct laboratory analyses; prepare reports	6	1 year	Diploma	Analytical skills; data analysis; communication skills	0	Permanent
Mechanical assistants	Assist mechanical engineers	12	1 year	Diploma	Boiler and turbine mechanics; communication skills	0	Permanent
Plumbers	Install, repair and maintain plumbing fixtures	12	1 year	Certificate	Plumbing installation; repair and maintenance; communication skills	0	One-year contract, renewable
Assistants	Prepare bagasse bottom ash	30	None	Primary education	Communication skills	0	One-year contract, renewable
Compost operators	Conduct mixing and composting processes	10	Not indicated	Primary education	Manure handling and composting	10	One-year contract, renewable

Source: Drafted by the authors.

Table 3.3 describes the social welfare conditions at Alpha Sugar Company. According to respondents, these figures have not changed considerably in the past five years.

Table 3.3. Overview of social welfare conditions for workers associated with industrial symbiosis operations at Alpha Sugar Company

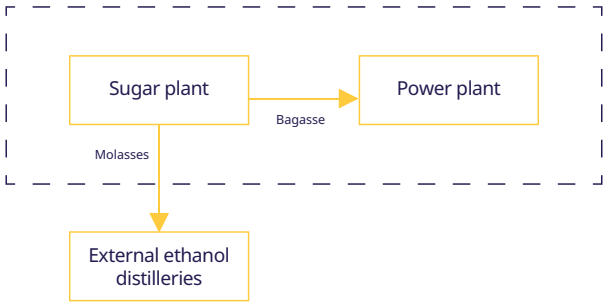
Social welfare aspect	Key findings
Number of new enterprises created and formalized owing to IS activities	Two
Total number of jobs formalized	All jobs are formal
Average wage per month	Varies with occupation and experience but above national minimum wage
Working hour limits	Eight hours per day
Workplace hazard protections in place	The company has an occupational health and safety policy, and all workers are given personal protective equipment and receive regular training
Reported occupational health and safety incidents per day/week	Four incidents per week reported
Unionization rate	Not disclosed
Social dialogue opportunities and activities (such as consultations, negotiations and workplace cooperation, including the parties involved and the frequency)	Internal meetings and workplace cooperation with an independent chemical company

Source: Drafted by the authors.

3.3.2. Case study 2: Beta Sugar Company

Figure 3.2 depicts the IS relationships identified at Beta Sugar Company. As illustrated, there is just one internal IS arrangement – namely, the use of bagasse for power generation in a 5-megawatt power plant. Other sugar manufacturing waste and by-products are stored on site or sold to external third parties. Press mud is not used in agricultural fields because it is incompatible with the soil type in the region. The molasses is sold to domestic and international markets, including those in Kenya and Uganda.

Figure 3.2. Material flow model for Beta Sugar Company



Source: Drafted by the authors.

The company employs approximately 1,500 individuals in total. IS operations have generated a substantial number of direct jobs. When fully operational, the power plant directly employs more than 63 staff members across various occupations, representing some 4.2 per cent of the workforce. Tables 3.4 and 3.5 summarize the employment and working conditions at the company.

Table 3.4. Occupations linked to industrial symbiosis operations at Beta Sugar Company

Occupational group (official title)	Tasks and duties performed	No. of jobs (2022)	Experience requirement	Educational requirement	Skills requirement	Women employed	Working contract
Engineers	Perform troubleshooting; conduct maintenance and repairs; oversee safety and compliance; provide supervision	7	4 years	Bachelor's degree	Electrical or mechanical engineering, including piping and instrumentation; management; communication skills; leadership; computer skills	0	Fixed term (1 year), extendable
Plant operators	Monitor processes and communicate with other staff	8	3 years	Diploma	Communication skills; computer skills	0	Fixed term (1 year), extendable
Casual workers	Perform picking, lifting and loading, cleaning and sorting	45	None	Primary education	Communication skills	0	Temporary

Source: Drafted by the authors.

▶ Table 3.5. Overview of social welfare conditions for workers associated with industrial symbiosis operations at Beta Sugar Company

Social welfare aspect	Key findings
Number of new enterprises created and formalized owing to IS activities	One
Total number of jobs formalized	All IS-related jobs are formal
Average wage per month	Varies with occupation and experience but above national minimum wage
Working hour limits	Eight hours per shift
Workplace hazard protections in place	There is a safety management system in place, and safety equipment is provided
Reported occupational health and safety incidents per day/week	None since the start of operations
Unionization rate	All eligible workers are permitted to join a trade union (main unions are Tanzania Union of Industrial and Commercial Workers and Tanzania Plantation and Agricultural Workers Union); around 70% of eligible workers are unionized
Social dialogue opportunities and activities (such as consultations, negotiations and workplace cooperation, including the parties involved and the frequency)	Internal meetings with management in groups, and external meetings with trade unions

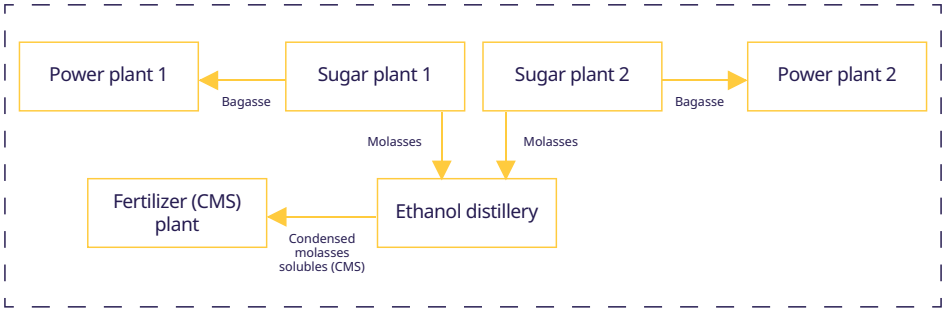
Source: Drafted by the authors.

3.3.3. Case study 3: Gamma Sugar Company

The analysis of Gamma Sugar Company revealed four major IS exchanges within six integrated industrial units, as depicted in figure 3.3:

- direct application of press mud/filter cake from sugar production as a soil conditioner in agricultural fields;
- utilization of bagasse from sugar production as fuel in two power cogeneration plants with a combined capacity of 10 megawatts, diverting nearly 14,000 tonnes of bagasse from landfill each day;
- utilization of molasses from sugar production as feedstock in ethanol production; and
- utilization of condensed molasses solubles (CMS) as feedstock in a fertilizer/CMS factory that produces fertilizers for agriculture.

Figure 3.3. Material flow model for Gamma Sugar Company



Source: Drafted by the authors.

The company employs around 4,500 people during the peak season. IS operations have created some 97 direct jobs across various occupations, as summarized in tables 3.6 and 3.7. This represents about 2.2 per cent of the overall workforce.

▶ Table 3.6. Occupations linked to industrial symbiosis operations at Gamma Sugar Company

Industrial symbiosis unit	Occupational group (official title)	Tasks and duties performed	No. of jobs (2022)	Experience requirement	Educational requirement	Skills requirement	Women employed	Working contract
Power plant 1	Supervisors	Perform maintenance and servicing	1	2 years	Diploma/ degree	Electrical skills; mechanical skills; communication skills	0	Permanent
	Technicians	Measure and monitor processes	4	1 year	Certificate	Electrical skills; mechanical skills; piping and instrumentation	1	Permanent
	Operators	Conduct unit processes and operations	4	None	Secondary education (Form IV)	Unit operations; safety; troubleshooting	1	Permanent
	Casual workers	Perform fuel feeding, de-ashing and cleaning	28	None	None	Communication skills	4	Temporary/ seasonal
Power plant 2	Supervisors	Perform maintenance and servicing	1	2 years	Diploma/ degree	Electrical skills; mechanical skills; communication skills	0	Permanent
	Technicians	Measure and monitor processes	4	1 year	Certificate	Electrical skills; mechanical skills; piping and instrumentation	0	Permanent
	Operators	Conduct unit processes and operations	4	None	Secondary education (Form IV)	Unit operations; safety; computer skills; troubleshooting	0	Permanent
	Attendants	Oversee outside environment	4	None	None	Multiple skills	0	Permanent

Ethanol distillery	Factory managers	Manage and oversee factory operations	1	5 years	Bachelor's degree	Engineering and management; computer skills; communication skills	0	Permanent
	Maintenance managers	Maintain and repair facilities	1	3 years	Bachelor's degree	Electrical or mechanical engineering; diagnostics	0	Permanent
	Laboratory managers	Manage laboratory operations	1	3 years	Bachelor's degree	Laboratory science; engineering; management	1	Permanent
	Production team leads	Manage the production team	4	3 years	Bachelor's degree	Production engineering; computer literacy; management	1	Permanent
	Operators	Operate units	24	None	Certificate	Unit processes and operations	0	Permanent
	Laboratory technicians	Conduct laboratory analyses	4	1 year	Diploma	Laboratory science	2	Temporary/ seasonal
	Sample collectors	Collect samples	2	None	None	Communication skills; accuracy	2	Temporary/ seasonal
CMS plant	Plant managers	Manage plant operations	1	3 years	Bachelor's degree	Management; engineering; computer skills; communication skills	0	Permanent
	Infield supervisors	Perform supervision	1	2 years	Diploma	Management	1	Permanent
	Operators	Operate units	3	None	None	Communication skills	0	Temporary
	Mixers	Perform mixing	4	None	Primary education	Communication skills	0	Temporary
	Cleaners	Perform cleaning	1	None	None	Communication skills	0	Temporary

Source: Drafted by the authors.

Table 3.7. Overview of social welfare conditions for workers associated with industrial symbiosis operations at Gamma Sugar Company

Social welfare aspect	Key findings
Number of new enterprises created and formalized owing to IS activities	Four
Total number of jobs formalized	All IS-related jobs are formal
Average wage per month	Varies with occupation and experience but above national minimum wage
Working hour limits	Eight hours per shift
Workplace hazard protections in place	The company has a health and safety management system
Reported occupational health and safety incidents per day/week	Minor incidents only, which occur rarely
Unionization rate	About 80 per cent of all eligible staff
Social dialogue opportunities and activities (such as consultations, negotiations and workplace cooperation, including the parties involved and the frequency)	Limited to regular internal meetings and consultations with workers' organizations

Source: Drafted by the authors.

3.3.4. Comparison across the three case studies

Table 3.8 provides a comparative overview of the quantity and quality of jobs created in IS-related activities in the Tanzanian sugar sector. The findings indicate that IS networks within the Tanzanian sugar sector are still developing. When comparing the scale and scope of IS activities across the three cases, it is clear that, in each case, the company has engaged in some form of IS, but with varying degrees of ambition. Beta Sugar Company has the fewest IS linkages, with bagasse usage in power cogeneration being the only existing IS activity. Bagasse power cogeneration appears to be a well-established IS activity in the Tanzanian sugar industry, with every case study reporting at least one plant. Gamma Sugar Company reported the most IS linkages. In addition to two bagasse cogeneration plants, two other industrial units had been integrated to utilize residues: an ethanol distillery and a fertilizer plant. The other two companies, on the other hand, did not have integrated ethanol distilleries and therefore exported their molasses to external independent distilleries.

Table 3.8. Comparative overview of workers employed in industrial symbiosis operations

Company	Total workforce	Number of IS-related enterprises	Number of jobs created	Number of female workers	Number of temporary workers	Unionization rate
Alpha Sugar Company	1 900	2	88 (4.6%)	10 (11.4%)	52 (59.1%)	Not disclosed
Beta Sugar Company	1 500	1	63 (4.2%)	0 (0.0%)	45 (71.4%)	70%
Gamma Sugar Company	4 500	4	97 (2.2%)	13 (13.4%)	38 (39.2%)	80%
Total	7 900	7	248 (3.1%)	23 (9.3%)	135 (54.4%)	

Source: Drafted by the authors.

Meanwhile, the data show that IS activities in the three sugar companies have directly led to the employment of around 248 people, equivalent to 3.1 per cent of the total workforce. Although the number of direct jobs created appears to be proportional to the size of the IS network (namely, the number of IS-related enterprises), the overall job creation potential is determined by the labour intensity of IS operations. For example, despite having just one IS-related unit, Alpha Sugar Company has created nearly the same number of direct jobs as Gamma Sugar Company, which has six IS-related units. Most jobs are created in old, labour-intensive cogeneration plants. Labour intensity is relatively low in new cogeneration plants and ethanol distillery operations because of the high level of automation, and in fertilizer plants because few activities are performed.

The findings reveal variations in job quality in different IS-related occupations. These range from good-quality skilled occupations, such as engineers, scientists and technicians, to relatively poor-quality unskilled temporary roles, such as assistants and cleaners. Table 3.8 shows that female workers account for only 9.3 per cent of the direct jobs created. Largely owing to the seasonal nature of sugar production activities, most workers are employed temporarily, especially low-skilled workers such as casual workers. The findings reveal that 54.4 per cent of the direct jobs created are temporary, implying that the majority of workers face job insecurity. Furthermore, these workers typically execute simple activities under direct supervision and are required to observe stringent punctuality, resulting in minimal autonomy. The majority of the remaining 45.6 per cent of workers, on the other hand, are skilled workers who enjoy some degree of task complexity, autonomy and higher wages. They also benefit from possibilities for skill development and career advancement.

Additionally, the physical work environment is relatively good. All the companies surveyed reported having robust occupational health and safety management systems to reduce workplace hazards. The prevalence of workplace accidents and incidents is generally low across the three cases. In addition, eligible and willing workers are generally free to join trade unions and participate in social dialogue activities, and the majority have done so. However, the findings show that workers lack adequate opportunities for social dialogue beyond regular meetings with management representatives and trade unions. This is, therefore, one area where further improvement is necessary.

3.4. Success factors for positive employment effects

During the second part of the study, key informants were interviewed to identify the most important factors influencing the employment effects of industrial symbiosis (IS) in the United Republic of Tanzania. Respondents identified various overarching and sector-specific factors. Two main enablers/drivers and eight barriers were reported, as described below and in the following section.

3.4.1. High energy costs

Several interviewees cited high energy costs as one of the primary drivers of IS and its consequences for employment in the sugar sector. They noted that typical sugar companies consume a lot of energy. Given the high price of energy from the national grid and the proven viability of cogeneration technology, all sugar companies have been compelled to develop power cogeneration plants, through which they can meet their energy requirements with some energy to spare. Sugar companies' increasing use of bagasse-fed power cogeneration plants has led to increased job opportunities. Respondents also highlighted that, without cogeneration systems, most sugar companies would be unable to make a profit, which would have a detrimental impact on both direct and indirect employment.

3.4.2. A growing market for ethanol

According to several respondents, there is a widening gap between demand and supply for industrial and potable alcohol in the country. Respondents noted that a number of small and medium-sized alcoholic beverage enterprises are booming in the United Republic of Tanzania and neighbouring countries, such as Kenya and Uganda, leading to an increased demand for ethanol. This is prompting sugar firms that have not yet established distilleries to do so, which is, in turn, creating employment opportunities in the construction and operation of ethanol plants in sugar complexes. At the time of writing, one sugar mill in the country was constructing an ethanol distillery to meet the growing demand, and another sugar mill already had a distillery up and running.

3.5. Barriers to positive productive employment effects

From the key informant interviews, it became apparent that there are eight main barriers to the adoption of industrial symbiosis (IS) and its positive employment effects.

3.5.1. Limited policy incentives

Limited policy incentives constitute an important macro-level barrier to business expansion into ethanol production and further cogeneration. The interview findings indicate that there are few incentive programmes to encourage sugar companies to venture into ethanol production and increase cogeneration. The respondents noted two pressing issues.

The first issue is the lack of a clear policy on feed-in tariffs that would set a minimum purchase price for power purchased from independent power producers. The interviewees lamented that, while the adoption of individual power purchase agreements was a commendable step in the right direction, the implementation of such agreements was riddled with issues such as excessive bureaucracy and payment delays.

The second issue noted by respondents was the lack of a policy on blending. According to the respondents, the country has no standards for blending bioethanol from sugarcane with petrol. These factors create uncertainty and deter commercial-scale investment in bioenergy production, including cogeneration and bioethanol.

▸ 3.5.2. Policy fragmentation

Policy fragmentation is a problem that is closely tied to the issue of inadequate policy incentives. Respondents remarked that the country's different national and sectoral policies are too narrowly focused to address the big picture. They emphasized the missing link between the agriculture and energy industries in particular. They cited the National Energy Policy (2015), which is essentially silent on the importance of cogeneration and biofuels derived from sugar waste products. Similarly, despite noting the potential of biofuel and bioelectricity production in the sugar sector, the National Agriculture Policy (2013) provides little direction on integrating the sugar sector with the energy sector. No designated policy instruments are in place to encourage investment in waste and by-product utilization. The absence of a stand-alone sugar policy further aggravates the situation.

▸ 3.5.3. Lack of specific skills-related policies

The Tanzanian Government has recognized skills development as a priority for the sugar industry, especially through the establishment of the National Sugar Institute. However, some respondents were concerned that, while the Institute exists to develop requisite skills for the sector, there are no real education and training programmes specifically designed to promote IS.

▸ 3.5.4. Food security concerns

The issue of food security further complicates the policy environment. According to industry sources, the sugar production deficit in the country has caused periodic sugar shortages, which have threatened food security. The Tanzanian Government's sugar strategy has focused on sugar production to avoid a food/co-product conflict. The sources noted that sugar is the most sought-after – and most profitable – product from sugarcane; investment has therefore focused on increasing sugarcane production and yield per hectare, rather than on diversifying into other co-products. They added that the high start-up costs of ethanol distillery plants and the absence of subsidized finance further aggravate the situation. Diversification was viewed as an evolutionary process, with the expectation that sugar companies would diversify when conditions allowed. The sources stated that some companies had already done so and that others would do the same as long as it was financially viable.

3.5.5. Limited competition

The interviews with key informants revealed that there is very little competition in the sugar sector. Currently, the country has only seven sugar mills, six of which are fully operational. The situation is exacerbated by the unlikelihood that new competitors will enter the market and by the strong protections in place against sugar imports. According to some academics and industry insiders, this creates a market environment that lacks sufficient incentives to stimulate the kind of competitive rivalry and innovation that would push companies to make full use of the potential of IS and produce more green jobs.

3.5.6. Automation

According to industry insiders, automation constitutes a major barrier to employment generation through IS in the sugar industry, especially in linked ethanol distilleries and cogeneration plants. Ethanol is highly flammable and can form explosive vapour clouds. Consequently, distillery owners rely on automated systems to reduce the risk of human error and prevent accidents caused by improper handling of flammable materials. At a more general level, sugar industry experts added that the industry is shifting towards production systems that increasingly rely on mechanization and digitization, thereby reducing labour demand. It was highlighted, for example, that most of the activities of modern cogeneration systems are automated, which decreases the need for casual workers to perform tasks such as de-ashing. In this context, significant uncertainties surround labour intensities and direct employment opportunities in future IS networks in the sector.

3.5.7. Insufficient supply of by-products

Another significant hurdle mentioned by interviewees was the scarcity of molasses. It was noted that most alcohol-based industries in the country were already starved of feedstock. The shortage was most severe at the peak of the coronavirus disease (COVID-19) pandemic, when alcohol-based sanitizer and disinfectant businesses boomed. It was further remarked that the existing supply of molasses in sugar mills is insufficient to justify investment in alcohol plants and to allow the full-capacity utilization required for economic viability. This predicament is exacerbated for independent alcohol producers by the risk that sugar mills will vertically integrate and establish their own alcohol plants, thereby effectively cutting off the supply of raw materials.

Another significant aspect compounding this problem is the distances between sugar factories, which are too great to justify investment in storage facilities to pool bagasse from diverse sources. According to respondents, this factor has made it financially difficult for any private investor (except sugar mill operators themselves) to invest in ethanol distilleries.

The same is true of power cogeneration. A major barrier to further power cogeneration development is associated with fluctuations in bagasse supply. Industry insiders said that sugar plants experience seasonal fluctuations in their bagasse supply throughout the year, with abundant feedstock available during the crushing season and shortages during the off months. This has discouraged investment in expanding power cogeneration facilities, which would generate further employment opportunities.

▶ 3.5.8. Ethical and religious concerns

Ethical and religious considerations appear to be an important barrier, especially to investors concerned about the social impact of and religious objections to alcohol production and consumption. Most of the ethanol generated in Tanzanian sugar mills is consumed by the liquor business, followed by the chemical industry and other sectors. According to some respondents, investors with ethical and religious concerns have refrained from expanding their operations to include ethanol distilleries, thereby effectively foregoing job creation opportunities.

▶ 3.6. Availability of specific skills

The findings indicate that adopting circular practices in the sugar industry has no disruptive effect on the labour market with regard to skill needs. Respondents agreed that circular manufacturing operations involved both low- and high-skilled workers. According to one academic, the installation of ethanol production facilities will increase the demand for specialized skills in design and technology, thereby necessitating a large number of highly skilled workers. In contrast, increased reuse and recovery of filter cake and boiler ash will necessitate the hiring of new lower-skilled workers. It was also mentioned that, as sugar projects advance to operation, there will be greater demand for management and maintenance expertise.

Cross-cutting skills and reskilling programmes will therefore be required in order to enable workers to adapt to the evolving labour market.

Participants in the study generally agreed that, while circular operations require enhanced skills, these skills do not necessarily differ significantly from those required in traditional industries. It was noted that general skills for industrial symbiosis-related tasks are widely available in the Tanzanian labour market and that only additional training and retraining are required to impart the new specialized skills. New skills training is especially important for designing, constructing and operating ethanol distilleries. Generally, respondents agreed that there was no scarcity of workers, such as graduate engineers, who could be trained or retrained to take on roles in circular operations.

3.7. Actions needed to promote positive productive employment effects

Tanzanian industry is complex, containing multiple stakeholders each with their own mandates and objectives. Broadly speaking, the Tanzanian sugar sector constitutes three broad categories of actors that play either operational or supporting roles:

- **producers,** namely sugar farmers and mill operators, including corporate entities and smallholders;
- **regulators,** including the government, which acts as a regulator through the Sugar Board of Tanzania and the Ministry of Agriculture; and
- **supporting organizations,** comprising social partners such as sugar grower and producer associations, and other relevant stakeholders such as the National Sugar Institute and other educational institutions.

The analysis reveals that these actors may be instrumental in addressing the Tanzanian sugar industry's transition to a circular economy, while also promoting employment creation and adequate skills. According to the respondents, these actors could deploy, individually and collectively, a set of strategies aimed at creating opportunities and fostering an environment conducive to steering the industry towards greater circularity and more positive employment outcomes. These strategies and interventions are outlined for each category of actor in table 3.9. The discussion in the present study is focused on what the various actors should do, rather than how they should do it.

▶ Table 3.9. Strategies for promoting positive productive employment effects

Actor	Strategy/intervention
Producers	▶ Recognize the opportunities and threats presented by the sugar industry's transition to a circular economy.
	▶ Integrate IS measures into their strategies for business growth and product development.
	▶ Invest in larger, more efficient energy cogeneration plants so that more power can be sold to the national grid, stimulating the introduction of feed-in tariffs.
	▶ Provide supplementary training and retraining to develop the skills needed in circular operations.
Regulators	▶ Develop institutional structures, including legislative, regulatory and administrative frameworks that incentivize technological innovation, circular practices and employment creation.
	▶ Integrate circular economy measures into sectoral development strategies, for example by conducting a sectoral environmental assessment to plan and manage the transition to a circular economy.
	▶ Promote education and training policies for the circular transition within the sugar industry.
	▶ Promote informational policies to raise awareness of the opportunities arising from the circular transition.
	▶ Restructure the tax system to create fiscal incentives, such as tax exemptions and tax credits for capital investment in IS, that help to scale up bagasse cogeneration and ethanol production.
	▶ Encourage the establishment of independent power companies, separate from sugar mill operators, thereby allowing greater cogeneration capacity and flexibility.

Supporting organizations	▶ Continuously assess the sugar industry's training needs, establishing relevant training programmes and updating human resource capabilities in order to boost circularity.
	▶ Strengthen the ties between education and training institutions and sugar producers to improve skills development along sugar value chains and manage the drivers of work changes, including the transition to a circular economy.
	▶ Conduct research into the circular economy in the sugar industry, including into technologies and information systems that can facilitate the transition to circularity by providing more job opportunities. Work performance research is also needed, including into standards for working conditions, occupational safety and job specifications, with the aim of optimizing circularity and productivity. It is also important to understand the efficacy and weaknesses of national and sectoral policies with regard to promoting the circular transition and positive employment effects, and to share global lessons. The findings should be used to raise awareness and understanding among the general public regarding the social, environmental and economic opportunities arising from the circular transition in order to increase public support and acceptance.
	▶ Provide technical advice and consultancy services to sugar companies.
	▶ Advocate for a conducive policy environment, including cogeneration feed-in tariffs and tax incentives for skills development and technological innovation.
	▶ Advocate for explicit recognition of bagasse cogeneration as a strategy for encouraging and supporting local renewable energy within national environmental policy.
	▶ Create broad forums for policy coordination and social dialogue, including task forces, with a view to incorporating policy and skills needs into industrial and environmental policies in order to reduce skill gaps and sustain positive environmental, economic and employment effects.
	▶ Implement financing schemes targeting the adoption of circular technologies and practices, including bagasse energy cogeneration programmes.

Source: Drafted by the authors.

3.8. Conclusions

- While industrial symbiosis (IS) networks are still evolving, they are, overall, creating a good number of (fairly decent) jobs. Moreover, the employment figures provided here are conservative as they exclude indirect and induced jobs.
- The bulk of the jobs created are of rather poor quality.
- As sugar firms grow, IS is becoming an important strategy to support business growth and employment creation in the country.
- The good practices seen in the three case studies described in this chapter must be emulated by other sugar producers in the country and worldwide.
- Rising energy costs and a burgeoning ethanol market will continue to encourage sugar companies to pursue more circularity for the foreseeable future. Their ability to fully seize the opportunities that IS provides will depend on a greater understanding of the obstacles outlined here and on the provision of policy support to create a favourable sectoral and national context for IS to prosper.
- Consistent rules for power feed-in tariffs and fuel blending appear to be indispensable for scaling up bagasse cogeneration and encouraging investment in ethanol distilleries. An increase in investment in such facilities would therefore boost future employment creation.
- Sugar producers, regulators and supporting organizations must work together on multiple fronts to create a more enabling environment. There are clear opportunities to boost IS in the sector.
- The findings suggest that, as sugar companies adopt more complex circular business models, demand for labour inputs will fall and demand for multi-skilled workers will increase.
- Targeted training and education will become essential in matching skills demand and supply.
- The sugar industry can serve as a model of the circular economy in the United Republic of Tanzania.

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Industrial symbiosis and its impact on the creation and quality of productive employment

in Costa Rica

4

Lucía Rodríguez Delgado,
Roberto Quirós Vargas and Luis Valerio Pérez

4.1. The circular economy and industrial symbiosis in Costa Rica

In 2016 the National Comprehensive Waste Management Plan 2016–2021 was launched in Costa Rica, establishing guidelines and strategies for adequate waste management in the country and promoting waste reduction, reuse, recycling and recovery (Government of Costa Rica 2016). Then, in 2018, the National Decarbonization Plan 2018–2050 was presented, which includes a comprehensive plan to achieve carbon neutrality in the country by the year 2050 (Government of Costa Rica 2018). The plan includes measures to promote the circular economy and sustainable management of natural resources.

More recently, in 2021, a document in the form of a step-by-step guide to transitioning to a circular economy was drafted (Mercado and Rivera 2021). It lays out a series of actions that could be carried out to promote the circular economy in Costa Rica. These actions include the creation of a national strategy for the circular economy, the promotion of innovation and technological development, the creation of economic incentives for companies that adopt circular practices, such as industrial symbiosis (IS), and the promotion of education and awareness-raising on the topic. The importance of collaboration between different actors and sectors to achieve a transition is highlighted.

Along with the above-mentioned documents, the National Circular Economy Strategy of Costa Rica was presented in 2022 (Ministry of Environment and Energy 2022). This document presents the objectives, strategies and actions for the implementation of a circular economy in the country. The document refers to IS as a key tool. It proposes the establishment of an IS platform that will make it possible for participating companies to identify and exchange resources and that accelerates the transition to a circular economy. Measures will be established to encourage collaboration between companies, such as tax incentives and financing. In addition, the strategy proposes the implementation of a zero-waste policy, which seeks to reduce the amount of waste generated and to

encourage its reuse, recycling and recovery. The creation of closed value chains will be promoted, where waste from one company becomes raw materials for another.

4.2. Methodology

Data were collected on the topic of industrial symbiosis (IS) in Costa Rica because there are no previous studies of specific IS cases in the country. To accomplish this, a proposal was made to collect information from interviews and questionnaires in order to evaluate how many jobs were created and to fill in data gaps regarding the quality of these jobs.

First, contact was made through a virtual information workshop with six large companies recognized for their experience in industrial sectors in which IS networks were likely to have developed. Three companies that indicated they had IS networks were then selected as representative anchor enterprises. After the anchor enterprises had been surveyed, four other companies that had been created as a result of IS networks were chosen. They responded to the same questionnaire as the anchor companies. A second questionnaire was addressed to employees, mainly in order to evaluate employment quality.[1]

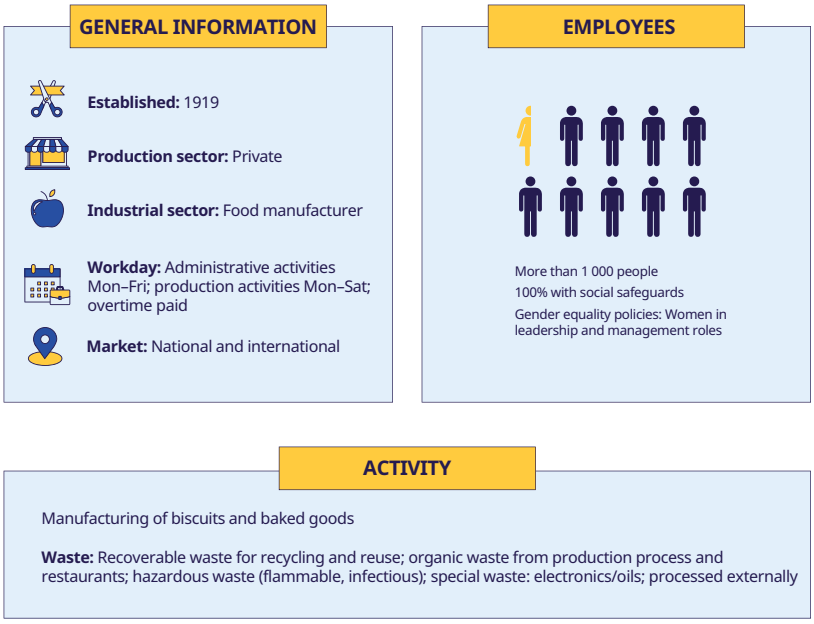
4.3. Overview of anchor enterprises

The three anchor enterprises participating in the study all operate within the private sector. They are large companies, with between 500 and 5,000 employees, and have a significant track record both within the country and in external markets. The workforce of these companies consists mainly of men aged 35–59 years. All the companies are formalized and have insurance and social safeguards for all of their employees. Regarding waste, the three companies have mechanisms to dispose of waste, either internally or through other companies. The operation of these waste management arrangements within industrial symbiosis (IS) networks will be analysed below (sections 4.3 and 4.4).

1 For further details on the methodology used in this country study and on the study more broadly, see Rodríguez Delgado, Quirós Vargas and Valerio Pérez (2023).

Company A is a food producer operating in both national and international markets (figure 4.1). It was set up in 1919, with its headquarters in Costa Rica, and has a workforce of more than 1,000 employees. According to the interview, the number of women working in the company was around 50, representing 5 per cent of all employees. This small percentage notwithstanding, the company indicated that it has gender equality policies and that women occupy management and leadership positions.

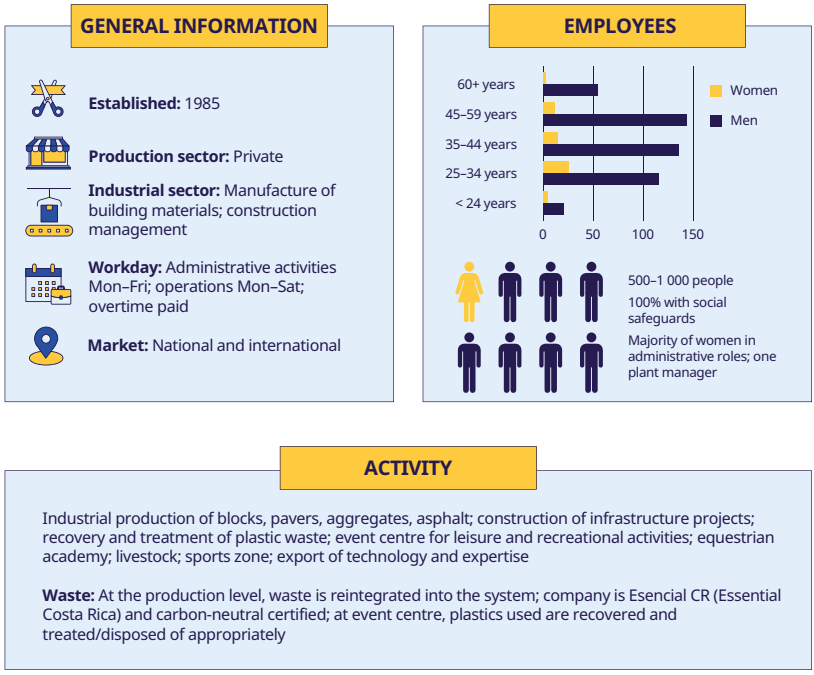
Figure 4.1. General overview of the first anchor enterprise: company A



Source: Drafted by the authors.

The main activities of company B are related to the construction sector: the production of concrete, asphalt and derivatives (figure 4.2). This company works both nationally and internationally and has been in the country since 1985. It has a total of 523 employees, 56 of whom are women, representing about 11 per cent of the total. The majority of employees are 35–59 years old (280 men and 25 women); however, there is a significant number of younger employees, who are 25–34 years old (116 men and 25 women).

▶ Figure 4.2. General overview of the second anchor enterprise: company B

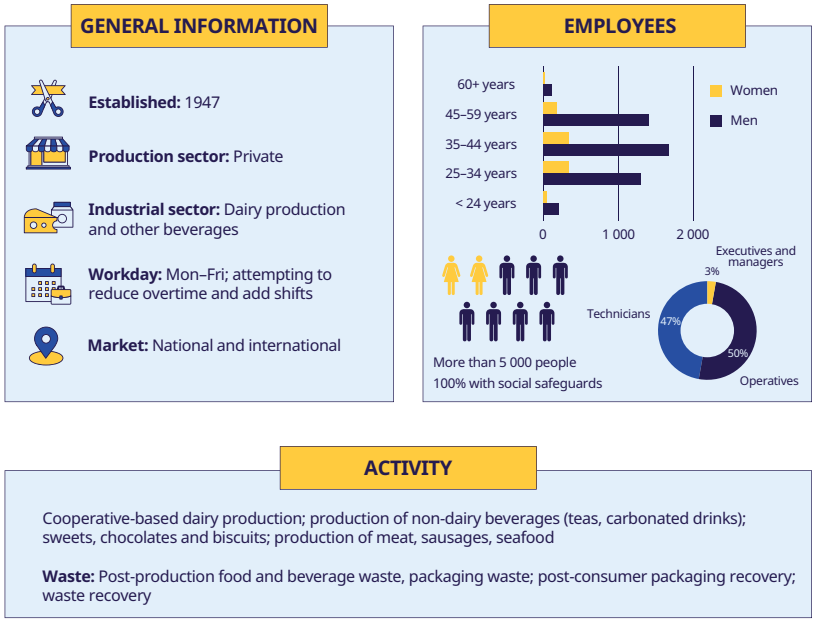


Source: Drafted by the authors.

It should be noted that, although the proportion of female employees with higher levels of education is higher than that of male employees, quantitatively women represent the minority of the company's total workforce. Likewise, the majority of women work in administrative positions, with just one woman working as a plant manager at the production level. This indicates that, although people with lower levels of education can be hired in the construction sector, there is still a barrier preventing women from accessing operational duties.

Finally, company C produces dairy products and other beverages (figure 4.3). Its operations have taken place in Costa Rica since 1947, and it has a national and international market. The company has about 5,500 employees, of whom 916 are women, representing about 17 per cent of the workforce. The majority of men (3,082) are 35–59 years old, with a significant number (1,301) aged 25–34. As for women, the largest group (340) is young people aged 25–34 years, followed by women aged 35–44 (335). The company reported that 50 per cent of the women work in operational positions, 47 per cent perform technical tasks, and 3 per cent hold executive and managerial positions.

Figure 4.3. General overview of the third anchor enterprise: company C



Source: Drafted by the authors.

Based on the information collected from the three case studies, it appears that the food industry (represented by companies A and C) allows more women to be employed in operational tasks and has a slightly higher percentage in leadership positions compared with the construction sector. It is also worth noting that, although the companies mentioned that they have gender equality policies, the majority of women work in administrative and technical positions.

The three companies were of the view that increased production, new income from sales of waste or by-products, and savings in the purchase of raw materials can emerge from their IS networks. The companies were asked to quantify the number of jobs generated as a result of increased production, new income and savings. All three companies reported that new income allowed them to hire more people, while two said that savings and increased activities made hiring possible. As shown in table 4.1, around 35 new jobs were created in the three companies as a result of increased production, savings and new activities. Of these 35 jobs, 28 are held by men and 7 by women. Most of the jobs are operational positions, and most of the women's jobs consist of extra waste-sorting tasks performed in between their domestic and other tasks.

Table 4.1. New jobs identified by the anchor enterprises as resulting from increased production, new activities or savings due to industrial symbiosis networks

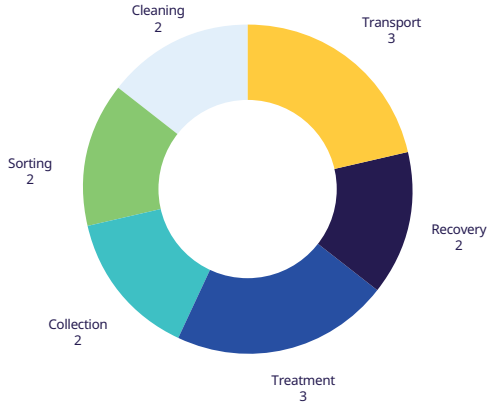
Company	New job	Men	Women
A	2 in company A, 4 in company E	6	0
	Separate plastic in recycling company H; not permanent positions (in between other tasks)	0	4
B	Production/operations personnel	6	1
C	Separate waste management plant	16	2

Source: Drafted by the authors.

Company A allowed the formal hiring of six men in the 15 years that it had worked with company E (a relationship that will be explained later). After 12 years of working together, it also allowed 4 women who fit in work in between their other tasks to be hired for non-permanent positions within recycling company H. This could be an indication that there is informal work for women within the waste treatment and recovery sector. However, these jobs were generated within the company participating in the IS network and so do not count as jobs in the anchor enterprise. On the other hand, company B created six operational positions for men and one plant manager position for a woman within its operational process within a year of starting. These jobs represent 1.3 per cent of the company's total male staff and 1.8 per cent of its total female staff. Finally, company C indicated that 16 jobs were generated for men and 2 for women in a recyclable waste management plant; however, these do not appear in company C's payroll. This demonstrates that, although IS networks do create jobs, they do not have a significant impact on the number of jobs in anchor enterprises as large as the ones studied here.

Similarly, all three companies were of the view that jobs had been created by waste processing; however, as these jobs are situated in an external enterprise, the specific data on them are unknown. Nonetheless, the qualitative perception of the companies is that most jobs are created in treatment and transportation activities, followed by waste collection, sorting, cleaning and recovery. This information is shown in figure 4.4.

Figure 4.4. Mechanisms identified by anchor enterprises as creating employment in waste processing due to industrial symbiosis networks



Note: The number next to each label indicates the number of anchor enterprises identifying that mechanism.

Source: Drafted by the authors.

In addition, the three companies indicated that they carry out research and development (R&D) strategies to recover waste and by-products generated in their main production processes and/or to evaluate the use of new inputs into these processes. They also indicated that IS networks have contributed to the creation of more jobs in this area. Ghisellini, Cialani and Ulgiati (2016) argue that this is the case because IS can promote R&D in new technologies and production processes, which can generate highly specialized jobs in the field of science and technology. The data related to the number of jobs created are shown in table 4.2.

Table 4.2. New jobs identified by the anchor enterprises as resulting from increased activity in research and development due to industrial symbiosis networks

Company	New job	Men	Women
A	Eco-design	1	4
B	Research	1	1
C	Research and development	7	13

Source: Drafted by the authors.

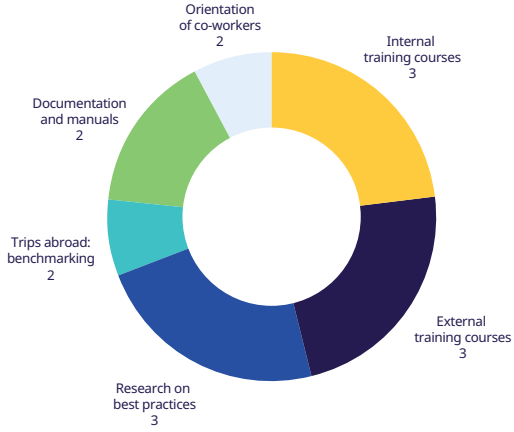
Specifically, 27 R&D jobs were created (in addition to the 35 jobs previously identified); of these, 18 were filled by women. According to the information compiled, IS networks allow more women to be hired through R&D mechanisms than through increased production or savings. Some research

suggests that companies tend to hire more women in R&D positions because they consider women to have skills such as good teamworking, empathy and the ability to solve problems creatively – characteristics that drive the research process and produce results (Hall et al. 2018; Misra et al. 2017; Restrepo, Unceta and Barandiaran 2021; Riedl et al. 2021; Smith-Doerr, Alegria and Sacco 2017). Another possible explanation that could be explored further is whether R&D positions in companies might offer more flexible opportunities and greater autonomy than other positions in industry, which may be attractive to women seeking to achieve a reasonable work–life balance. These considerations could lead to the perpetuation of gender roles imposed by society in which there is limited participation of women in more operations-related jobs and of men in administrative or R&D jobs.

Only one of the three companies indicated that it belongs to a United Nations Development Programme project which facilitates the logistics for collection of plastic and other waste. However, overall, the companies reported that they did not receive support from the State or from for-profit or non-profit organizations to promote the IS projects in which they participate.

The three companies train employees who have to perform new tasks and develop new skills as a result of IS (figure 4.5). All the companies use internal and external training courses, as well as research on best practices. Two companies carry out training using documentation and manuals. One uses overseas travel to identify success stories abroad as a benchmarking method, and one indicated that new employees go through an orientation process. It should be noted that these training processes could create indirect jobs, such as in consulting and project management (Chertow 2000).

▶ Figure 4.5. Training practices used by the anchor enterprises to train employees needing new skills as a result of industrial symbiosis



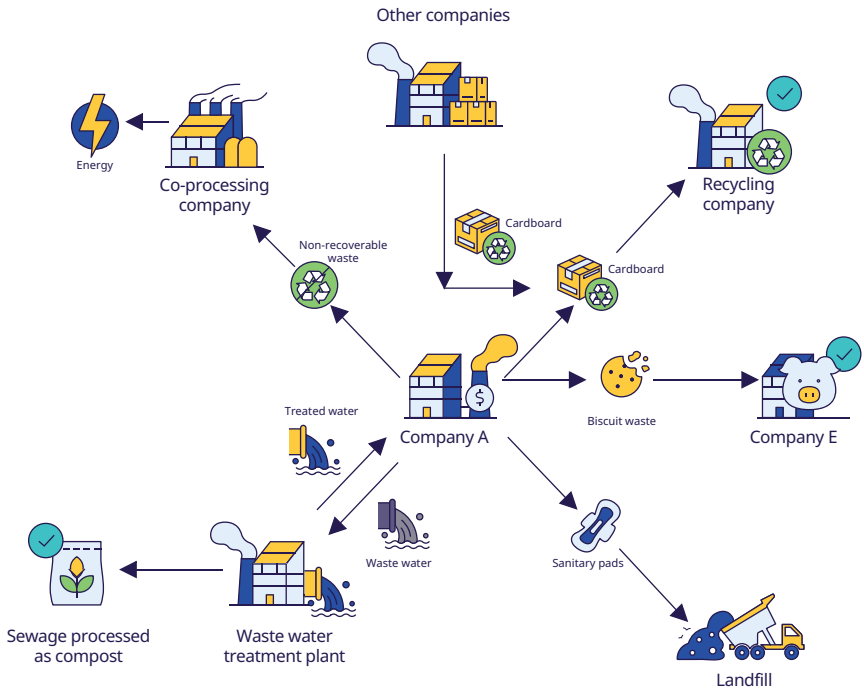
Note: The number next to each label indicates the number of anchor enterprises identifying that mechanism.

Source: Drafted by the authors.

4.3.1. Case study 1: Industrial symbiosis network of company A

Figure 4.6 shows the IS relationships of company A. The IS network of this company is based mainly on the delivery of its waste and by-products to other companies. The first by-product exchanged is biscuit dough and powder, which is generated in the course of its commercial activity. If the packaged biscuit does not meet quality inspection standards, the product is not released and is ground up. The waste resulting from the grinding process is biscuit paste, powder and plastic. The production of this by-product has led, since 2008, to the forging of an IS relationship with company E, which is a pig farm responsible for separating plastic from the biscuit paste, which is then processed and sold as animal feed. The commercial activity of this second company is carried out within the premises and using the storage facilities of company A; however, it (the company receiving the waste) hires the operators in charge of handling the equipment. Neither company charges for the services performed. From this IS activity, a total of six operational jobs, in the employment of the receiving company, were created.

Figure 4.6. Industrial symbiosis relationships of company A



Note: The turquoise checkmarks indicate relationships known to have resulted in job creation by virtue of IS activity.

Source: Drafted by the authors.

It should be noted that company A carries out studies to ensure that it creates commercial relationships with companies that meet certain requirements, such as those related to environmental management. Consequently, the electrical installation at the pig farm (company E) has been improved, and it has acquired a biodigester, improved its waste water treatment plant, and registered biscuit powder as a commercial product. This kind of behaviour is indicative of the benefits that anchor enterprises engaged in IS can bring, since they can establish quality standards for service providers, thereby improving the quality of the services provided. At the same time, they can help service providers to improve their efficiency and productivity through training, the use of advanced technologies, and the adoption of more effective and sustainable management practices, such as biodigester installation. Anchor enterprises can also promote fair and sustainable labour practices among their service providers, thereby improving working conditions for workers involved in the supply chain. These changes help service providers to improve their competitiveness in the market by allowing them to access new business opportunities and expand their customer base, which can, in turn, indirectly generate more jobs (Maldonado and Catalina 2014; Sisalema Naranjo 2019).

The next type of waste that is sent to another company for processing is cardboard, from which plastic and scrap are derived. This waste is sent to a recycler, which does not charge company A for treating the waste. This relationship has been ongoing since 2011. This IS activity has created approximately four jobs for women, who are in charge of separating plastic from cardboard. However, these positions are not permanent; rather, the women perform these jobs in between their domestic and other tasks. Because these jobs were presumed to be informal, it was not possible to contact the women involved to participate in this study.

In the cardboard-recycling process described above, company A receives waste from another company; however, the treatment of this waste is carried out, logistically, by the recycling company. In other words, company A provides the physical space for the recycler to set up its operations, and employment is created through the recycling company. This is another benefit that the anchor enterprise brings to its partner companies, as it allows them to set up their production process at no cost in return for treating company A's waste.

More recently, in 2018, company A began to send its non-recoverable waste to a formal company established in the country for co-processing. For this activity, company A pays a monthly sum, which represents income for the processing company.

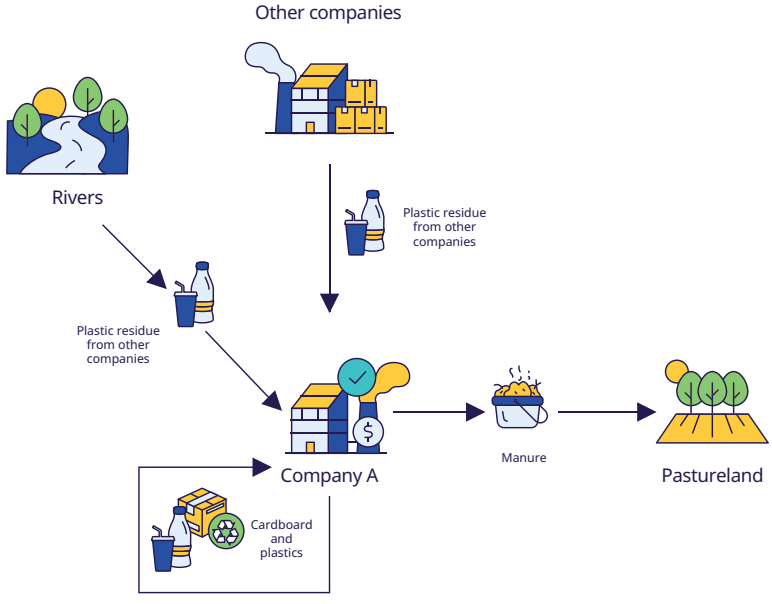
Meanwhile, management of company A's waste water has been carried out by a formalized treatment plant since 2011. Drinking water is reused within the facilities, and treated water leaving the plant is reused in the on-site toilets. At the same time, sewage from the waste water treatment plant is sent to another enterprise that processes it as compost. This company also receives food waste. Company A pays the waste water treatment plant for processing.

The last type of waste generated by company A is sanitary napkins (towels), which are collected in a closed container and processed in an autoclave. Since 2015 this waste, as well as toilet paper, has been disposed of in a landfill site. In terms of quality, there seems to have been an improvement in jobs in treatment companies.

4.3.2. Case study 2: Industrial symbiosis network of company B

Figure 4.7 shows the IS relationships of company B. While the second company interviewed carries out various commercial activities, its main products are associated with the construction sector. Recently, an alternative process has been created: plastic waste is used to make a valuable product – a concrete modifier. The introduction of plastic into the concrete mixture makes it lighter and more resistant, in addition to increasing its thermal properties. The manufacturing activity is carried out, and its products marketed, at the national level. However, technology related to modifier design is exported to other countries in the region; the objective of this export activity is to create capacity to treat the plastic waste that is generated in each country, based on the technology and expertise created in Costa Rica.

Figure 4.7. Industrial symbiosis relationships of company B



Note: The turquoise checkmark indicates relationships known to have resulted in job creation by virtue of IS activity.

Source: Drafted by the authors.

The activity related to the concrete modifier has led to the creation of IS networks with other companies and even municipalities since 2022, the year in which the production process began. An example of these networks is an intermediary company that previously collected post-industrial waste from another company and took it to a landfill site. Since the IS relationship was created, the intermediary has sorted its waste and sent it to company B. As a result of this change, only 10 per cent of its waste is now sent to landfill. Importantly, the intermediary's opening of a line of activity consisting of waste sorting has led to the formal hiring of more people.

Similarly, company B receives plastic waste from municipalities. It also has a mining concession to extract minerals from rivers to produce aggregates. Sometimes, residues such as plastic are recovered in the extraction process, which is used to produce other aggregate. The rest of the non-plastic recyclable materials are collected, recovered and sent to recyclers, while non-recyclable materials are sent to landfill or other treatment plants, to be disposed of in accordance with national standards, as per the company's policy.

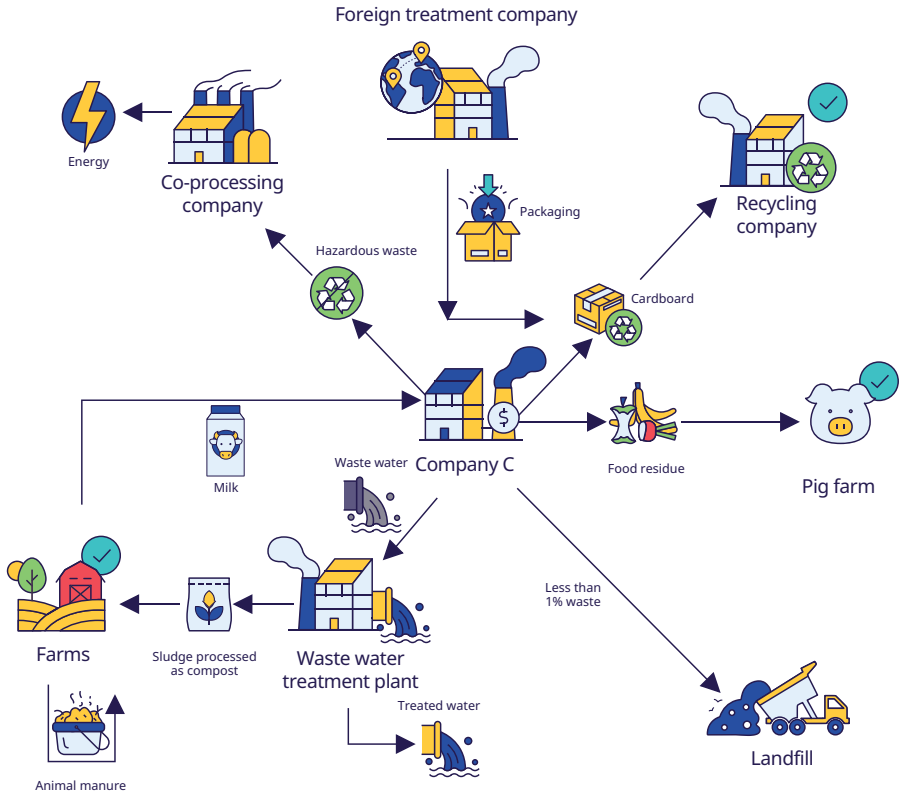
It should be noted that the company's actions are demonstrably related to the circular economy (Balboa and Somonte 2014; Sandoval, Jaca and Ormazabal 2017). At the production level, no waste is generated, as 100 per cent of its products are recyclable and are reintegrated, if necessary, into the system. The plastic waste generated in company B's event centre – its venue for recreational activities that forms part of its commercial activities – is also reincorporated into the company's new productive activity.

In terms of internal jobs, this new production activity has created seven operational jobs in the plant. Notably, the position of plant manager is held by a woman. Furthermore, two jobs related to this production activity, both formal, have been created in R&D, one of which is held by a woman. At the same time, this new activity has promoted job retention, with those interviewed indicating that former employees now perform new tasks related to the new activity. Job retention may be the result of increased company efficiency, competitiveness and financial stability created by IS networks. By improving their market position, companies can put themselves in a better position to retain existing jobs (van Berkel 2006; Yeo et al. 2019). Finally, one of the interviewees commented that it was expected that around 12 direct hires and 4 additional hires for manual river waste collection would be made, all of them formal, as the plant expanded.

4.3.3. Case study 3: Industrial symbiosis network of company C

Figure 4.8 shows the IS relationships of company C. The last company interviewed operates in the food sector, focusing mainly on dairy products. A sustainable approach is taken throughout the value chain, from farm to recovery and treatment of the waste generated (Sandoval, Jaca and Ormazabal 2017). The company puts less than 1 per cent of its post-industrial waste in landfill sites – in other words, it manages to recover 99 per cent of its waste. At the post-consumer stage, it recovers packaging materials. To do this, it works in alliance with other waste management companies and carries out awareness-raising programmes in schools.

Figure 4.8. Industrial symbiosis relationships of company C



Note: The turquoise checkmarks indicate relationships known to have resulted in job creation by virtue of IS activity.

Source: Drafted by the authors.

The IS activity of this company resides mainly in its delivery of its waste to other companies. First, hazardous waste, which is contaminated with chemicals, hydrocarbons, inks and other substances, is sent for use and generation of energy in a formally established co-processing company. Recyclable packaging is sent to a waste treatment plant, which is managed jointly with other recyclers. Plastic, aluminium and cardboard waste is treated by companies operating nationally. Carton packaging, however, is exported to be treated abroad. It should be noted that the national waste management plant has generated 18 formal jobs, which are held by 16 men and 2 women.

Regarding waste water treatment, company C has a treatment plant that allows it to discharge water that exceeds national quality standards. Over the years, expansions have had to be made to the plant, and it is estimated that, without these extensions, there would have been a risk of incurring significant financial penalties for environmental non-compliance. The money thus saved makes it possible to hire more people to work within the same treatment plant or to invest in other management businesses within the IS network, thereby functioning as an enhancer of national undertakings. Sludge from the treatment plant is handled by authorized handlers, who make organic compost/fertilizer. This product is distributed to veterinary warehouses for use on farms.

Food and whey waste are sent to associated companies in the pig sector for processing as animal feed. Animal manure residues are reused by partner companies for soil treatment, thereby improving the quality of pastures.

▸ 4.3.4. Barriers to implementation of industrial symbiosis networks and opportunities for improvement, according to anchor enterprises

All the companies interviewed consider that the IS networks in which they are involved will expand over the next five years and thereby create more jobs. However, a series of barriers were identified that could prevent or slow down such expansion.

First, many companies maintain a high level of confidentiality and are not willing to publicly share information on how the waste they generate is treated internally. This situation presents a significant barrier since many IS networks are based on the exchange and commercialization of such waste. Public knowledge of a problem with a specific type of waste could generate an undertaking to treat it within the framework of an IS relationship (Mirata 2004; Perero and Rodríguez 2021). There is also a significant gap in the implementation of the country's laws and regulations, which is linked to bureaucracy within public

institutions. In this context, it should be acknowledged that many of the relevant processes represent a cost for companies, and they are rarely compensated for this because environmental, social or economic incentives for companies are lacking (Perero and Rodríguez 2021).

An important barrier mentioned by the companies interviewed is that many of the activities undertaken initially generate informal roles that lack many social safeguards. This situation goes hand in hand with the lack of incentives available at national and local levels or provided by already established companies themselves (Chertow 2007; Mirata 2004).

The final barrier identified encompasses the others that have been previously mentioned: education of consumers within civil society. Many sustainability efforts remain invisible within today's linear economic thinking. An important reform is required at the societal level to change thinking about consumption and production, and this requires extensive training programmes for members of society (Sakr et al. 2011). In the context of such reform, the previously discussed barriers could be overcome.

Companies were also asked to give their recommendations on what actions the Government of Costa Rica, local governments (municipalities) and the private sector could take to promote IS networks. These recommendations are summarized in table 4.3.

Table 4.3. Recommended actions to be taken by various actors to promote industrial symbiosis and generate productive employment, as identified by the anchor enterprises

Company	Private sector	National government	Local governments
A	No industry secrecy	Consistent law Consumer education for members of society Social and economic incentives Environmental compliance certification	Consumer education for members of society

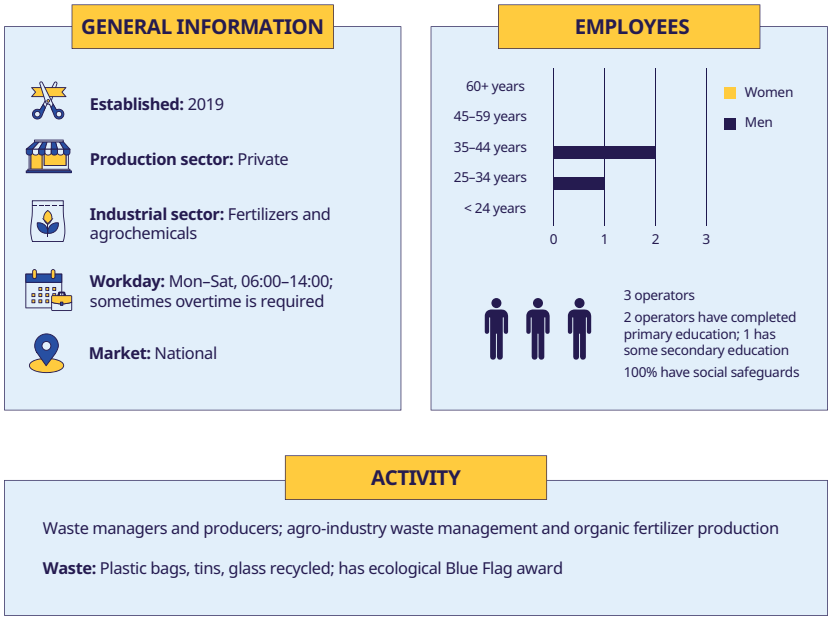
B	Design and development investment with a focus on circular economy Greater awareness in production Education Regulations for circularity, environmental regeneration, standardization of production Financial sector that supports circular economy projects Change of mentality in economic production	Education; thinking more linked to the circular economy Preparation of professionals with a focus on circular economy Public policies to promote circular economy Rapid transformation of purchasing systems with a sustainability focus	Rapid transformation of purchasing systems with a sustainability focus
C	Public–private partnerships Investments	Incentives Science-based public policy Technical support Academic research	Greater availability of existing resources (trucks, land) Databases

Source: Drafted by the authors.

4.4. Overview of small enterprises

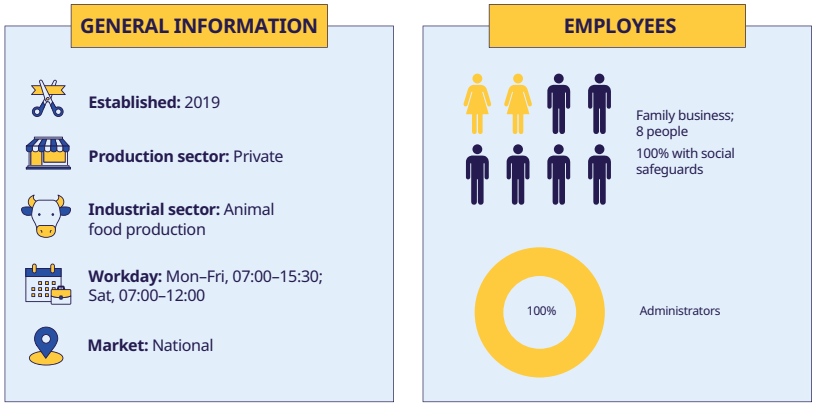
In total, four different small companies participated in the survey. Overviews of each are given in figures 4.9 (company D), 4.10 (company E), 4.11 (company F) and 4.12 (company G). All four participating companies are within the private sector, and all are relatively small – the largest, company F, has 20 employees. The workforce of these companies consists mainly of men, who (according to the information provided) are mostly in the age range of 25–44 years. All the companies studied indicated that they have insurance and social guarantees for all of their employees. Company D produces fertilizers from agro-industrial waste; company E produces animal food from biscuit waste; company F produces and sells fertilizers made from organic waste; and company G sells compost bins and produces compost from market waste. The four companies are waste managers, and the little waste that is generated is recycled or managed by authorized handlers.

Figure 4.9. General overview of the first small enterprise: company D



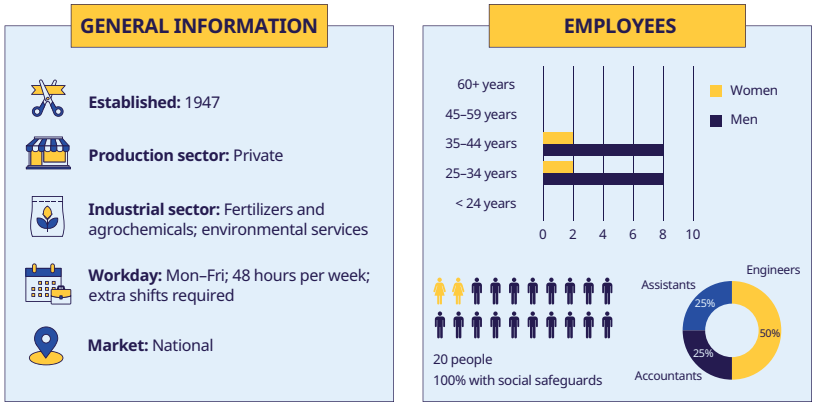
Source: Drafted by the authors.

▶ Figure 4.10. General overview of the second small enterprise: company E



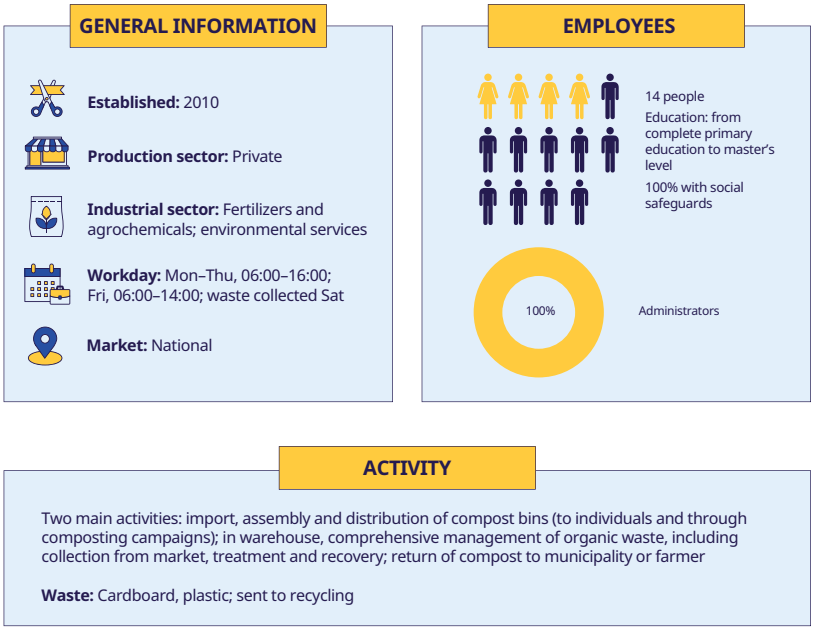
Source: Drafted by the authors.

▶ Figure 4.11. General overview of the third small enterprise: company F



Source: Drafted by the authors.

Figure 4.12. General overview of the fourth small enterprise: company G



Source: Drafted by the authors.

As in the case of the three anchor enterprises, the majority of workers in the small enterprises are men and, for the most part, women carry out administrative tasks. One company indicated that the absence of women in other positions was due to the fact that working in the field was hard and required great physical exertion. The perception that jobs that involve physical exertion are more suitable for men than for women is one of the main gender barriers in the workplace. Williams (2014) suggests that women also face barriers to promotion to leadership positions in male-dominated fields because of the perception that they are not as strong or capable of performing physical tasks.

According to the information provided by the four small companies interviewed, there is a clear perception that the number of jobs created through industrial symbiosis (IS) networks could be increased. They were asked to quantify the number of jobs that had been generated as a result of increased production, savings and new economic activities. The data provided are shown in table 4.4.

Table 4.4. New jobs identified by the small enterprises as resulting from increased production, savings or new activities

Company	New job	Men	Women
D	Fertilizer packaging support operators	2	–
E	Operators	4	–
	Administrative tasks	0	2
F	Manager	1	–
	Environmental regent/project manager	–	1
	Accountant	–	1
	Agricultural engineer	–	1
	Chemical engineer	1	–
	Assistant	–	1
	Operatives	6	–
G (Alajuela)	Driver	1	–
	Coordinator	–	1
	Operators	2	–
G (San Pedro)	Drivers	2	–
	Warehouse manager	1	–
	Builders of compost bins	2	–
	Municipal campaign coordinators	–	2
	Sales coordinator	–	1

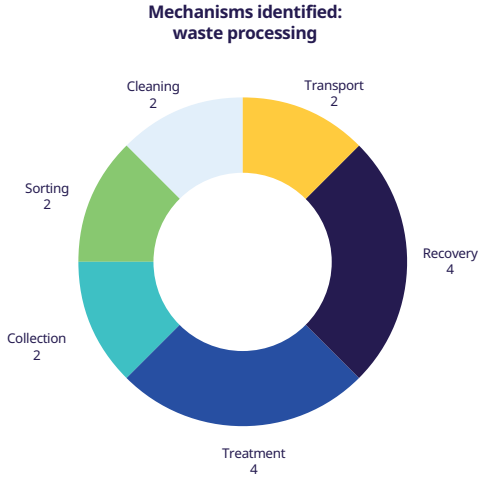
Source: Drafted by the authors.

Across the four companies, some 32 new jobs were created as a result of increased production, savings or creation of new business. Of these 32 jobs, 22 are held by men and 10 by women. Most of these jobs are operational positions. The jobs held by women are administrative, with the exception of company F, where a woman is project manager. It should be highlighted that the majority of the current jobs in the companies interviewed emerged from the IS networks they maintain with other companies.

For the most part, the situations identified were increased production, new income streams, and the creation of the business itself. For these small businesses, unlike anchor enterprises, IS networks provide an important boost in the development of their activities. In the cases studied, the undertaking emerges as a waste management plant serving a particular industrial sector or anchor enterprise – in other words, it was thanks to the IS network that the company was created and all current employees were hired. At the same time, small and medium-sized enterprises (SMEs) may have difficulty competing in larger markets because they lack resources and economies of scale. By working in IS networks, they gain access to new supplies and markets, allowing them to expand and generate more local jobs (Ruiz Puente, Arozamena and Evans 2015).

The four companies indicate that jobs have been created with respect to their waste processing activities. Treatment and recovery are the activities that have created the most jobs in these businesses. This information is shown in figure 4.13.

Figure 4.13. Mechanisms identified by small enterprises as creating employment in waste processing due to industrial symbiosis networks



Note: The number next to each label indicates the number of small enterprises identifying that mechanism.

Source: Drafted by the authors.

Quantitative data about the number of jobs created through waste processing activities are shown in table 4.5. Many of the jobs created are the same as those reported in table 4.4; however, because of transportation and other activities, extra jobs such as driver were created.

Table 4.5. New jobs within companies identified by the small enterprises as resulting from waste processing activities

Company	New job	Men	Women
D	Fertilizer packaging support operators	2	–
E	Operators	4	–
F	Driver	1 (internal)	–
	Truck contractors	6–7	–
	Environmental regent/project manager	–	1
	Operators	6	–
G	Driver	1	–
	Operators	2	–
	Family businesses outside the company generate compost and sell it to neighbours		
	Machine manufacturers (Costa Rican)		

Source: Drafted by the authors.

According to the aforementioned information, in addition to the 24 jobs identified in table 4.5, around eight jobs were created by transportation activities. In addition, the activities of company G created indirect jobs, including manufacturers of the machines used in the treatment centre and family businesses that purchased the compost bins from the company and then sold the fertilizer produced.

In contrast to the information received from the anchor enterprises, the small undertakings identified do not have a research and development strategies department. In these cases, the companies indicated that they paid attention to new suppliers or technologies relevant to their processes, or that they created alliances with academia. University students could then provide support in improving their processes.

The small and medium-sized companies generated were of the opinion that they did not receive external support to promote IS networks. Nor did they think that current employees had to perform new tasks as a result of IS networks. That may be due to the fact that these companies were created with the purpose of treating and processing the waste of other companies, so they were not themselves engaged in other activities before they were established and their employees hired to perform the specific tasks required. Furthermore, it should be noted that these are small companies

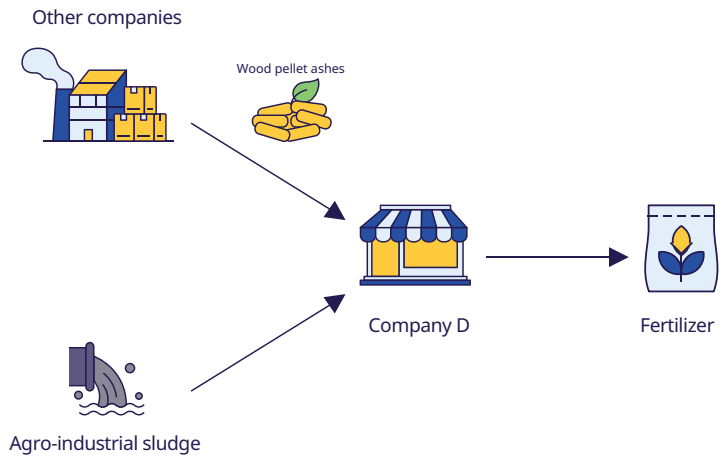
with no more than 20 employees. During the interviews, some companies commented that they hired more people in times of greater production. These were temporary jobs, but a considerable increase in production could allow them to hire more people in permanent positions.

The instances of IS found can be classified mainly under materials recovery (Perero and Rodríguez 2021).

4.4.1. Case study 4: Industrial symbiosis network of company D

Figure 4.14 shows the IS relationships of company D. The IS network in which company D is involved emerges principally from the treatment and recovery of agro-industrial waste and sludge. This, together with wood pellet ashes, is used to produce a fertilizer for crops. The sludge received goes through a biodigestion process before arriving at the company, and after a sludge-drying treatment process, the fertilizer obtains the required consistency and humidity. This product is sold to pineapple growers and vegetable farmers. The company is selective with the waste it receives in order to avoid having bad odours impact the community located near the production site. To avoid these odours, microorganisms are added during the production process; they are fermented and added to the fertilizer to accelerate and complete the decomposition process and improve the odour, which is said to be similar to cocoa. In addition, the company has agricultural production facilities, as well as its own chickens, and employees are allowed to take these products home. For this production activity, the agro-industrial sludge comes from three different companies. However, a single anchor enterprise provides 85–90 per cent of the company's raw materials and income.

Figure 4.14. Industrial symbiosis relationships of company D



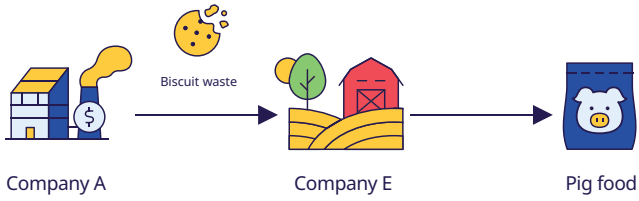
Source: Drafted by the authors.

4.4.2. Case study 5: Industrial symbiosis network of company E

Figure 4.15 shows the IS relationships of company E. This case of IS is developed through company A, one of the anchor enterprises analysed in the previous section. In this case, company A delivers the biscuit paste, biscuit powder and plastic waste that it generates to company E. Only the biscuit powder is paid for – the rest of the raw material is obtained at no additional cost. From this IS, a total of six jobs were created for the company. As explained previously, company A provides the premises and storage facilities for company E to carry out its activities.

In the survey it was mentioned that company E had previously worked with another anchor enterprise, before its involvement with company A. This indicates that IS networks can give SMEs access to new markets and potential customers, allowing them to expand their operations and increase their income, which can lead to increased hiring of personnel (Schlüter et al. 2022).

Figure 4.15. Industrial symbiosis relationships of company E



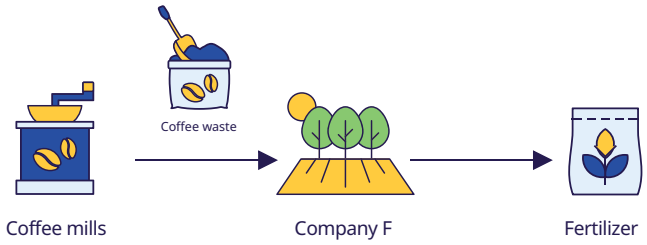
Source: Drafted by the authors.

4.4.3. Case study 6: Industrial symbiosis network of company F

Figure 4.16 shows the IS relationships of company F. This undertaking emerged as a partnership between a family business and a foreign contact. Initially, they were seeking an alternative for the agrochemicals used, which were contaminating the drinking water. The project began with vermicomposting and processing of coffee waste to produce fertilizer. Through this product, the use of agrochemicals in crops was reduced by 50 per cent, while maintaining or even improving production. Currently the product is sold for cultivation of pineapple, banana and palm crops, among others. The company recommends the use of organic fertilizer as a complement to chemical fertilizer to avoid a drop in production levels, but there is also an improvement in terms of environmental impact.

Company F emerged from an IS network that was generated by coffee mills and pineapple growers. In total, around 20 jobs were created. In this processing, around 35,000 tonnes of waste from coffee cultivation are captured. The subsidy provided by the coffee mills to treat the waste and the raw materials supplied is the basis on which the undertaking is able to operate. As in the previous cases, it can be concluded that anchor enterprises are a fundamental factor within IS networks in promoting and supporting the activities of SMEs in the country.

Figure 4.16. Industrial symbiosis relationships of company F

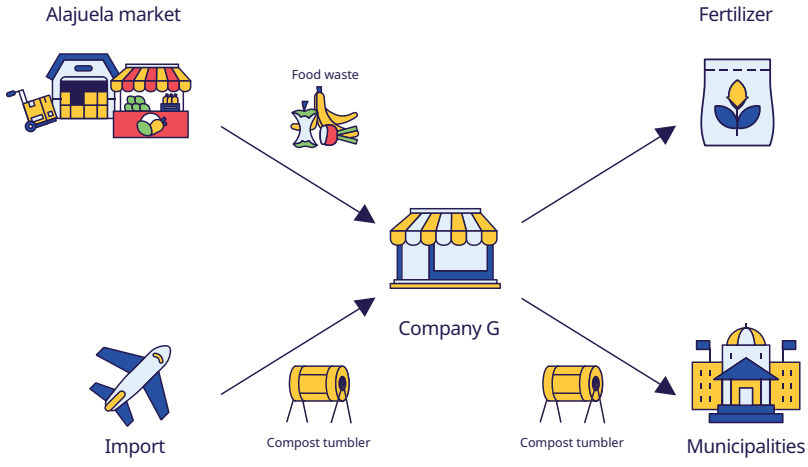


Source: Drafted by the authors.

4.4.4. Case study 7: Industrial symbiosis network of company G

Figure 4.17 shows the IS relationships of company G. This undertaking carries out two main activities. At its San Pedro facilities, compost bins are imported, assembled and sold. These composters are sold individually or distributed through composting campaigns, working with municipalities. In these campaigns, civil society representatives can request a compost bin from their own municipality, which is delivered free of charge and comes with training on how to use it. This partnership with municipalities has been created because it is more economically viable for them to train the population in how to treat their waste than to collect and dispose of it themselves. Obtaining compost bins in these campaigns allows some families to produce and sell their own fertilizer, which shows how economic openings for civil society can be created indirectly.

Figure 4.17. Industrial symbiosis relationships of company G



Source: Drafted by the authors.

The second activity takes place in the warehouses of Alajuela, where comprehensive management of organic waste is carried out. Waste from the Alajuela market is collected, treated and recovered, producing compost that is either returned to the municipality or sold to the agricultural sector. The production of fertilizer is carried out using equipment produced nationally; however, sometimes this activity is not carried out by company G itself but by a third party, which buys the necessary equipment and pays a commission (to company G) on its sales.

Jobs were created by the increase in the production of fertilizer using the collected waste. At the same time, jobs related to the sale of composters and the logistics of conducting recycling campaigns are directly linked to the level of support provided by the municipalities to carry out these activities; in other words, the more municipalities get involved in composting campaigns, the more people are required to manage the events, sales and assembly of the equipment. In this case, company G does not work directly with an anchor enterprise as such. However, it is a clear example of how the backing of local governments can promote and support this type of undertaking, which brings with it a clear vision of the circular economy.

4.4.5. Barriers to implementation of industrial symbiosis networks and opportunities for improvement, according to the small enterprises

Like the anchor companies, the small enterprises interviewed are of the opinion that their production and IS networks might expand over the next five years. This expansion would mean an increase in jobs created in the country. However, a number of barriers were identified that could hinder such expansion.

One of the barriers identified was placement of the product on the market. Some noted that producing fertilizer had an associated cost and that, when entering the market, they had to compete with the prices of lower-quality products. While some pointed out that large agricultural companies valued the quality of the product delivered over the price, there was still a barrier in terms of consumer education with respect to the rest of the population. One of the companies interviewed has an organic certification which requires it to meet certain quality requirements, and this, in turn, increases the price of the product. If these price increases mean that the fertilizer cannot be sold on the market, it is placed on the soil in the local area. While this is environmentally beneficial for the soil, it represents a significant economic loss for the entrepreneur. In other cases, by contrast, the price of their products on the market is much lower than some commercial fertilizers; however, the benefits in terms of production levels that farmers derive from using chemical fertilizers make product placement more complicated. In this respect, education of both consumers and producers is needed at national level (Sakr et al. 2011).

In the case of these four companies, common barriers were found in the issue of financing and taxes. Procedures were often quite bureaucratic and could result in additional costs for both the small enterprises and the anchor companies. These costs are rarely compensated because environmental, social or economic incentives are lacking (Perero and Rodríguez 2021). In terms of financing, it was noted that accessing loans was often a complicated process for SMEs.

Another important barrier for entrepreneurs is the high interest rates that must be paid. This situation is also linked to the lack of incentives at national and local levels and to the status of companies that are already well established (Chertow 2007; Mirata 2004). The obstacles revealed disproportionately affect entrepreneurs, in comparison to large companies that are already established. High tax rates relative to those applied to large companies can affect the profitability of startups and reduce their ability to invest in their businesses, and this results in fewer opportunities to hire more staff (Sun et al. 2017; Vargas Rubio 2019).

The small enterprises were also asked to give their recommendations on what actions the Government of Costa Rica, local governments (municipalities) and the private sector could take to promote IS networks. These recommendations are summarized in table 4.6.

▶ Table 4.6. Recommended actions to be taken by various actors to promote industrial symbiosis and generate productive employment, as identified by the small enterprises

Company	Private sector	National government	Local governments
D	Access to financing opportunities (development bank) Companies that generate waste should use waste management companies to deal with it (they should not send it to landfill sites)	Simplification of procedures	Simplification of procedures
F	Support from academia; research	Incentives such as non-reimbursable funds Support to academia; waste development research	Incentives Project support (instead of barriers)
G		Genuine development bank Seed capital for loans based on the project and not on guaranteed returns Entrepreneur incentive	Business promotion

Source: Drafted by the authors.

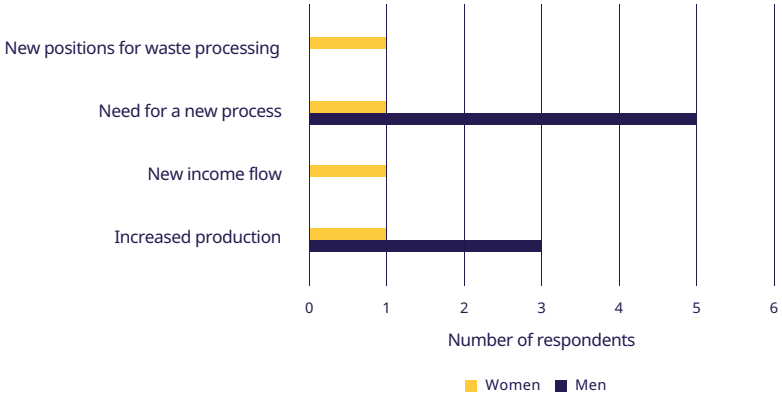
4.5. Quality of the work generated in companies within industrial symbiosis networks

To complement the analysis carried out, a survey related to the quality of work generated in the participating companies within the industrial symbiosis (IS) networks was drafted and administered. Across all the businesses interviewed, around 32 jobs were counted, and 9 interviews were conducted with employees. Thus, the sample represented around 30 per cent of the workers.

Given their low level of education, many of the operators did not understand some of the questions asked. The people who were more comfortable responding to the survey typically had higher positions and educational levels.

Five of the employees interviewed thought that their job emerged from IS activity, while four thought that this was not the case. Next, people who indicated that their job came about through an IS network were asked to indicate which mechanisms they considered to be the reason for their employment. The results are shown in figure 4.18. The majority thought that the need for a new process was what created the business or their job, followed by an increase in the company's production. The notion that the need for new ventures to treat different waste products and increased production act as drivers to bring in new employees to perform different tasks within the production system is supported by a range of academic opinion (Chertow 2000; Johnsen et al. 2015; Yeo et al. 2019; Chertow and Lombardi 2005).

▶ Figure 4.18. Perception of which industrial symbiosis mechanisms are responsible for creating employment



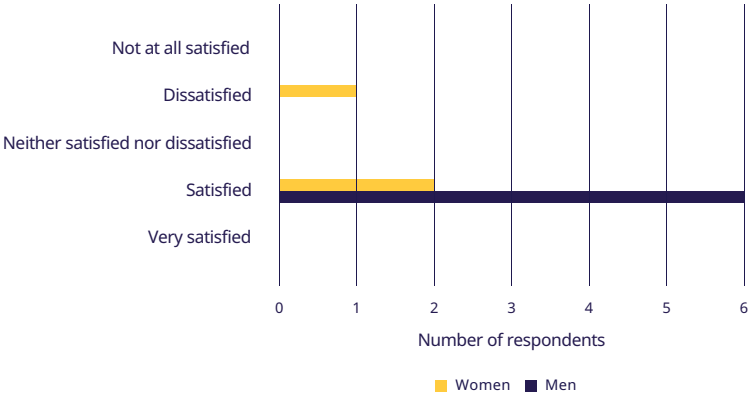
Source: Drafted by the authors.

The interviewees were then asked whether opportunities and access to senior positions were open to all, irrespective of gender. All participants answered yes to this question; however, in some cases the question did not apply as there were no women employed in production activities. In one of the companies, there were women in senior positions, such as project managers.

The interviewees were also asked about opportunities for professional growth within the company. Most of them were satisfied or very satisfied; however, one person reported being dissatisfied.

Next, they were asked about salary satisfaction. The results are shown in figure 4.19. In general, the respondents were satisfied with their salary, though some were not.

▶ Figure 4.19. Perception of salary within the company



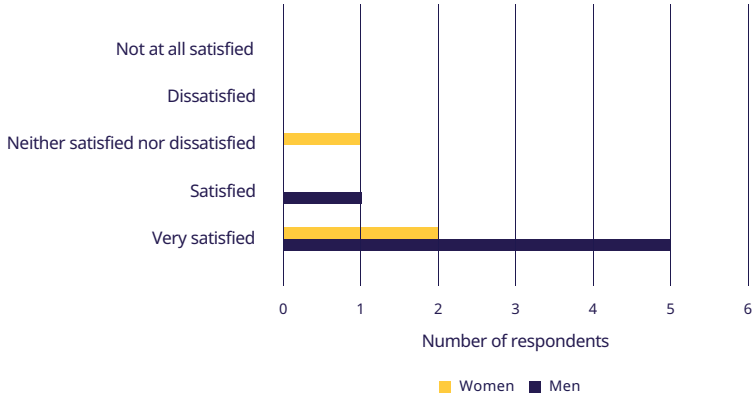
Source: Drafted by the authors.

All employees are satisfied with their personal work–life balance, which indicates that the work produced is of a relatively high quality.

The questions that followed were asked to assess satisfaction with the company's work environment. Most employees are satisfied; however, one employee indicated their dissatisfaction.

Figure 4.20 shows the results obtained regarding the promotion of inclusivity and protection against discrimination and harassment in the company. Most of the results are positive or neutral in this regard. Interestingly, in the interview with one of the companies, it was stated that the anchor company with which they worked was the promoter of the policy against discrimination and harassment. This is associated with the benefits that anchor companies bring in these IS networks: they enhance the quality not only of products but also of the working conditions in the companies or SMEs with which they work (Maldonado and Catalina 2014; Sisalema Naranjo 2019).

Figure 4.20. Perception of the promotion of inclusivity and protection against discrimination and harassment within the company



Source: Drafted by the authors.

All employees are insured. Insurance coverage, such as health or life insurance, is a form of financial protection for employees and their families in the event of illness, accidents or death.

Turning to working time, table 4.7 shows the number of hours and days that employees spend at work. This information confirms that all the companies interviewed comply with Costa Rican law on working hours (Ministry of Labour and Social Security, n.d.). In one case, there was an indication that extra hours were worked outside the working day but that these were unpaid.

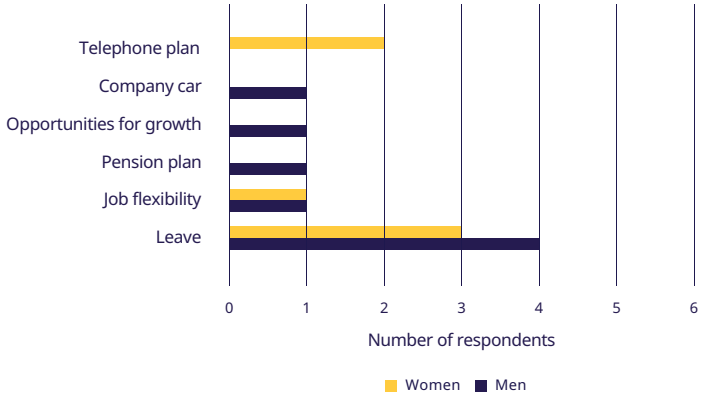
Table 4.7. Information on the working day of the people interviewed from the companies created

Gender	Workday	
Male	Days a week	6
	Number of shifts	1; 06:00–14:00
	Overtime	–
Male	Days a week	6
	Number of shifts	–
	Overtime	–
Male	Days a week	6
	Number of shifts	1; 06:00–14:00
	Overtime	–
Male	Days a week	6
	Number of shifts	Mixed: 3 days, 05:30–12:30 and 16:30–18:30; 3 days, 06:00–14:00
	Overtime	–
Female	Days a week	6
	Number of shifts	–
	Overtime	–
Female	Days a week	4
	Number of shifts	–
	Overtime	–
Female	Days a week	6
	Number of shifts	Daytime
	Overtime	Yes, unpaid

Source: Drafted by the authors.

Next, the interviewees were asked to list the benefits that the companies offered them as workers. Figure 4.21 shows the benefits mentioned. Among the social safeguards offered to employees, all companies provide leave, which was the main benefit identified. Other benefits, such as work flexibility, pension plan, growth opportunities, company car and telephone plan, were also mentioned.

Figure 4.21. Perception of employment benefits within the company

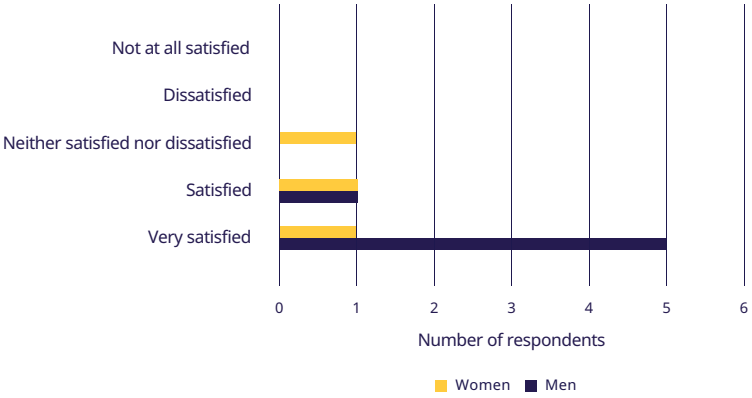


Source: Drafted by the authors.

Employees who receive work benefits are more motivated and more productive than those who do not receive such benefits (Frempong, Agbenyo and Darko 2018; Martínez Salazar and Murillo Baltan 2021). In the interviews with managers and company owners, the view was expressed that, as the company was still small, the question of providing benefits was complicated; however, they thought that benefits might be provided more readily as the company grew. They also commented that training programmes in recycling and handling of fire extinguishers were being introduced within the company, to improve job growth satisfaction.

Perceptions of working conditions with respect to basic services, lighting, decoration, noise and ventilation are shown in figure 4.22. In general, perceptions were positive or neutral. According to the Ministry of Labour and Social Security (n.d.), if workers eat at the workplace, the employer must install canteens and keep them in good condition. Likewise, providing basic services, such as drinking water, clean bathrooms, and a noise-free and ventilated environment, promotes people's physical well-being. If operators carry out hazardous activities, they must be provided with appropriate protective equipment.

▶ Figure 4.22. Perception of working conditions within the company

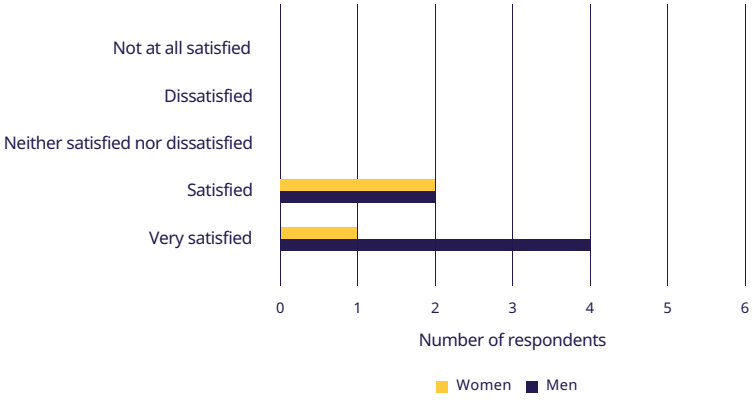


Source: Drafted by the authors.

Participants were then requested to evaluate their satisfaction with training on performing tasks in the company. There was general satisfaction on this issue, with the exception of one person who indicated that they were not satisfied at all because they had not received any training.

There was, however, high satisfaction with tools and technologies available to carry out tasks, as shown in figure 4.23. This finding is positive because having appropriate technologies can improve overall performance and efficiency in the production process, as well as competitiveness in the market (Taddeo et al. 2017).

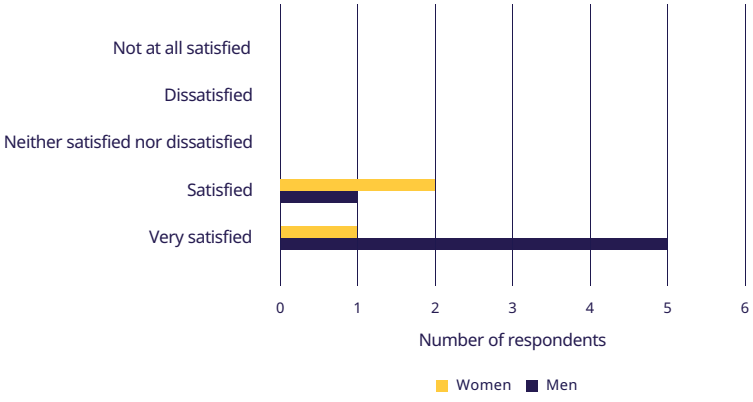
Figure 4.23. Perception of tools and technologies available within the company



Source: Drafted by the authors.

Finally, an evaluation of general satisfaction with work in the company was requested. Although some responses to previous questions were less positive, the overall level of satisfaction with the work being done was high, as seen in figure 4.24. In broad terms, it could be concluded that the jobs created by IS are of high quality.

Figure 4.24. General level of satisfaction within the company



Source: Drafted by the authors.

4.6. Conclusions

- Increased production, savings, new income and business creation are effective mechanisms for job creation in industrial symbiosis (IS) networks.
- IS in anchor enterprises allows more women to be hired through research and development mechanisms than through incentives to increase production or save income.
- According to the anchor enterprises interviewed, it can be concluded that the waste treatment activities that generate the most jobs are transportation, treatment, collection, sorting and cleaning.
- Although they do create new jobs, IS networks do not significantly impact job creation in companies as large as the anchor enterprises studied, within which new jobs represent around 1 per cent of total employees. The majority of jobs are created within the companies or SMEs involved in the IS network.
- According to the anchor enterprises, the main barrier to creating IS networks is the lack of social education fostering an understanding of a circular production and consumption model.
- SMEs participating in an IS network are highly dependent on anchor enterprises for their supply of raw materials, and these provide an important source of income for SMEs (up to 90 per cent of income).
- According to the small enterprises interviewed, the main barriers to promoting IS networks are the difficulty in accessing financing and the lack of tax incentives.
- SMEs face significant barriers preventing the provision of additional employment benefits to their employees.
- In general, the work carried out by people employed in IS networks is viewed as satisfactory.

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Exploring the effects of industrial symbiosis on informal employment:

National study in Benin, based on the Songhaï model

5

G. Agossou, C. Adjallala
and G.K. Gnonhoué

5.1. Institutional framework

The institutional framework of reference for the circular economy and for industrial symbiosis (IS) in the agro-industrial sector in Benin is the integrated agricultural production model of the Songhaï Centre, which has been practised since 1985 not only in Benin but in other African countries as well.

The Songhaï Centre is a non-governmental organization (NGO) that supports the development of African communities by providing individuals with the skills to become farmers, entrepreneurs and/or artisans in the agrifood sector. This structure was founded by a member of the clergy, Father Godfrey Nzamujo.

The Songhaï Centre was established in Benin in 1985. Its name is taken from the Songhaï Empire, which was the most powerful State in West Africa in the fifteenth and sixteenth centuries. The Songhaï Centre, the headquarters of which are located in Porto-Novo, is dedicated to a range of different functions: plots reserved for annual and perennial crops; breeding of various types of livestock; marshes and fishponds; agro-industrial units and units for agricultural machinery production; a platform intended for production of decentralized energy using agricultural waste; and community, service and market facilities (see figure 5.1).

▶ Figure 5.1. Songhaï green rural city model

Source: Songhaï Centre.

In addition to its headquarters in Porto-Novo, the centre has three other regional sites in Benin: 26 hectares in Kinwedji/Lokossa (1993); 250 hectares in Parakou (1999); and 241 hectares in Savalou (1999). There are also other sites in Nigeria and other countries.

5.2. Methodology

Two questionnaires were developed to collect the data: a questionnaire for managers of industrial symbiosis (IS) companies and a questionnaire for employees of those companies. The two questionnaires were structured according to the questions asked as part of the study.

In total, 81 people were interviewed: 65 in the Songhaï Centre of Benin, 3 in the Songhaï Centre of Nigeria, 8 managers belonging to the National Network of Songhaï Farmers (RENAFERS)[1] and 5 independent managers (table 5.1).

Table 5.1. Distribution of persons interviewed in Benin and Nigeria

		Gender			
Category	Target	Men	Women	Total	Percentage (%)
Managers	Managers of Songhaï Centre of Benin	7	8	15	18.52
	Managers of RENAFERS of Benin	8	0	8	9.88
	Independent managers of Benin	4	1	5	6.17
Employees	Songhaï Benin	36	14	50	61.7
	Songhaï Nigeria	3	0	3	3.70
Total		**58**	**23**	**81**	**100**

Source: Drafted by the authors.

1 RENAFERS (Réseau national des fermiers Songhaï) is an association of former farmers trained at the Songhaï Centre who have set up agricultural farms that operate in accordance with the Songhaï model.

It should be noted that the managers of most of the companies in the IS network that participated in this study were trained by the Songhaï Centre of Benin. As such, the involvement of these different actors in IS was effective thanks to this collaboration, as well as to awareness-raising conducted by the Songhaï Centre.

The various tools developed (interview guides, questionnaires, etc.) were used in an electronic application to allow the collection of data by tablets or mobile phones.

The processing of the data collected consisted in extraction of the various databases, reconciliation of the data collected during interviews with Stata software or Excel spreadsheets, and profiling of the data contained in the verified database. The data analysis has two parts: a descriptive analysis that made it possible to carry out simple and cross-tabulations, and a multidimensional analysis that took into account the various research parameters.[2]

5.3. Quantitative effects of industrial symbiosis on employment

The Songhaï industrial symbiosis (IS) network in Benin has 18 members. Those who currently have the largest workforce are, in descending order, the Songhaï Centre of Porto-Novo, the managers of RENAFERS and independent managers (table 5.2). Among the members, some have seen their workforce increase significantly thanks to the IS network, such as the Songhaï Porto-Novo centre (+1,071 per cent), Agro Initiatives (+300 per cent), Loti & Fils (+200 per cent) and Ferme agro-écologique Sèmèvo (+127 per cent).

2 For further details on the methodology used in this country study and on the study more broadly, see Agossou, Adjallala and Gnonhoué (2023).

Table 5.2. Quantitative effects of industrial symbiosis on employment, by Songhaï network member

	Personnel		
Category	Before IS	Current (after IS)	Variation (%)
Agro Initiatives	4	16	300
Eau source de vie	3	4	33
EDENIA	8	8	0
Farmers without Borders Benin	12	12	0
Ferme Acia Production	3	3	0
Ferme agro-écologique Sèmèvo	15	34	127
Ferme agro-pastorale Saint-Joseph Gbedegbe	8	8	0
Honfo	3	3	0
Independent managers	58	59	2
La Gloire de Dieu vivant	1	2	100
Loti & Fils (No-Day)	1	3	200
Managers, members of RENAFERS	54	88	63
Mirad S.A.R.L.	19	19	0
Songhaï Parakou	10	13	30
Songhaï Porto-Novo	38	445	1 071
Songhaï Savalou	75	75	0
Terre et Associés Nouvelle Génération S.A.	32	32	0
Togo & Fils	3	3	0
Total	**347**	**827**	**58**

Source: Drafted by the authors.

Following the legal definitions currently used in Benin,[3] our sample is made up of 47 per cent microenterprises, 29 per cent small enterprises, 18 per cent medium-sized enterprises and 6 per cent large enterprises. The relationships between the headquarters of the Songhaï Centre in Porto-Novo and the other Songhaï centres in Benin and other countries, on one hand, and the member farms of RENAFERS, on the other, are a perfect illustration of an IS network. All these centres have their own industrial processing units, larger or smaller depending on their size. The Porto-Novo centre and its satellites located in Benin have the largest. All these units have engaged in a collective approach to create a competitive advantage, particularly with regard to the exchange of agricultural raw materials, inputs, agricultural equipment and industrial consumables. This collaboration allows smaller companies to acquire inputs and technologies through the Songhaï Centre and then to deliver back to the centre the quantities of products that lack of technical capacity prevents them from transforming themselves.

There were 465 jobs before the IS network was set up. Technicians, with 141 jobs (30.32 per cent) represented the largest number of jobs, followed by skilled agricultural workers, with 121 jobs (26.02 per cent) (table 5.3).

▶ Table 5.3. Distribution of jobs before the industrial symbiosis network was established, by category

Category of personnel	Independent managers	Managers, members of RENAFERS	Songhaï	Total	Percentage
Department managers	7	7	15	29	6.24
Machine operators	4	7	16	27	5.80
Artisans/workers	6	35	7	48	10.32
Skilled agricultural workers	18	16	87	121	26.02
Technicians	8	14	119	141	30.32

3 Companies are categorized according to the average number of employees – namely, microenterprises (fewer than 10 employees), small enterprises (10–49 employees), medium-sized enterprises (50–250 employees) and large enterprises (more than 250 employees).

Office employees	9	10	13	32	6.88
Service and sales staff	13	10	44	67	14.41
Total	**65**	**99**	**301**	**465**	**100**

Source: Results of the data collection carried out in 2023.

The departure of 17 employees was noted after the implementation of the IS network (table 5.4). Two categories, in particular, account for the great majority (70.59 per cent) of these departures: service and sales personnel (41.18 per cent) and office workers (29.41 per cent). These categories of personnel are not sector-specific, and the individuals involved can find opportunities in other sectors more easily.

Table 5.4. Number of persons leaving their job after the industrial symbiosis network was established, by category

Category of personnel	Independent managers	Managers, members of RENAFERS	Songhaï	Total	Percentage
Department managers	0	2	0	2	11.76
Machine operators	0	0	0	0	0
Artisans/workers	0	0	0	0	0
Skilled agricultural workers	0	0	0	0	0
Technicians	0	3	0	3	17.65
Office employees	0	5	0	5	29.41
Service and sales staff	0	7	0	7	41.18
Total	**0**	**17**	**0**	**17**	**100**

Source: Results of the data collection carried out in 2023.

The establishment of the IS network enabled 138 technicians (30.80 per cent) and 121 skilled agricultural workers (27.01 per cent) to keep their jobs (table 5.5). These two categories represent the majority of the personnel concerned. These are sector-specific categories of personnel who have a lower degree of mobility.

▶ Table 5.5. Number of jobs retained after the industrial symbiosis network was established, by category

Category of personnel	Independent managers	Managers, members of RENAFERS	Songhaï	Total	Percentage
Department managers	7	5	15	27	6.03
Machine operators	4	7	16	27	6.03
Artisans/workers	6	35	7	48	10.71
Skilled agricultural workers	18	16	87	121	27.01
Technicians	8	11	119	138	30.80
Office employees	9	5	13	27	6.03
Service and sales staff	13	3	44	60	13.39
Total	**65**	**82**	**301**	**448**	**100**

Source: Results of the data collection carried out in 2023.

Of the 360 personnel entries between the two periods, the highest proportions were recorded in the categories of office workers with 110 jobs (30.56 per cent), technicians with 98 jobs (27.22 per cent) and skilled agricultural workers with 103 jobs (28.61 per cent) (table 5.6).

Table 5.6. Distribution of jobs created as a result of the industrial symbiosis network, by category

Category of personnel	Independent managers	Managers, members of RENAFERS	Songhaï	Total	Percentage
Department managers	0	0	36	36	10.00
Machine operators	0	3	6	9	2.50
Artisans/workers	0	0	0	0	0
Skilled agricultural workers	0	3	100	103	28.61
Technicians	0	1	97	98	27.22
Office employees	0	3	107	110	30.56
Service and sales staff	0	4	0	4	1.11
Total	**0**	**14**	**346**	**360**	**100**

Source: Results of the data collection carried out in 2023.

5.4. Qualitative effects of industrial symbiosis on employment

The qualitative effects on employment observed in the Songhaï industrial symbiosis (IS) network are: (i) employment formalization; (ii) improved working conditions; (iii) skills development; (iv) diversification of employment opportunities; and (v) promotion of innovation.

5.4.1. Company formalization

Company formalization implies that businesses carry out the administrative formalities in force so that they can be recognized by the State. These formalities enable companies to obtain an IFU number (unique tax identifier). They must declare at least part of their staff to the National Social Security Fund (CNSS), comply periodically with the tax authorities, and present financial statements at the end of each year. The results of the study show that only 19 per cent of companies in the IS network have declared all or part of their staff to the CNSS, highlighting their low rate of formalization.

5.4.2. Declaration of employees to the CNSS

No significant variation in the proportion of employees registered with the CNSS after the entry of companies into the IS network was observed (table 5.7). These results in themselves represent a poor performance on the part of the Songhaï IS network. Even if the declaration of employees to the CNSS was not an IS network objective, it could have had a positive impact on job formalization in this field and improve job security and workers' rights. The main reasons given to justify this poor performance are:

- the poor performance of the companies themselves in terms of profitability of the activities carried out, which does not yield the resources necessary to pay social security costs;
- the instability of certain employees who only stay in their jobs for fairly short periods of time, which does not allow companies to build a career plan for them;
- the recent establishment of businesses (less than ten years);
- the absence of career development plans in companies, probably because of the precariousness of existing resources; and
- the weak pressure exerted by public officials on businesses to compel them to fulfil their obligations towards their employees, particularly with respect to the issue of social security.

▶ Table 5.7. Percentage of employees registered with the CNSS, before and after entry into the industrial symbiosis network

	Women		Men	
	Before company entry into the IS network	After company entry into the IS network	Before company entry into the IS network	After company entry into the IS network
Songhaï centres				
Songhaï Nigeria	n/a	n/a	100	100
Songhaï Parakou	12	12	12	12
Songhaï Porto-Novo	100	100	100	67.86
Songhaï Savalou	100	100	100	100
Independent managers				
Honvo	0	0	0	0
La Gloire de Dieu vivant	0	0	0	0
Mirad S.A.R.L.	0	2	0	2
Terre et Associés Nouvelle Génération S.A.	0	100	0	100
Togo & Fils	0	1	0	1
Managers, members of RENAFERS				
Agro Initiatives	0	16	0	16
Eau source de vie	0	0	0	0
EDENIA	0	0	0	0
Ferme Acia production	0	0	0	0
Ferme agro-écologique Sèmèvo	0	2	0	2
Ferme agro-pastorale Saint-Joseph Gbedegbe	0	0	0	0
Farmers without Borders	0	0	0	0
Loti & Fils (No-Day)	0	82	0	82

Source: Field data, September 2023.

5.4.3. Work conditions

Before the companies entered the Benin Songhaï Centre IS network, the employees interviewed worked an average of 48 hours per week, compared with 50 hours after the companies entered the IS network. At the Songhaï Centre in Nigeria, the number of hours worked per week was 33 hours both before and after entry into the IS network (table 5.8).

Irrespective of the type of company considered, entry into the IS network did not bring about significant change in the number of hours worked by staff, which continued to be higher than is legally provided for.[4]

Table 5.8. Number of hours worked by staff per week, before and after entry into the industrial symbiosis network

Name of company	Type of company	Average number of hours of work per week before entry into the IS network			Average number of hours of work per week after entry into the IS network		
		Women	Men	Average	Women	Men	Average
Songhaï Porto-Novo	Large enterprise	49	55	53	49	55	53
Songhaï Parakou	Medium-sized enterprise	52	52	52	52	52	52
Songhaï Savalou	Medium-sized enterprise	44	44	44	44	44	44
Songhaï Nigeria	Medium-sized enterprise	33	33	33	33	33	33

Source: Field data, September 2023.

4 In Benin, according to Law No. 2017-05 of the Labour Code, the number of regulatory work hours per week is 40.

Use of protective equipment

The use of protective equipment is an important aspect of workplace safety. The various interviews revealed that 75 per cent of business managers stated that there was protective equipment in the workplace, compared with 25 per cent who said that there was not.

The employees interviewed indicated that there was not a significant difference in the availability of protective equipment in the workplace before and after their company entered the IS network (table 5.9).

Table 5.9. Percentage of employees using protective equipment in the workplace, before and after entry into the industrial symbiosis network

Location	Before entry into the IS network (%)	After entry into the IS network (%)
Songhaï Nigeria	100	33.33
Songhaï Parakou	46.15	58.33
Songhaï Porto-Novo	53.57	50
Songhaï Savalou	100	0
Honvo	0	0
La Gloire de Dieu vivant	0	0
Mirad S.A.R.L.	100	0
Terre et Associés Nouvelle Génération S.A.	100	0
Togo & Fils	100	0
Agro Initiatives	0	0
Eau source de vie	0	0
EDENIA	0	0
Ferme Acia production	0	0
Ferme agro-écologique Sèmèvo	0	0
Ferme agro-pastorale Saint-Joseph Gbedegbe	0	0
Farmers without Borders	0	0
Loti & Fils (No-Day)	0	100

Source: Field data, September 2023.

Planned annual leave for employees

In the interviews, 89 per cent of business managers said that employees received annual leave, while 11 per cent indicated that they did not, pointing to an area for further improvement.

Paid leave

The entry of the companies assessed into the IS network resulted in the proportion of employees entitled to paid leave increasing significantly (table 5.10). This was particularly the case in Songhaï Nigeria, which reached 100 per cent.

Table 5.10. Percentage of employees entitled to paid leave, before and after entry into the industrial symbiosis network

Location	Before entry into the IS network (%)	After entry into the IS network (%)
Songhaï Nigeria	66.67	100
Songhaï Parakou	76.92	75
Songhaï Porto-Novo	92.86	96.43
Songhaï Savalou	88.89	88.89

Source: Field data, September 2023.

According to the study, 79 per cent of company managers said that there was a change or an improvement in employee salaries, which is an important qualitative change following company entry into the IS network.

Generally speaking, IS aims to optimize resources, promote sustainable practices and improve working conditions, thus generating both quantitative and qualitative positive effects on employment.

5.5. Positive impacts of industrial symbiosis on informal work and informal businesses

The results of the study revealed some positive impacts of industrial symbiosis (IS) networks on informal work and informal businesses. The most important of these are: (i) access to resources and skills; and (ii) training and skills development.

5.5.1. Access to resources and skills

RENAFERS companies, independent businesses and Songhaï centres located in countries other than Benin – the overwhelming majority of which are informal – regularly benefit from access to resources and skills through the parent centre located in Porto-Novo to support their development. All the companies established in Nigeria according to the Songhaï model were, at their start, managed by teams of technicians made available by the Porto-Novo centre, who oversaw the training of local technicians who gradually took over. Their presence at the launch of these centres was a guarantee of their viability and contributed to good productivity in their activities. The Porto-Novo centre also provided the same assistance to companies established by former centre alumni. The development of these new enterprises, which are now members of the IS network, has led to the creation of 360 jobs in the network.

5.5.2. Training and skills development

Informal workers and informal satellite companies have benefited from training and skills development offered by the Songhaï parent centre in Porto-Novo. This has contributed greatly to their employability and the development of their ability to access decent work, often outside the IS network. The training has focused on a range of areas, including agricultural entrepreneurship; plant, animal and fish production; agro-industry; agricultural mechanization; decentralized renewable energies; information and communication technologies; techno-economic management of agricultural activities along the value chain; soil regeneration techniques; and irrigation techniques.

5.6. Specific skills required in the industrial symbiosis network

Certain categories of staff must have specific skills to ensure the proper functioning of member companies belonging to the Songhaï industrial symbiosis (IS) network. By far the most important of these are technicians, who are essential to Songhaï's integrated agricultural production model, which has been reproduced in all the satellite companies that are members of the IS network. This is because the conduct of activities in the primary, secondary and even tertiary sectors requires a certain level of technical skill. It is for this reason that basic and refresher training is organized periodically.

Service and sales staff, as well as workers, whose skills are equally valued by 71 per cent of the companies surveyed, also represent significant categories required for the proper functioning of the IS network. Workers labour alongside technicians, and service and sales staff are necessary in the tertiary sector (shops, transport, hotel industry, etc.).

Technicians, who represent the largest share of available workers (96 per cent of those surveyed), were trained in high schools and other agricultural technical schools in Benin. Office and support staff (71 per cent) and skilled agricultural workers (63 per cent) are the next two most represented categories. However, it should be noted that, while these workers are available and generally have the necessary basic training, the Songhaï Centre and partner companies conduct additional training to ensure they are truly operational.

The Songhaï Centre has provided training mainly to skilled agricultural workers (71 per cent) and technicians (67 per cent). Machine operators and office workers have also benefited from this training, reflecting the importance of these two categories of workers in the production system. As certain agricultural work is mechanized, the system needs machine operators. Office and support staff are also needed to assist the various departments of the company.

5.7. Conclusions

This study has made it possible to present the case of the Songhaï Centre industrial symbiosis (IS) network, which is organized around a few companies that all implement the Songhaï integrated agricultural production model. From the data collected from managers and employees, the following conclusions can be drawn:

- The integration of companies into the IS network has had certain quantitative and qualitative effects on employment – in particular, an increase in the number of jobs and improved working conditions.
- No improvement in terms of employment formalization was reported.
- Informal employees in the IS network have received training, in particular skilled agricultural workers and technicians.

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Industrial symbiosis in Argentina:

Its impact on productive employment in value chains

Bruno Dante Abriata and Ariel Masut

6.1. The origin of industrial symbiosis networks in Argentina

While Argentina does not have a circular economy law, the Law on the Management of Domestic Waste (Law No. 25916) was passed in 2004. A draft law on the circular economy was submitted to the national legislative branch in 2018 (HCDN 2018).

There is a department within the Federal Government – the Sustainable Industry Directorate under the Ministry of Productive Development – that has specific and direct jurisdiction over the circular economy. In addition, the government has convened various cross-cutting round tables related to these issues, such as the circular economy round tables of the Ministry of Productive Development, the round tables of the Council for Climate Change of the Ministry of the Environment and Sustainable Development, and the missions of the Economic and Social Council.

Additionally, in 2023 the Ministry of the Environment and Sustainable Development launched a National Circular Economy Plan for Waste Management and developed a Provincial Strategic Plan of Waste Management towards a Circular Economy. Provincial and municipal governments must develop comprehensive waste management plans towards a circular economy (Ministry of the Environment and Sustainable Development 2023). Industrial symbiosis (IS) is not mentioned in this document, but measures to survey the market for recyclable and recoverable materials are described (section O), including some of the recommendations of the original version of this study, such as generating a geo-referenced database of the main links in the value chain (Abriata and Masut 2021).

Argentina already has a network of intermediary institutions that expressly promote IS. They can be classified into three groups:

i. institutions that specialize in sustainable development and the circular economy, such as the Association for the Study of Solid Waste, the Partnership for Action on Green Economy, the Global Compact Network and the Argentine Business Council for Sustainable Development;

ii. business associations and non-specialized intermediary institutions, such as the Argentine Petrochemical Institute, the Argentine Chamber of the Plastic Recycling Industry, the Association of Argentine Industrial Parks and the Argentine Industrial Union; and

iii. public sector institutions, such as the National Institute of Industrial Technology and various local institutions.

The IS networks in the country have diverse origins. In some cases, they arose spontaneously in response to a logistical problem or with a view to obtaining marginal cost savings, while in other cases they are the result of an active process to create partnerships in order to achieve synergies. In the latter case, the networks may have been created for different reasons, such as to obtain economic benefits from the establishment of a new business, to earn a better reputation and greater visibility, or to comply with sustainability regulations, quality standards and corporate social responsibility goals. Although there is no organization at the institutional or public policy level that keeps organized records of these networks, our survey has managed to identify more than 20 specific cases. Environmental engineering services seem to be a key part of the emergence of IS networks.

The case studies chosen in this effort to assess the impact on employment are the reuse of whey in the Pampas region and the generation of electrical energy from wood waste in the province of Corrientes.

▶ 6.2. Methodology

The main source of primary information for the case review is a series of interviews carried out with authorities on industrial symbiosis (IS)-related topics. To have a sufficiently broad sectoral and territorial perspective, representatives from the public sector and business associations, as well as specialists in circular economy, were contacted.

To collect data on the case studies, remote and partially structured surveys were carried out. To complement the surveys, we also turned to data from secondary sources. First, we used the 1997 Argentina Input–Output

Matrix to obtain the coefficients of intersectoral requirements and employment per unit of expenditure and employment multipliers of the various economic activities (INDEC 2001).[1] Data on the socio-demographic structure of the industrial sectors were obtained from the Permanent Household Survey (INDEC 2020). We then complemented this information with studies of more specific and current sectoral cost structures, among which we highlighted the 2015 National Census of Sawmills (Ministry of Agro-Industry 2017). Third, we turned to academic articles and sectoral reports from government sources, as well as periodicals.[2]

6.2.1. Quantitative impact on employment

The quantitative impact of IS on employment is two-fold. On one hand, the effect can originate from changes in the production process ("substitution effect") or from changes in the level of production of the company's main activity ("activity effect"). On the other hand, the impact can be direct (affecting jobs in companies that directly participate in the symbiosis), indirect (affecting employment in the supply chain of companies, which experience changes in the amount and structure of their spending) or induced (affecting economic activity through higher consumer spending as production factors result in higher income).

6.2.2. Qualitative impact on employment

In this chapter the focus is on two types of qualitative impact on employment. First, there is the "composition effect", the origin of which is found in the socio-demographic characteristics of the sectors in which jobs are created or eliminated. Second, there is the "condition effect", which corresponds to changes in the conditions in which employment activities and relationships develop as a consequence of the changes induced by IS.

The composition effect describes how IS contributes to equity in employment and formalization opportunities and is directly linked to quantitative impact. This effect originates in the jobs created or eliminated by IS. Here, the focus is on the quality of employment opportunities based on their formality and the participation of different socio-demographic groups in the changes in labour demand. From an equal opportunity perspective, it is interesting to know not only the socio-demographic composition of the direct jobs created or eliminated, but also the composition of those jobs generated indirectly throughout the

1 The 1997 version of the matrix of intersectoral transactions of the Argentine economy referenced is the most up-to-date version available.

2 For further details on the methodology used in this country study and on the study more broadly, see Abriata and Masut (2021).

value chain. Each industrial sector has its own socio-labour composition in terms of gender, education and formality status. As such, the relative weight of these sectors in the variation of employment will determine the percentages of participation of the socio-demographic groups of interest (women and persons with a low level of education) in total and formal employment opportunities.

The condition effect is purely qualitative and depends on changes in the technical and operational characteristics of the production processes. Within the framework of these processes, workers perform tasks that have two characteristics that contribute to the quality of the job. On one hand, there are risks to the safety and health of workers that are inherent in the tasks, because they require exposure either to situations (height, insecurity, climate, heavy moving objects, etc.) or to elements (toxic or flammable substances, contamination) that may harm them or put their integrity at risk. On the other hand, each task requires the execution of a different set of knowledge and skills. Therefore, if the tasks of the production processes are eliminated, replaced or modified, the same will happen with the risks to which workers are exposed and the training they receive.

▸ 6.2.3. Limitations

The methodology implemented has certain limitations. To begin with, it does not provide an exhaustive or systematic survey of IS networks in Argentina. Nor are the surveys in the case studies themselves exhaustive, since the networks are made up of more companies than those surveyed. It is also important to highlight the lack of data from worker surveys, which could enrich the database and test other hypotheses, especially of qualitative impact, but are difficult to collect. All calculations of indirect effects, meanwhile, are distorted by the fact that the input–output matrix dates back to 1997, which is the last one available for Argentina that was produced on an official basis[3] and has an appropriate degree of sectoral disaggregation – conditions that are not met by any of the subsequent works, such as the social accounting matrix for 2018 prepared by Michelena (2019).[4] Furthermore, the use of this tool implies acceptance of the assumptions that are built into it, such as that of production functions of fixed proportions. Similarly, the composition effect calculations are limited by the lack of correspondence between the industrial classifications

3 The input–output matrices available until 1997 were prepared by the National Institute of Statistics and Census. Subsequent works on the subject are re-estimates by researchers that have not been validated by the National Institute.

4 This work groups certain key activities for our model, such as sawmills, forestry, livestock and land transport, within other broader categories; this would introduce substantial distortions in the employment–product coefficients and intersectoral demands used in this chapter.

of the Permanent Household Survey and the 1997 input–output matrix, which required a reclassification at the discretion of the authors. Finally, the quality and quantity of data required by the methodology were higher than that actually obtained through surveys from primary and secondary sources, which is why it was necessary to carry out conversions and imputations on numerical data that were missing or considered defective.

6.3. Case studies

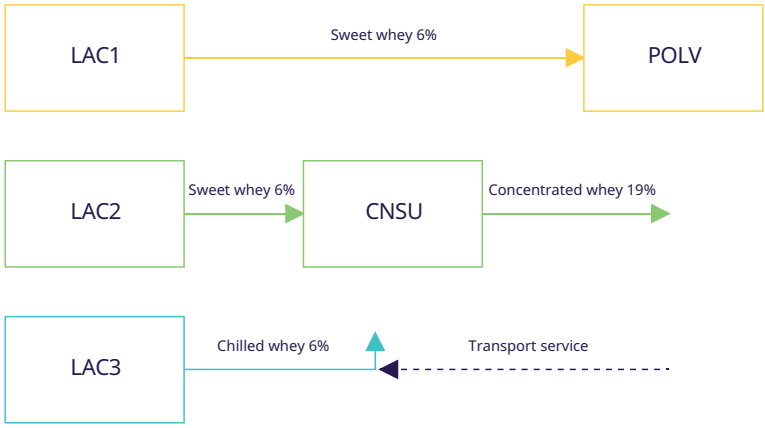
6.3.1. Case study 1: Industrialization of whey in the Pampas region

The industrial symbiosis (IS) network in this case is made up of a group of companies in the Pampas and Buenos Aires dairy sector that organized to solve the problem of whey disposal. It was a joint initiative, the Whey Recovery Programme, in which regional dairy producers, the Ministry of Science, Technology and Innovation, and the Argentine Industrial Union joined forces to address the environmental problem of whey waste disposal (UIA 2014).

The IS network is made up of three types of companies. At the beginning of the network value chain, there are dairy plants, which manufacture cheeses, cottage cheese, dulce de leche and other dairy derivatives. Then there are concentrator companies, which receive whey from dairy manufacturers to increase the percentage of solids from 6 per cent to 19 per cent so that it can be transported in adequate conditions to the last link in the chain: the whey powder factory. Here, whey is received at different stages of processing to be transformed into powder that is either sold to local industry or exported.

The main actor in the network is the only whey powder factory that was part of the survey, Powder Company 1 (POLV) (figure 6.1). This company is located in a town in the province of Buenos Aires, in the heart of the dairy basin. It supplies large food and pharmaceutical companies based in the country, with products also exported to Colombia, Algeria and the Plurinational State of Bolivia, and provides the input for an important multinational player in the food sector. It employs 15 people.

▶ Figure 6.1. Whey valorization scheme (companies surveyed)



Note: LAC = Dairy Company; CNSU = Whey Concentration Company; POLV = Powder Company.
Source: Drafted by the authors.

POLV's own supply of liquid whey comes from nine companies and enters the plant at different stages of processing. First, it receives untreated whey (6 per cent solid matter) from Dairy Company 1 (LAC1), which is owned by the same proprietors as POLV and located in the same town; this company was also included in the survey. Second, it receives whey (6 per cent) from other dairy plants in the area; this whey is cooled to prevent its degradation during transit. And third, it receives concentrated whey (19 per cent) from more distant whey concentration plants. POLV is also responsible for transporting chilled whey between some dairy plants and their respective concentration plants.

The network's concentrated whey is produced by three companies. One of them, Whey Concentration Company 1 (CNSU), located in a small town in the Pampas region, was part of the survey. The rest of the whey comes from two other dairy plants, which provide chilled whey via logistics overseen by POLV. CNSU provides direct employment to three people.

The other link in the chain is made up of dairy plants. These companies are the ones that produce the liquid whey and supply it to the concentrators and compacters. In addition to the aforementioned LAC1 and LAC2, there are at least five other companies that supply POLV. One of these is Dairy Company 3 (LAC3), located in another town in the Pampas region, which was also surveyed. Like the other dairy plants in the scheme, it produces cheese, dulce de leche, cottage cheese and other milk derivatives. LAC3 directly employs 31 people, while LAC1 has 30 employees and LAC2 14.

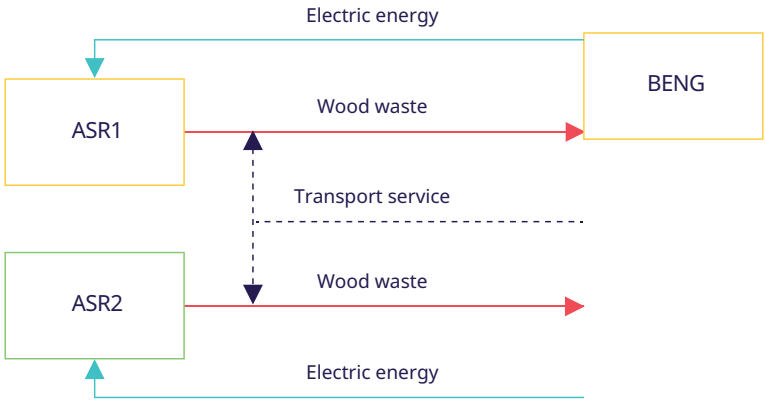
6.3.2. Case study 2: Bioenergy derived from sawmill waste in Corrientes

In 2010 a profound energy crisis occurred in the province of Corrientes that left the local industrial sector paralysed. Working together with businesspeople and the local government, the provincial government designed a plan to solve the crisis:

- The installation of an industrial forest park was planned, with a view to bringing together the sawmills of the area in the same place, organizing energy demand, and making the energy distribution system more efficient. A further objective of the plan was to remove the sawmills from the outskirts of the town. This would have a positive environmental impact and protect the health of the residents, as previously the sawmills had no place to dispose of the waste they generated in the course of wood processing. Waste accumulated on the property and was burned in the open, resulting in uncontrolled dispersal of ashes.
- As a definitive solution to the energy problem, the plan sought to recover the large amount of wood waste generated by the wood-processing activity through a plant that generates energy from forest biomass. This initiative would strengthen the sawmills in two significant ways: sufficient energy, in terms of both quality and quantity, would enable them to invest in more and better technology; and an increase in their total income, resulting from the greater availability of space for wood drying, would allow them to solve the problem of waste accumulation.

The industrial forest park was inaugurated in 2015. The company responsible for installing the plant that generates energy from forest biomass in the town of Corrientes is referred to here as BENG (figure 6.2). The company's capital is 25 per cent national and 75 per cent foreign. In November 2020 the plant began to generate electricity and feed it into the system (Argentina Forestal 2017).

▶ Figure 6.2. Wood waste reuse scheme (surveyed companies)



Note: BENG = biomass-powered electricity-generating company; ASR = sawmill.
Source: Drafted by the authors.

According to initial calculations, the plant was expected to consume 20,000 tonnes of biomass per month. This volume includes waste from the forest and sawmills in the area which, before the plant was built, was either burned, affecting the environment, or accumulated in the sawmills, creating a fire risk. Thus, the plant adds value to wood waste, such as sawdust and waste by-products, which is mainly generated by industries that are local or in the surrounding area. The company is concluding 20-year private agreements with raw material suppliers.

Thirty-four people are required for the operation and maintenance of the plant. The company's direct staff is made up of technicians and professionals, mostly from the region. This field of work requires specific qualifications, and 70 per cent of the staff are university-educated, of whom one fifth are women. Eighty per cent of the plant's staff had other jobs at the time they were hired, and only a fraction of the technicians were unemployed at that time. Local workers were prioritized in the recruitment process.

In addition to the thermal biomass-powered generation plant BENG, the sawmills in the area play a role in the IS network. Two of these sawmills, referred to in figure 6.2 as ASR1 and ASR2, were included in the survey. Most of the sawmills are located within a distance of 20 km of BENG, to which the waste they produce in the course of wood processing is taken.

This IS plan is based on the reuse of wood waste. The initial waste from wood processing is sawdust, and there are other types of waste that come from both forestry and processing in sawmills. The biomass plant is currently supplied by about 20 sawmills, and it is estimated that this number will double in the coming years. The supply is governed by quarterly contracts.

The plant uses up to 30 per cent sawdust, which is the lowest-cost raw material, but the rest of the input (70 per cent) must be processed to convert it into woodchips prior to use in the boiler. Some of the sawmills that supply the plant have chipping machines; this increases the value of the waste they supply as it facilitates the internal logistics of the bioenergy plant BENG, which only has to process waste from the sawmills that do not have such machines.

Logistics are essential for the supply of the plant. Eighty truckloads are required per day. The majority of the delivery trucks operate within a 20-km radius of BENG, and some are no more than 1 km away, since the plant is located within the industrial park. No deliveries are made from locations more than 50 km from the plant.

Freight can be provided by the supplier (approximately 70 per cent) or by the plant (30 per cent). The logistics process is formal, for both trucks and drivers. The trucks are marked with the plant's logo. BENG's supply logistics cycle is completed with just one shift a day (no work is performed at weekends).

6.4. Quantitative impact of industrial symbiosis on productive employment

The results of this work show that industrial symbiosis (IS) has a clear positive impact on job creation (table 6.1). In the case of whey, total employment is 19 per cent higher than it would be if the dairy plants discarded the waste instead of it being converted into whey powder. In the case of wood, the positive impact is 52 per cent compared with a scenario in which wood waste is stored for later controlled burning.

Table 6.1. Total quantitative impact

Total	Gathered	Base	Substitution effect	Activity effect	**TOTAL effect**
Whey	93	2 067	400	0	**19%**
Wood	246	2 473	130	1 151	**52%**

Source: Drafted by the authors.

In the case of whey, the impact on employment is entirely explained by the substitution effect. The chilling, logistical and industrialization processes of whey treatment generate an additional requirement for work, goods and services that would not occur if the whey were discarded. In the case of discarding, the construction and operation of an on-site effluent treatment plant would be necessary; however, even discounting the associated labour demand, the effect is still positive.

There is no activity effect in the case of whey. The volume of production of dairy products depends exclusively on the level of production of raw milk received from the dairy farms. According to the dairy companies' reports, the remuneration received for the whey does not alter the net income per litre of milk; it barely repays the costs linked to the conditioning and treatment of the whey for delivery. In fact, the main reason for dairy plants

to get involved in the IS network is to solve the logistical problem of whey disposal (equivalent to 85 per cent of the volume of milk received) without causing the environmental damage that direct disposal in agricultural land would imply. Thus, participation in the network does not generate incentives to increase the processing of milk from more distant and hence higher-cost dairy farms.

By contrast, in the case of wood, there is a predominant activity effect that is exhibited through two channels. On one hand, IS provided a higher-quality electricity supply, facilitating the incorporation of technologies that make the production process more efficient (saving time and physical space in sawmills) and increase product quality (compliance with European phytosanitary requirements), thereby allowing access to more external markets. According to the interviewees, the nature of this project and the availability of RenovAr (an auction-based renewable energy programme) were what made it possible to have the improved electricity supply, given that alternative sources, without subsidies, were very expensive and did not have positive environmental externalities. On the other hand, finding an immediate destination for the waste freed up even more space in the sawmills, allowing a greater volume of final product to be dried and stored.

The substitution effect is also present in the case of wood. This effect originates in the construction and operation of the biomass plant, the investment in chipping machines in the sawmills, their operation and maintenance costs (labour force, electricity and spare parts), and additional logistical expenses in terms of bringing the waste to the biomass plant. At the same time, the labour force is no longer required to conduct controlled waste incineration or to supply alternative sources of electrical energy that have been replaced by the installation of the plant. The latter has a significant downward impact on the indirect substitution effect.

6.4.1. Direct effect

The revaluation of whey resulted in the direct creation of jobs, increasing company employment by 19 per cent (table 6.2). The companies surveyed have a total of 93 employees, which, discounting the jobs generated by IS and applying the expansion factors, results in a base employment of the network of a total of 137 workers operating nine dairy products factories. The substitution effect creates a total of 25 direct jobs held by the entire staff of the whey powder plant and the three whey concentrator plants that supply it. There is also a marginal part-time workforce for logistical tasks, which are reported as having no involvement in any part of the whey industrialization process.

Table 6.2. Quantitative impact: Direct effect

Direct	Gathered	Base	Substitution effect	Activity effect	**TOTAL effect**
Whey	93	137	25	0	**19%**
Wood	246	556	43	204	**44%**

Source: Drafted by the authors.

Regarding the reuse of wood waste, most of the effect can be explained by the impact on production levels. Faced with an expanded export market, the incorporation of technology and greater efficiency in the use of space resulted in expanded production. This, in turn, also increased the demand for employment. The substitution effect of this IS network comprises the total workforce of the bioenergy plant, the maintenance and operation personnel of the chipping machines in the sawmills, and additional personnel assigned to transportation and internal logistics.

6.4.2. Indirect effect

The impact of IS on the value chain is also positive (table 6.3). Changes in production processes and the impact on activity lead to greater spending directed towards the value chain, which then results in the generation of new jobs. Thus, the reuse of whey increases indirect employment by 20 per cent, while in the case of wood the impact is 67 per cent.

Table 6.3. Quantitative impact: Indirect effect

Indirect	Gathered	Base	Substitution effect	Activity effect	**TOTAL effect**
Whey	–	810	165	0	**20%**
Wood	–	427	–15	299	**67%**

Source: Drafted by the authors.

In the case of whey, the positive impact stems mainly from the new demand for goods and services for the operation of the concentrated whey and whey powder plants. This generates a significant demand for land transportation, energy consumption (gas and electricity), and industrial inputs that in turn drive new acquisitions of goods and services. Likewise, the construction of the plants also drives spending in the construction value chains and on metal structures and machinery of national origin, although the impact is attenuated by the fact that dairy factories stop

spending on installation, operation and maintenance of effluent treatment plants. Finally, it should be noted that, although the dairy industry has one of the highest employment multipliers in the Argentine economy (6.92 indirect jobs for every direct job), the absence of an activity effect means that the IS network does not spill over to the rest of the economy through that channel. Instead, its impact is visible in the aforementioned expenditures in other sectors with a lower multiplier effect.

The IS network has a more powerful impact in the case of wood. The total employment generated is equivalent to two thirds of the amount that would exist in the absence of IS. However, here the effect is due entirely to the impact on the level of activity, since expense substitution results in job reduction.

This negative substitution effect is explained by the impact on the electricity market. On the sawmill side, the only activity suppressed is the incineration of waste, while the processing and sale of woodchips is added. This generates additional investment expenditure in new equipment and its operation and maintenance, and in transportation services to handle the journey that the waste must take from sawmill to plant. Likewise, although bioenergy generation is a capital-intensive activity, the installation of the biomass plant and its operating expenses spill over into various sectors, including construction, personal services, supplies, machinery and equipment. However, the plant injects electrical energy into the distribution system, producing a volume greater than that demanded by the expansion of the sawmills and thus replacing generation from other sources. According to the coefficients of the input–output matrix, employment due to the demand derived from alternative sources of electricity exceeds that generated by the construction and operation of the biomass plant and the other positive substitution effects.

The activity effect has two aspects. On one hand, the activity carried out by the new equipment brought into the sawmills will require operational inputs that are practically proportional to the new added activity (raw wood material, electrical energy, cargo transportation, etc.). On the other hand, the reduction in the risk of fire will translate into greater activity in the group of local sawmills, with the expenditure flowing into all the sectors where it would ordinarily go (mainly, wood extraction and cargo transportation).

The difference in the magnitude of impact in the case of wood, as opposed to whey, is explained by operational and cost-structure differences. Although the employment multiplier of the dairy industry is significantly higher than that of sawmills (6.22 versus 1.77), the absence of an activity effect in the former nullifies the expansion of employment through these emerging demands. Regarding the substitution effect, the difference lies in the magnitude of the investment expenditure in the construction of the biomass plant, with an impact on sectors with a high direct and indirect employment requirement, such as construction and machinery.

▶ 6.4.3. Induced effect

The induced effect is a simple expansion of the direct and indirect effects (table 6.4). The total payrolls associated with these increases in employment are impacted by the same expenditure multiplier and the same employment coefficient per dollar of added value. As such, apart from some intersectoral differences in wages, both the base and the effects maintain the sum of the direct and indirect effects.

▶ Table 6.4. Quantitative impact: Induced effect

Induced	Gathered	Base	Substitution effect	Activity effect	**TOTAL effect**
Whey	–	1 121	209	0	**19%**
Wood	–	1 490	101	648	**50%**

Source: Drafted by the authors.

▶ 6.5. Qualitative impact of industrial symbiosis on productive employment

▶ 6.5.1. Composition effect

Industrial symbiosis (IS) performance in terms of the quality of the employment generated is uneven. The contribution to equal opportunities is modest since the percentage of vulnerable socio-demographic groups in IS-generated jobs is lower than the percentage of such groups in the unemployed and economically active populations.

Comparison of tables 6.5 and 6.6 suggests that IS does not help to close the gap in employment opportunities. As previously explained, our estimate of the composition effect considers the gender and educational level of the jobs created directly and then compares this with the gender structure and

educational level of the sectors in which indirect employment is created. Producing an estimate in this way, it is apparent that the participation of vulnerable groups in IS-created employment opportunities is well below the percentage these groups represent in total unemployment in the regions considered. In both regions, women account for at least half the total unemployment rate, but the percentage of jobs created by IS that are taken by women barely reaches 26 per cent in the case of whey and 12 per cent in the case of wood. A similar phenomenon is observed with respect to the population without secondary education. For women with a low level of education, the problem is especially bad, as the unemployment level of this socio-demographic group in the regional labour market is between three and seven times higher than their level of employment in jobs generated by IS.

Table 6.5. Total composition effect

Direct and indirect	Whey	Wood
Percentage of women in the total number of jobs created or eliminated	26%	12%
Percentage of the population without secondary education in the total number of jobs created or eliminated	22%	35%
Percentage of women without secondary education in the total number of jobs created or eliminated	7%	2%

Source: Drafted by the authors.

Table 6.6. Characteristics of the regional labour market

Characteristics of the regional labour market	Pampas region	North-east region
Percentage of women without employment in the region	53%	50%
Percentage of the population without secondary education who are unemployed in the region	41%	39%
Percentage of women without secondary education who are unemployed in the region	23%	14%

Source: Drafted by the authors.

IS performance in terms of formality is not satisfactory (tables 6.7 and 6.8). In aggregate terms, the rate of formality in the new jobs created by both schemes (whey and wood) is lower than the regional averages (63 per cent

versus 75 per cent in the case of whey, and 38 per cent versus 61 per cent in the case of wood).

Table 6.7. Indirect composition effect

Indirect effect	Whey	Wood
Formality rate in the total number of jobs created or eliminated	63%	38%
Percentage of formal female jobs in the total number of jobs created or eliminated	11%	–2%
Percentage of women in the total formal jobs created or eliminated	17%	–6%
Formality rate in the total number of female jobs created or eliminated	37%	–45%
Formality rate in the total jobs created or eliminated for workers with low levels of education	59%	40%

Source: Drafted by the authors.

Table 6.8. Characteristics of the regional labour market

Characteristics of the regional labour market	Pampas	Corrientes
Employment formality rate	75%	61%
Female employment formality rate	70%	59%

Source: Drafted by the authors.

In the matter of gender equity in access to formal employment opportunities, no favourable impact was observed either. Considering female employment in the case of whey, it is notable that the problem of formality of female jobs is exacerbated (37 per cent versus 70 per cent in the regional labour market). Likewise, only 11 per cent of the jobs created are formal jobs for women, and the participation of women in all formal jobs created by IS is only 17 per cent. In the case of wood, an adverse effect on formal jobs for women is observed, in absolute terms, as IS results in the elimination of formal female jobs equivalent to 2 per cent of all jobs created or, more narrowly, of 45 per cent of all female jobs created.

Regarding the formality of indirect jobs, an extension of the regional situation is observed. In La Pampa province, labour informality was 21.7 per cent

in 2017, while in Corrientes province it was 37.6 per cent, so the formality rates of indirect employment created by IS do not greatly alter the situation (National Directorate of Provincial Affairs 2017a, 2017b).

The interpretation of this result is subtle, leading us to reflect on which sectors have the capacity to achieve qualitative changes. In principle, it might seem obvious that the informality rates in jobs created indirectly will be very similar to those in the rest of the economy, since the indirect effect simply implies the expansion or contraction of sectors that are of particular significance to the provincial economy. However, IS only boosts some of these sectors through its indirect effects, which could have different socio-demographic characteristics from other sectors. Thus, our result concerning the impact of indirect employment on formality rates simply tells us that the sectors driven by the creation and expansion of the IS network are not those that have, on average, a socio-demographic structure that is very different from that of the regional economy.

The opportunity gap in IS is very noticeable. Only 11 per cent of the indirect jobs created by the revaluation of whey are formal opportunities for women, and there is a destruction of formal female job opportunities of 2 per cent in the case of wood. Likewise, the percentage of women in the total number of formal jobs created is seen to be even lower than the already low percentage of women in all available opportunities. Moreover, in the case of whey, the gender gap is even deeper when it is considered that the formality rate in female employment is noticeably lower (37 per cent) than the formality rate in all jobs created (63 per cent). Finally, it should be noted that, in the case of wood, less than half the indirect jobs created for workers with a low level of education (40 per cent) are formal.

Regarding direct jobs, the data only allow us to evaluate the impact on formalization of plants dedicated entirely to IS activities (table 6.9). In the case of the whey concentration and whey powder production plants, 72 per cent of the employment generated was formalized by workers previously in a situation of informality or unemployment. In the case of wood, given that this indicator only takes into account jobs created by the bioenergy plant, the impact is lower, but this is because the employment profile of this establishment requires higher levels of training and specialization. It is therefore less probable that the jobs would come from precarious employment. In neither case were there women who benefited from these changes in the labour formality situation. In any case, it should be remembered that these results are not very representative as they are limited to bioenergy and whey industrialization plants.

Table 6.9. Direct composition effect

Direct effect	Whey	Wood
Percentage of previously informal or unemployed workers in the total number of jobs created or eliminated	72%	12%
Percentage of previously informal or unemployed workers in the total number of female jobs created or eliminated	0%	0%

Source: Drafted by the authors.

It should be noted that IS could generate a significant qualitative improvement with regard to direct employment in the case of wood. The very high degree of informality is one of the main labour problems associated with sawmills – particularly the smaller-scale ones – in the Corrientes region (In Situ 2013). Large projects, as represented here by BENG, can bring about a significant increase in the labour formality rate by making the labour situation in the supply chain (in this case, the industrial forestry sector) visible and by offering an incentive. The actors involved that have high exposure in terms of corporate social responsibility, such as multinational companies, governments, development banks and investment funds, are anxious to maintain their reputation as responsible participants, and therefore insist on an increase in formalization in the local value chain as a precondition of making an investment available. Thus, while these actors are actively working to make an increased level of formality a precondition of the project progressing, the forestry industry agrees to carry out the changes required to the extent that it recognizes the benefits flowing from them – such as (in this case) better electricity supply, reduced fire risk and saving of physical space.

6.5.2. Condition effect

A project such as the bioenergy plant BENG requires a higher level of training on the part of the local workforce. Standardization of processes, implementation of hygiene and safety standards, incorporation of technologies and participation in markets with higher quality demands require a workforce with a level of education far above that currently found in sawmills and their raw material suppliers. However, the average educational level of logging workers is much lower than the average for the economy, even in regions with a major forestry sector (Peirano, Bustos Hinostroza and Nahirñak 2009). Likewise, the profile of human resources continues to be characterized by low levels of education and high relevance of knowledge acquired in the workplace and specific skills throughout almost the entire forestry chain (Ramos et al. 2015).

The case studies present marked differences in this respect. The dairy industry is low risk for workers and their participation in IS does not entail greater risks. However, the activities associated with sawmills and logging carry a high level of risk to the physical integrity of workers, and IS can contribute to mitigating such risks.

In the dairy sector, care of raw materials in all its phases is crucial, which is why there is such emphasis on quality and standards of personal care and the work environment. Given the nature of their products and raw materials, dairy establishments make a greater investment in care and preparation of the work environment than sawmills. In turn, employees in the dairy industry receive more training on process issues, preparation of the work environment and care. In the case of whey analysed, there is no specific risk that is added or mitigated by IS, nor an incremental effect on the investment in any specific process conducted in the plant.

Forestry activity, by contrast, is one of the most dangerous work activities in the world. All jobs in the forestry chain carry the risk of serious injury. In Argentina this sector has one of the highest accident rates, and it has been rated as one of the most hazardous sectors (ahead even of mining) by the Office of the Superintendent of Labour Risks. Workers in this sector are still twice as likely to suffer a work accident or occupational disease as the average Argentine worker. When compared with the forestry sectors of other countries, accident rates in Argentina are among the highest. International experience has shown that training of people, modernization and automation of processes, and adoption of preventive measures have been effective in reducing these risks (Ramos et al. 2015). It is apparent, therefore, that IS has the capacity to mitigate occupational risks through the technological improvements it brings.

6.6. Public policies

6.6.1. Skills training

The cases studied show that industrial symbiosis (IS) generates new training activities, but that there are certain limitations. The majority of these new activities arise not because they are strictly linked to the process of working with waste but because they represent new units of production that require compliance with the quality, hygiene and safety standards that are typical of any company in their sector. Regarding training specifically linked to changes in waste management, the impact is limited to particular tasks conducted in a particular type of company.

In the two cases studied, only the sawmills have included specific IS training. Both ASR1 and ASR2 have trained their staff in the use and maintenance of chippers and ramps. In terms of types of training, ASR1 mentioned taking courses from, and engaging in consultations with, an agro-industrial company that was its first buyer of waste.

The most high-tech sawmills, applying modern business organization and management methods, have incorporated technology into their processes as a way to improve efficiency and productivity and to enhance their chances of competing abroad. Technology allows products to be reworked with greater added value and the use of wood to be optimized. In general, the best-managed companies tend to be vertically integrated, specializing in a limited number of products and scaling their operations. This allows resources to be optimized and quality standards improved. In turn, this specialization tends to demand operators with more specific qualifications (Ramos et al. 2015).

▸ 6.6.2. Research and development

In general terms, research and development (R&D) has not played an important role in IS. In our surveys and case studies, mentions of the topic have been few and negligible.

The whey concentration company CNSU and the dairy company LAC2 indicated that there are R&D initiatives within the framework of the IS network. They mentioned that there are projects with the National Institute of Industrial Technology (INTI) and the National Institute of Agricultural Technology (INTA) to test new whey-based products and that they have also invested in travelling to and attending conferences to obtain new ideas and open new markets.

The bioenergy company BENG does not itself invest in R&D. However, the international company of which it is a subsidiary does make expenditures in this area, from which the subsidiary in Corrientes and the IS network can benefit.

By contrast, the case of battery recovery shows intensive and institutionalized use of R&D. One of the companies in this area receives support from the National University of Rio Cuarto through a formal collaboration agreement. The university has made available electrochemistry, nanotechnology and microcapacitor equipment.

6.6.3. External assistance

In the two cases studied in depth, there was some type of external assistance. In both cases there was some type of financial assistance and some type of public sector involvement. The latter was much more active and decisive in the case of wood.

The whey IS network received various types of assistance. The project was promoted by the Argentine Industrial Union (UIA) and received technical and financial assistance from the National Scientific and Technical Research Council (COFECyT). The latter is a decision-making body made up of the respective science, technology and innovation departments of the federal and provincial governments; it evaluates technology transfer projects to the productive sector and finances them through direct subsidies (non-refundable contributions) for up to 70 per cent of their investment cost, subject to compliance with certain guarantees and eligibility conditions (COFECyT 2021).

The wood waste network was, by contrast, actively promoted by the public sector. The provincial government of Corrientes actively participated in the planning and assembly of the actors involved. At the same time, the bioenergy generation company BENG received financial assistance from the Federal Government through the RenovAr programme, while its financing was coordinated by a consortium of banks in which public and development banks participated. From a technical point of view, the contribution of knowledge by the foreign company that owns and operates the plant can also be seen as assistance. Finally, it should be mentioned that the sawmill ASR1 reported that the IS network received assistance from the public provincial bank.

6.6.4. Human resources

The labour skills demanded by IS networks are varied. At an operational level, they only require knowledge of the process and/or the waste, calling for skills such as driving vehicles, collecting and preparing material, loading, bundling, palletizing and unloading. However, more highly trained profiles are also required, such as chemical, metallurgical, electronic and industrial engineers, specialized workers, and managers and professionals specializing in environmental and IS issues.

The companies surveyed did not report any difficulty in finding the workforce skills required for the IS tasks in the country. There are no special requirements and almost all the labour is local, with the exception of a few professionals hired from other locations.

In the case of sawmills, the expansion effect of IS replicates the demand for current job skills. In general terms, employers point to the need for worker versatility and flexibility and for companies to save costs in uncertain environments, rather than to techno-productive issues. The rotation of workers between different positions highlights the low specificity of many of the occupations, especially at the first stage of innovation.

The sawmills ASR1 and ASR2 show similar results, indicating that the required skills are from trades that already have a presence in the country. However, they highlighted a lack of skills specifically linked to waste exchange and the difficulty of finding local labour, which is why they had to hire personnel from other parts of the country.

According to specialists, the greatest difficulty lies in finding professionals with the skills to match waste supply with demands. These are difficult skills to codify, transmit and acquire – although they are the kind of skills that could be supplanted by technology.

Similarly, a deficit of interdisciplinary management profiles has been identified. IS requires management and economic analysis skills that include environmental and social issues and expertise in properly valuing initiatives.

6.7. Factors of success and failure in productive job promotion

Success factors for promoting industrial symbiosis (IS) include:

- Good coordination between participants in IS networks. Information transparency and coordination of decisions between different actors are important to ensure that the expansion is simultaneously convenient for all parties concerned.
- Economies of scale. The industrialization of whey is profitable only on a large scale; as such, to expand the reuse of whey, sufficient demand must be generated, which may imply, in turn, improving transportation infrastructure to expand the market area for whey powder. Market opportunities to expand IS in the wood waste network were also identified.

- Advertising and adjustment of the economic and social evaluation of these projects. In this way, private initiative in these projects is encouraged and public promotional resources are allocated more efficiently.
- Strengthening of municipalities. If municipalities had sufficient knowledge to promote the development of cooperatives engaged in economic activities involving waste, then the promotion of IS networks could be disseminated and state support brought closer to entrepreneurs, who have difficulty starting projects. Consequently, training and support for municipal authorities is required from higher levels of government.
- Focus on promoting investment by companies that will provide demand for waste. Public policies should focus more on addressing this link in the IS chain, which appears to be the most critical.
- Industrial parks. Given that IS-related synergies require proximity and involve the transportation of materials, the gathering of companies and relevant infrastructure in parks facilitates operations. The main attraction of parks for IS may be, in some cases, purely fiscal.
- Early involvement of all company workers. Generally, the promotion of this type of activity tends to concentrate on the owners of companies, whereas success is actually more dependent on adaptation of workers to new processes.
- A system that maps waste supply and demand and its characteristics. In Argentina, cases arise more often in response to specific needs and as a result of other informal contact networks. This is also reflected in the fact that existing cases of circular economy in the country involve large companies, rather than SMEs, which are less inclined to carry out corporate social responsibility activities.

Obstacles to overcome for the development of IS include:

- Logistics (electric transportation infrastructure, transportation inadequacies, especially short-distance and mountain transportation, housing and urban infrastructure) and access to marketing channels.
- Labour and logistical problems for sawmills. The municipality does not have a sufficient workforce, so it must resort to neighbouring towns. In addition, the workforce lacks the basic training necessary for operations, including primary education.
- Regulatory obstacles. There are laws that block initiatives, such as those intended to obtain platinum and palladium from recycling or the reverse logistics applied to waste oil. IS markets, in short, need clear and harmonized environmental regulations that operate across jurisdictions.

6.8. Conclusions

- Industrial symbiosis (IS) occurs in various sectors and locations in Argentina. More than 15 cases were identified in various provinces of the country, with various socio-economic characteristics.
- The impact of job creation in the two cases studied is 19 per cent in the case of whey and 52 per cent in the case of wood. In both cases, there is an export outlet for products of the scheme that functions in such a way that the process does not replace local consumption.
- The bulk of the quantitative impact is observed in the indirect effect. It is important to include the effects of IS in the generation of employment due to the flow of spending towards the value chain.
- The most successful and economically sound cases of IS involve the incorporation of technology.
- The results justify some scepticism as to whether the quality of jobs is enhanced.
- The job opportunities created by IS continue to marginalize vulnerable socio-demographic groups, such as women and people without secondary education. In fact, the results show that the intersection of both factors further reduces the chances of obtaining a job generated by IS.
- In terms of formality, direct job creation has in part lifted the majority of workers hired out of situations of informality. However, in terms of indirect employment, estimates show that IS increases gender and education inequalities with respect to access to formal jobs and, in the case of wood, directly eliminates formal female employment by changing the sectoral composition in the value chain.

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Industrial symbiosis networks and employment

in the South African informal sector

7

Kiera Crowe Pettersson
and Riaan Rossouw

7.1. Industrial symbiosis in South Africa and regulatory constraints

The national literature on the employment effects of industrial symbiosis (IS) in South Africa demonstrates a growing interest in such schemes as a means of fostering economic growth, improving workforce dynamics, and enhancing environmental sustainability (Govender 2017). The studies reviewed by Govender emphasize how IS can create new job opportunities, promote skills development, and contribute to the socio-economic advancement of local communities. However, challenges related to policy design and implementation, collaboration and logistics must be addressed in order to fully leverage the employment generation benefits of IS in the country (O'Carroll et al. 2017).

Studies such as O'Carroll et al. (2017) have argued that supportive policies and subsidies designed to incentivize collaborative initiatives and resource-sharing can significantly amplify the "triple bottom line" (social, environmental, economic) effects of IS. Conversely, the absence of clear policies, along with regulatory barriers, may hinder the growth of IS initiatives and limit their ability to generate employment opportunities. The relevant challenges and constraints posed by the regulatory landscape in South Africa are as follows:

1. **National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008).** This law is aimed at promoting efficient and effective waste management in South Africa. However, it lacks specific provisions that address IS explicitly. This may create uncertainties and challenges for industries seeking to formalize IS relationships involving waste exchange and resource-sharing.

2. **National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014).** This amending legislation introduced the concept of extended producer responsibility and the requirement to have waste management plans in place for specific waste streams. Although the new concept is intended to encourage industries to take responsibility for their waste, it may not adequately address the complexities and benefits of IS, where waste from one industry becomes a valuable resource for another.

3. **Water Services Act, 1997 (Act No. 108 of 1997).** This law regulates water use and water pollution control. However, it does not contain specific provisions for the exchange and reuse of water among industries, which are essential aspects of IS. A lack of clear guidelines on water-sharing may discourage businesses from exploring IS opportunities.

4. **National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004).** This law focuses primarily on air pollution control, emissions standards and atmospheric impacts. While it addresses emissions from individual industries, it may be said to neglect the potential for collective reduction of emissions that can be achieved through IS arrangements.

5. **Lack of interdepartmental coordination.** The formalization of IS requires coordination among various government departments responsible for waste management, water, air quality and industry regulation. The lack of such coordination, and more generally of a holistic approach, may lead to conflicting regulations and create challenges for businesses seeking to engage in IS relationships.

6. **Incentive mechanisms.** The regulatory environment in South Africa may not provide sufficient incentives to encourage businesses to adopt IS. Financial and non-financial incentives, such as subsidies, tax benefits, grants and recognition, could drive greater formalization and participation in IS initiatives.

7. **Liability and risk-sharing.** The existing regulatory framework may not provide clarity on liability- and risk-sharing arrangements between the industries involved in IS. Any ambiguity on these matters may deter businesses from pursuing IS relationships because of the fear of potential legal and financial repercussions.

In a study of industrialization in Botswana and the United Republic of Tanzania, Mkwizu and Monametsi (2021) identified some challenges that are common to all countries in the region, including South Africa:

- **Policy implementation challenges.** The implementation of policies is often hindered by duplication of efforts and competing objectives. This is best exemplified by the Western Cape Industrial Symbiosis

Programme, where competition between public and private sector interests caused bottlenecks. This challenge was largely overcome through the establishment of public–private partnerships (EBRD, n.d.).

- **Governance challenges.** A poor level of participation by the private sector and limited accountability hamper governance in the industrial sector.
- **Energy supply constraints.** Frequent power shortages and load shedding are significant hindrances to industrial progress.
- **Low innovation.** Limited investment in research and development (R&D) and weak interlinkages between creative industries and R&D institutions pose innovation challenges.
- **Extensive informal sector.** The informal sector, which accounts for a substantial part of gross domestic product (GDP) in the region's countries, is often excluded from formal industrial strategies.
- **Skills gaps.** Mismatches between labour market demand and the skills offered by workers present additional challenges for industrial development.

7.1.1. Broad overview of existing industrial symbiosis networks

The Gauteng Industrial Symbiosis Programme (GISP) and the Western Cape Industrial Symbiosis Programme (WISP) are exemplary models of sustainable economic development in South Africa. While our primary focus lies on the impressive achievements under WISP, it is crucial to acknowledge the broader landscape of IS networks. According to Oguntoye et al. (2019), GISP accounts for around 10 per cent of total GDP in sub-Saharan Africa, or 7 per cent of the entire African continent's GDP. This confirms the significant economic potential arising from the introduction and expansion of IS initiatives in South Africa and across Africa as a whole (Madanhire and Mbohwa 2017).

WISP represents a sustainable economic development paradigm implemented in South Africa's Western Cape province. Launched in May 2013, WISP has sought to strategically tackle the rising costs of energy and other inputs encountered by businesses. It operates on a model of IS in which unused resources are repurposed in the operations of other entities, fostering a more circular and efficient economy. WISP is facilitated by GreenCape, a sector development agency specifically dedicated to advancing the green economy. GreenCape draws inspiration from the successful National Industrial Symbiosis Programme in the United Kingdom, adapting and implementing best practices to suit the

South African context. As a key player in the green economy, GreenCape actively promotes sustainable business practices, renewable energy and environmental resilience in the country. WISP encourages mutually beneficial links between companies from various industrial sectors, allowing them to share underutilized resources and reduce costs while operating more sustainably. WISP cuts across different industries and business sizes, with a team of facilitators working to identify potential synergies through workshops, meetings and industry events.

The success of WISP can be ascribed to meticulous planning and efficient execution. As shown in table 7.1, there were a total of 231 successful synergies between 2013 and 2023, comprising 81 "continuous synergies" and 150 "batch synergies".[1] These synergies, spanning industries such as textiles, food, manufacturing and electronics, have significantly contributed to waste diversion and generated economic benefits.

▶ Table 7.1. Key statistics for the Western Cape Industrial Symbiosis Programme, 2013–23

Outputs	Over ten years (2013–23)	Notes
Total successful synergies and connections	231	Synergies over ten years (2013–23); over the last two years, only introductions exceeding 100 tonnes per annum were tracked
Continuous synergies	81	Synergies that occur repeatedly
Batch synergies	150	Synergies that occur as a one-off between two companies
Waste diversion (tonnes)	139 685.00	–
Additional revenue (rand)	78 311 030.02	Additional revenue for the waste generator (through payment for the waste) or for the offtaker (through payment for removal of the waste)
Cost savings (rand)	55 996 238.51	Savings for the offtaker (as it does not have to pay for virgin material) or for the waste generator (as it does not have to pay for disposal)

1 Personal communication from Taahirah Ghoor, Senior Analyst, Circular Economy Programme, GreenCape, in the form of an email dated 24 August 2023 with the subject line "GreenCape – WISP dashboard for the last 10 years".

Private investment (rand)	20 832 259.00	Capital investment required to preprocess the waste for reuse
Total economic benefits (rand)	155 139 527.53	Sum of the three items above
Reduction of greenhouse gas emissions from fossil fuels (tonnes CO2e)	410 745.00	CO2e = carbon dioxide equivalent emissions
Reported job creation	126	Direct jobs (reported by either company in a synergetic relationship)
Inferred job creation	285	Indirect and induced jobs
Return on investment		
Ratio of economic benefits to funding	8.31	For every rand in funding, 8.31 rand in economic benefits is generated
Cost to create a job (rand)	45 425.79	–
Cost to divert 1 tonne of waste from landfill (rand)	133.66	–

Source: Personal communication dated 24 August 2003 from Taahirah Ghoor, Senior Analyst, Circular Economy Programme, GreenCape.

More specifically, the 231 synergies orchestrated by WISP in the decade after its inception in 2013 helped to divert 139,685 tonnes of waste from landfill, resulting in a substantial reduction of 410,745 tonnes in greenhouse gas emissions. Economically, in the same period, the programme generated over 155 million South African rand in benefits, including additional revenue, cost savings and private investments. This success translated into the creation of 411 jobs between 2013 and 2023, providing a fillip to the local community: 126 direct jobs, as reported by the companies involved, and 285 indirect and induced jobs.

A case study on the collaboration between EnviroServe and Combo Timber Structures within the WISP framework notes the creation of jobs in various areas related to wood remanufacturing and utilization of secondary products (Redflank 2021). The symbiosis between the two companies, centred on the remanufacturing of broken pallets into new usable pallets, has led to the creation of various roles related to wood processing and pallet production. In addition, further job opportunities are likely to arise from the repurposing of offcuts to make kennels and firelighters, for example. The overall impact of the collaboration includes

the creation of three permanent jobs in Combo Timber Structures to manage the increased volumes of wood. Although specific job titles and roles are not mentioned in this case study, it illustrates the potential for job creation across wood-related industries (including the creation of jobs in operational management) thanks to IS (Redflank 2021).

The programme's success is multifaceted and can be attributed to favourable government policies; collaboration with International Synergies, a network of diverse companies; and strong support from high-level stakeholders. WISP has played a crucial role in ensuring that carbon and resource-efficiency targets outlined in both national and Western Cape policies are met. However, among the challenges faced by the programme are the complexity of the regulatory framework, high transport costs and limited interest in alternative materials. These need to be carefully addressed, and robust public–private collaboration is required to pave the way for more seamless implementation of the programme. While celebrating the commendable achievements of WISP, it is important to recognize that attempts to introduce similar initiatives elsewhere in the country could run up against regulatory and infrastructural challenges.

▸ 7.1.2. Overview of industrial symbiosis in the South African textile and construction sectors

The textile and construction sectors, which play a pivotal role in South Africa's industrial landscape, have been major drivers of economic growth. However, they also face unique challenges, such as resource-intensive production processes, waste generation and compliance with environmental standards (Godfrey 2021). Given their significance, a thorough review of IS within these sectors is imperative.

In South African textiles, IS networks take shape through collaborative initiatives such as the training programme of The Clothing Bank (renamed Taking Care of Business in September 2022), which operates across multiple branches in Cape Town, Johannesburg, Durban, East London and Paarl. Under this programme, unemployed mothers are provided with training and access to discounted clothing that they can sell, resulting in profitable businesses and economic empowerment. In general, the geographical distribution of textile activities across the country's provinces suggests that there is considerable potential for regional IS, allowing local strengths and resources to be optimized for mutual benefit.

In the construction sector, IS networks are implicit in the employment dynamics, as the sector is notably reliant on large amounts of both formal and informal labour. Since provinces such as Gauteng and KwaZulu-Natal are central hubs for construction activities, there is good reason to believe that the strategic integration of industries there into IS networks can amplify synergistic benefits.

7.2. Methodology

This study employs a mixed methods approach, combining quantitative and qualitative methodologies to comprehensively assess the employment impacts of industrial symbiosis (IS) networks. The quantitative framework is informed by the research conducted by Abriata and Masut (2021) in Argentina.

The initial phase consisted of an extensive review of national and international publications and pertinent documents on IS in South Africa. The definition of IS advanced by Chertow (2000) was the guiding framework for evaluating existing cases. A detailed analysis of the Western Cape Industrial Symbiosis Programme (WISP) was conducted, focusing on both quantitative and qualitative dimensions of its employment effects. Special attention was given to discerning the mechanisms associated with job and enterprise formalization through IS.

Our methodology builds on the foundations laid by Martin and Harris (2018), incorporating elements from Kühnen and Hahn (2018), but also from Ibáñez-Forés et al. (2019), as exemplified in Ríos and Rodríguez (2021) for the case of Colombia. In estimating employment multipliers, we followed the approach outlined in Abriata and Masut (2021).

Primary data were collected using the following tools: (i) interviews with enterprise managers and representatives of employers' organizations; and (ii) surveys of individuals engaged in both formal and informal employment, covering various enterprises. The data were categorized by age and sex for clarity.

A key focus was on the questionnaire directed at informal workers, which sought to gauge the quality of their employment and identify any positive impacts of IS in terms of their formalization.

For the case studies, data collection involved remote and partially structured surveys. Three workers from the formal textile sector were interviewed, as were 13 workers from the informal textile sector. In the construction sector, eight informal workers were surveyed. The enterprise responses covered waste streams from two formal textile companies, one

informal textile company, one informal construction company and one formal construction company.

In addition to primary data, we supplemented our research with information and data from secondary sources. First, we used a national input–output table for South Africa based on 2022 prices, sourced from the consultancy firm Quantec in 2023.[2] This dataset was used to calculate coefficients related to intersectoral requirements and employment multipliers per unit of expenditure. Industry data were gathered from Quantec[3] and the South Africa Regional Explorer[4] of S&P Global Market Intelligence.

In assessing the qualitative dimension of job creation, we apply the same approach as Abriata and Masut (2021), which is based on a perspective of equal opportunities. The approach involves measuring the share of different socio-demographic groups in the employment change brought about by the IS scheme.[5]

The methodology used has several inherent limitations. First, it does not provide for a comprehensive or systematic examination of IS networks in South Africa. The surveys conducted as part of the case studies are not exhaustive either, as these networks comprise a far larger number of enterprises than those actually surveyed. In addition, there is a notable lack of data from worker or labour force surveys. Gathering such data was also challenging because of specific instances of force majeure during the data collection stage of the study. In particular, violent strikes and severe flooding in the Western Cape forced many workers (formal and informal) to stay at home in line with safety precautions. This meant that, when access was possible, many workers were making up for lost time and were therefore less willing to participate in the survey. Furthermore, it is essential to note that the accuracy of all computations of indirect effects relies on the aforementioned input–output table based on 2022 data, which is the most recent official record available for South Africa that offers the necessary sectoral granularity. Use of this table implies accepting its underlying assumptions, including the assumption of fixed proportions in production functions.

To meet the rigorous requirements of our methodology, we found it imperative to enhance the quality and quantity of the data beyond what was gathered from primary and secondary sources. This involved performing transformations and imputations on numerical data, and making inferences regarding responses that were either missing or deemed to be of suboptimal quality.

2 Specifically, from the Quantec EasyData Industry Service.

3 Specifically, from the Quantec EasyData Regional Service.

4 South Africa Regional Explorer: Geographic, Economic and Demographic Data.

5 For further details on the methodology used in this country study and on the study more broadly, see Crowe Pettersson and Rossouw (2024).

7.3. Survey results: Textile sector

7.3.1. A brief characterization of the textile sector

This characterization is based on the key statistics for the South African textile sector from 2018 to 2022, as summarized in table 7.2. The sector plays a significant role in the country's economy. In 2022 the sector's ratio of employment to output stood at 1.03, indicating a slight increase in output per employee compared with previous years. The ratio of remuneration to value added remained relatively stable, ranging from 47.28 per cent to 50.59 per cent in the period 2018–22, which suggests that a significant proportion of the value generated in the sector goes towards employee compensation.

Table 7.2. Key statistics on the South African textile sector, 2018–22

Year	Ratio of employment to output	Ratio of remuneration to value added	Remuneration per employee (rand)	Unit labour cost (index 2015 = 100)	Formal employment (no. of employees)	Informal employment (no. of employees)	Gross value added at basic prices (million rand, 2023 prices)
2018	1.35	47.28	145 487	114.42	86 481	21 903	26 819.15
2019	1.29	49.05	149 027	117.14	86 313	20 312	26 490.47
2020	1.21	50.59	151 044	121.61	75 506	15 083	22 839.62
2021	1.02	49.23	174 333	127.94	70 028	11 687	25 282.32
2022	1.03	48.80	181 970	136.56	71 231	15 377	27 322.81

Source: Quantec EasyData Industry Service.

Remuneration per employee increased significantly from 145,487 rand in 2018 to 181,970 rand in 2022. This suggests that employees in the sector have experienced an improvement in their earnings. However, it is essential to note that these data refer to both formal and informal workers.

The unit labour cost has steadily increased, with the cost of labour relative to output rising from an index of 114.42 in 2018 (the base year being 2015) to 136.56 in 2022. This may have implications for the sector's competitiveness.

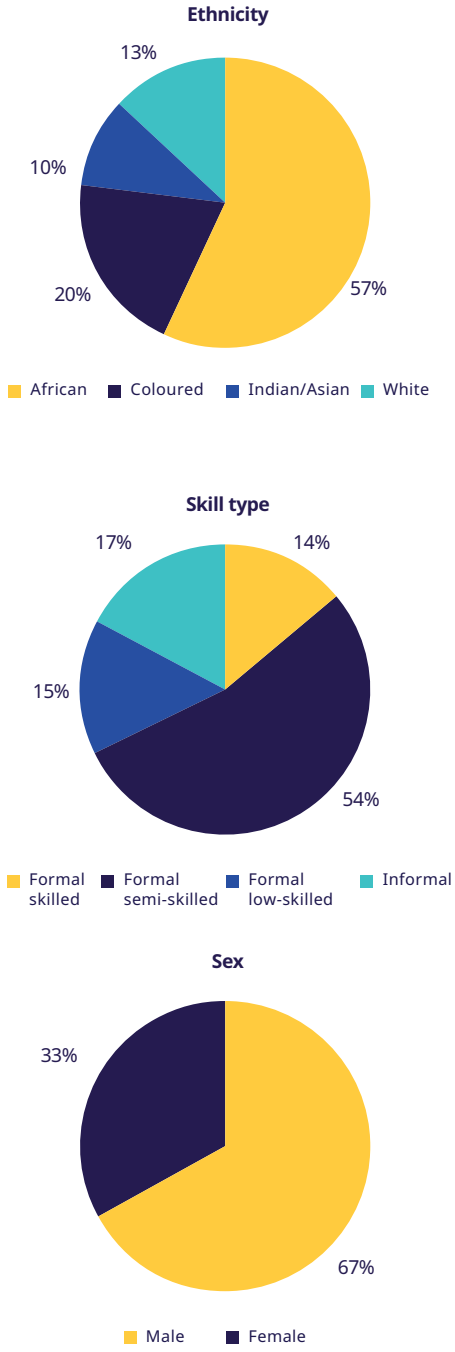
In terms of employment, the South African textile sector saw a decline in both formal and informal employment in the period 2018–22. In 2018 the total number of employees (formal and informal) was 108,384, but by 2022 it had fallen to 86,608. Formal employment also declined, dropping from 86,481 in 2018 to 71,231 in 2022. On the other hand, informal employment in the sector fluctuated, reaching its lowest point in 2021 at 11,687 employees, before rising to 15,377 in 2022.

Geographically, activities in the textile sector are distributed across various provinces. In particular, Gauteng is a significant hub for the sector, with gross value added at basic prices reaching 6.92 billion rand in 2022. This indicates that Gauteng makes a substantial contribution to the sector's overall economic output. Meanwhile, the Western Cape is the leading province when it comes to total employment in the textile sector. This could be due to the historical presence of the industry and the accessibility of resources in the province. KwaZulu-Natal follows close behind, likewise making significant contributions to the sector's employment landscape.

Furthermore, the data show that the textile sector has a relatively high concentration of formal employment compared with informal employment. Thus, in 2022, formal employment accounted for approximately 82 per cent of total employment in the sector.

Analysis of the employment distribution in the textile sector sheds light on the composition of the workforce (figure 7.1). In terms of ethnicity, workers of African descent dominate with a share of 57 per cent, followed by Coloureds at 20 per cent, Whites at 13 per cent and Indians/Asians at 10 per cent. In terms of skill type, 14 per cent of the sector's workforce are formal skilled workers, 54 per cent are formal semi-skilled, 15 per cent are formal low-skilled and 17 per cent are engaged in informal roles. Disaggregation by sex indicates that 67 per cent of the sector's workforce are male, while 33 per cent are female. As already mentioned, the textile sector leans towards a higher concentration of formal employment, which accounts for around 83 per cent of the total workforce.

Figure 7.1. Breakdown of employment in the South African textile sector by ethnicity, skill type and sex, 2022 (percentage)



Source: Quantec EasyData Industry Service.

Based on data from the South African Revenue Service Department of Customs and Excise merchandise trade database (2023), it is evident that the textile sector relies significantly on importing specific goods. Major imports include woven fabrics of synthetic filaments, woven cotton fabrics, synthetic staple yarn, cotton yarn, and woven fabrics of artificial and synthetic fibres. These imported goods contribute significantly to the production processes within the textile industry.

Furthermore, there was a consistent increase in the value of such imports between 2018 and 2022. This suggests a growing dependence on imported inputs in the production of textiles, clothing and leather goods. Demand for these imports is highest in the provinces of KwaZulu-Natal and Gauteng, but the Western Cape, the Eastern Cape and Mpumalanga also exhibit substantial import figures, reflecting the sector's widespread reliance on imported inputs.

Overall, the South African textile sector underwent some shifts in employment patterns and productivity between 2018 and 2022. Although remuneration per employee has increased, the sector is having to contend with rising labour costs. In addition, production activities are concentrated in provinces such as Gauteng, which plays a pivotal role in the sector's contribution to the economy.

▶ 7.3.2. An insight into the textile sector industrial symbiosis network

The industrial symbiosis (IS) network in the South African textile sector is characterized by a complex web of interactions. For formal workers, the IS relationships extend across different enterprises, each playing a distinct role in the sector's overall ecosystem. Table 7.3 summarizes the results of a survey conducted with three formal workers in the sector. The respondents brought a wide range of experience and skills to their current roles, in which they had been working from 16 months to 11 years. Their backgrounds are varied: the first had previously worked in an energy utility company, the second in a toyshop, and the third in the healthcare sector. They have transitioned successfully to their current positions, with two respondents now on full-time permanent contracts with additional benefits. Their roles have enabled them to use and develop interpersonal, communication and administrative skills, acquired through a combination of previous work experience, formal education and on-the-job training.

Table 7.3. Summary of responses to the survey of formal workers in the South African textile sector, September–October 2023

Respondent	T-F-A	T-F-B	T-F-C
Demographics	54; female; South African	38; female; South African	39; female; South African
Job tenure	16 months	11 years	4.5 years
Years in similar jobs	n/a	Not at a similar job; worked in retail	3 years
Previous work	Energy provider	Toyshop	Maternal health trust
Contract in previous job	Permanent employee	Standard permanent employment contract	Normal employment contract
Current contract	Manager, permanent position	Full-time permanent employment contract, with some benefits	Full-time permanent employment contract, with benefits
Skills used	Interpersonal, communication and administrative skills	Communication and people skills; delegation, problem-solving, crisis management	Strategy, vision, leadership, problem-solving, HR factors
Learning experience	Had prior administrative experience and interpersonal skills through church; learned system functions on the job	Developed communication and people skills through retail; other skills learned on the job with mentoring	Studied HR management and psychology; gained various skills through previous jobs
Job change cost	Relocation costs	No	Petrol costs for commuting
Job satisfaction	Yes	Yes	Yes
Treated well at work?	Yes	Yes	Yes
Monthly earnings	Not specified	22 000 rand	Not specified
Enough to live on?	Yes	No	Yes

Grants or assistance	No	No	No
Health insurance	Yes, privately	No	No
Support infrastructure (equipment, etc.) is adequate?	Yes	Yes, with room for improvement	Yes, proactive management
Working hours (daily, weekly)	Standard	7–8 hours per day, 5 days per week	7.5 hours per day, 5 days per week
Leave days	21 days	22–23 days	22–23 days
Sick days	Not specified	Not specified	n/a
Easy to take sick leave?	Very much so, more than 3 days requires doctor's note; Friday or Monday requires doctor's note	Yes, with doctor's note for more than 3 days	n/a

Note: n/a = not available; HR = human resources.

With regard to the costs involved in changing jobs, one respondent had incurred relocation expenses, another was facing commuting costs, and the third had not encountered significant costs. All three respondents were satisfied with their current position and felt well treated at work. As for remuneration, one respondent earned 22,000 rand a month; this allowed her to support her family, though she noted the high cost of living. Another believed that she could earn more in the corporate sector, given her qualifications and experience. None of the respondents received extra grants or government assistance. Responses on health insurance were mixed, with one respondent having private insurance and another expressing a desire for health insurance to be included in the benefits package. All agreed that their equipment was adequate but that it could be improved. The work schedule was typically 7–8 hours a day, 5 days a week, with 22–23 days of annual leave and flexible leave policies. Sick leave generally required a doctor's note to justify absences lasting more than 3 days.

The results of the survey of informal workers in the South African textile sector are summarized in table 7.4. The IS network in this sector involves a diverse range of individuals engaged in various types of informal work, from selling clothes to beadwork, often facilitated through programmes such as Taking Care of Business (TCB), a non-profit company that equips aspiring entrepreneurs with skills and resources to unlock their full potential. These individuals contribute to the network by providing goods and services, often reaching customers through various channels such as taxi ranks, social media and word of mouth. Experience levels vary, with some participants having been in their current job for just a few months and others boasting 3 years or more of experience. Significantly, many have transitioned from formal to informal employment, adapting their job roles and skills in the process.

Entrepreneurial skills are prominent among the individuals surveyed: these include problem-solving, market awareness, creative thinking, bookkeeping and time management. These skills were either pre-existing or honed through the TCB programme, for example. Start-up costs and equipment needs are diverse: some individuals required only a minimal investment, while others had to purchase a significant amount of equipment or rent spaces. The incomes earned by participants in the network are crucial to enable them to support their families; some also receive government grants. Job satisfaction levels vary, with some participants enjoying their work, while others face challenges and are treated poorly. Sick leave policies are not uniform: some respondents reported working despite being ill, while others had to rely on family support in such situations. A common aspiration among the participants is to grow their businesses, which involves, among other things, aiming for more stable selling spaces, acquiring additional equipment and being able to offer a wider range of products.

▶ Table 7.4. Summary of responses to the survey of informal workers in the South African textile sector, August–October 2023

Respondent	T-I-A	T-I-B	T-I-C	T-I-D	T-I-E	T-I-F
Demographics	21; male; South African	33; female; South African	45; female; South African	38; female; South African	39; female; South African	40; female; South African
Job tenure	1.5 years	2 years, 4 months	3.5 years	2 years, 9 months	1 year	1 year
Previous work	Spaza shop	Graduate of TCB programme; informal seller of clothing, shoes, snacks and food at Nyanga taxi rank	Had not been working for years before joining TCB; was unemployed and very depressed	Ambassador for TCB programme; informal clothes seller in Delft, through WhatsApp and Facebook; formerly at Woolworths	Enterprise Development Lady under TCB programme; clothes seller near Mfuleni taxi rank; street cleaner under Expanded Public Works Programme	Participant in Remake programme at TCB; clothes seller in Strand; cleaner at City of Cape Town
Contract in previous job	No	No	Yes, one-year full-time contract	Yes, casual permanent employee	Yes, one-year full-time contract	Yes (full-time permanent)
Skills used	Driving	Entrepreneurial skills, problem-solving, market awareness, creative thinking, bookkeeping, time management	Sewing, business skills, market awareness, interior decoration, fashion	Record-keeping, people skills, market awareness, finding new customers	Entrepreneurial skills, money management, saving, separating business and personal life	Fashion, sewing, business, people skills
Learning experience	Used earlier savings to learn how to drive; found someone to teach him	Had some entrepreneurial skills before, learned more at TCB	Started sewing in school, learned more at TCB	Had entrepreneurial skills before, learned more at TCB	Learned about business and saving at TCB	Basic sewing; learned advanced sewing, business, quality

T-I-G	T-I-H	T-I-I	T-I-J	T-I-K	T-I-L	T-I-M
35; female; South African	36; female; South African	37; female; South African	42; female; South African	42; female; South African	39; female; South African	36; female; South African
1 year	5 months	1 year	1 year	3.5 years	7 months	2.5 years
Participant in Remake programme at TCB; clothes and beads seller on WhatsApp, Facebook and at a public market next to police station in Kraaifontein; sometimes works as a hairstylist when other business is slow; previously selling to friends and family	Participant in Remake programme at TCB; clothes seller primarily in local neighbourhood in Nyanga and through WhatsApp; helped mother with clothing business	Participant in Remake programme at TCB; clothes seller in local community in Crossroads and at church; sometimes baking work at the end of the month if not enough money made selling clothes; community care worker for those living with tuberculosis and HIV/AIDS	Participant in Remake programme at TCB; clothes seller in local community (Khayelitsha) and at different markets; unemployed (stay-at-home mother)	Participant in Remake programme at TCB; clothes seller in local community (Khayelitsha); community care worker for those living with tuberculosis and HIV/AIDS	Enterprise Development Lady at TCB; clothes seller to passers-by at a stand in Mfuleni; uses WhatsApp and word of mouth to advertise and market the clothes; her children also help with this; sometimes sells at markets organized by TCB; domestic worker in private homes	Graduate of TCB Business Resell programme; seller of clothing, food (primarily meat) and homeware from home and sometimes door to door in local neighbourhood, among church members and via social media; cleaner (1 day a week); occasionally provides assistance in sister's clothing business
No	Yes (3 months)	Yes (full-time permanent)	No	Yes (full-time permanent)	No	No
Business skills, people skills, quality management	Sewing, business skills, customer care	Fashion, sewing, business skills, planning and saving, customer care, proactivity, discipline	Sewing and pattern making, technical knowledge of sewing machinery and equipment, financial skills, quality management, creativity, confidence, people skills, customer care	Fashion, sewing, business skills, planning and saving, customer care	Creativity, marketing, financial management, confidence	Financial and entrepreneurial skills, continuous business expansion, product variety, "know your customer", market awareness, creativity, fashion
Had basic sewing skills, learned more at TCB	Helped mother with clothing business, learned more at TCB	Acquired basics at Learn to Earn, gained more advanced skills at TCB	Acquired basics at Learn to Earn, gained advanced skills at TCB	Acquired basics at Learn to Earn, gained advanced skills at TCB	Learned about business and self-esteem at TCB	Familiar with business from sister, gained advanced skills at TCB

Start-up costs	700 rand for driver's licence	Bought a gazebo/metal stand for 1 800 rand; rents space at Nyanga taxi rank for 350 rand a month	80 rand a month for spot at Mfuleni taxi rank	350 rand a month for renting spot at Nyanga taxi rank	80 rand a month for spot near Mfuleni taxi rank	Started with little capital, received fabric donations
Job satisfaction	Unsure	Yes, but challenging	Yes	Yes, but challenging	Yes	Yes
Treated well at work?	Yes	Yes	Yes	Yes	Yes	Yes
Support infrastructure (equipment, etc.) is adequate?	Owns light truck for work; hopes to own car eventually	TCB provided support, but she had not properly appreciated its importance before graduating; TCB offered extensive assistance, including life coaches and counsellors	No sewing machine – relies on TCB equipment; after graduation, limited to weekly shopping; planning to buy own sewing machine; desires more men's clothing for daily sales	Wishes to have gazebo and permanent container in the future; needs a greater and better supply of men's clothing	Wants gazebo and steady supply of in-demand clothing; currently reliant on TCB equipment	Does not have a gazebo or shelter; would like to be able to buy in bulk and have a more steady and reliable supply of in-demand clothing
Working hours per day	9–11 hours	6–7 hours	6–8 hours	6–7 hours	6–8 hours	8–10 hours
Working days per week	Mon–Fri	Every day	5–6 days	5–6 days	5 days	5–6 days
Type of waste	Doors and windows from old houses	None	Repaired clothing	None	Repaired clothing	Repaired clothing
Customers buying waste	Various locations in the north	Customers at Nyanga taxi rank, malls, passers-by	Customers at Mfuleni taxi rank, residents in Gugulethu	Customers in Delft, Nyanga taxi rank, WhatsApp, Facebook	Customers near Mfuleni taxi rank, residents in Mfuleni	Customers in Strand, Somerset West

Taxi fare for transport	None, used existing resources	500 rand for sewing machine	None, used existing resources	50 rand a month for spot at Khayelitsha taxi rank	Only taxi fare for transport	No start-up capital needed
Yes	Yes	Yes	Yes, loves the work	Yes	Yes, loves the work	Yes, but challenging
Yes, treated well at TCB and in her business; only problem is that people in the community like to buy on credit	Yes	Yes	Yes	Yes	Challenging; some customers bargain or steal	Some customers try to lower prices
Needs a gazebo and more variety in products	Saving for overlocker; currently using small sewing machine	Saving for cover seam machine and overlocker	Wants permanent stand or gazebo; greater availability of men's clothing	Saving for cover seam machine or plain machine	Needs a gazebo; greater availability of men's clothing	Graduates need more support; needs gazebo
Varies depending on orders	6–7 hours	5–7 hours	7 hours	7 hours	4 hours	4 hours
Varies depending on orders	6 days	7 days	4 days	4 days	4 days	Varies
None	None	Fabric offcuts, old clothes	None	None	None	Clothing from TCB, meat from wholesaler, cake crumbs
Customers through WhatsApp, Facebook, public market in Kraaifontein	Customers in Nyanga, church members, WhatsApp	Community in Crossroads, church members	Community in Khayelitsha, markets, malls	Community in Khayelitsha	Passers-by in Mfuleni, social media, referrals	Neighbourhood, church members, social media

Pricing of waste sold	100–200 rand	2.5 times cost price	At least 2.5 times cost price	At least 2.5 times cost price	At least 2.5 times cost price	2.5 times cost price
Income shared with anyone?	No, uses employer's truck	Supports family (four brothers, three children)	Supports family (four children, three grandchildren)	Supports family (four children)	Supports family (four children)	Supports family (husband, two children, extended family)
Daily earnings	Around 500 rand	300 rand on average	700–800 rand	250–1 000 rand	700–800 rand	700–1 000 rand
Enough to live on?	Not really	Too little	Yes	Not enough	Yes	Yes
Grants received	No	Two children receive grants	None	One child receives a grant	None	None
Sick leave policy	Works unless very sick	No	Necessary to report and provide proof of sickness; someone helps with selling when she is unwell	At TCB, reporting is mandatory – cannot stay at home; doctor's certificate required for medical appointments; if she is sick and cannot sell, this is accepted	Daughter covers stand for her if unwell; proof of sickness required for TCB absence; non-compliance results in a one-week shopping ban	Report and bring certificate for TCB absence; no sales when too sick; husband helps with social media; teaching nieces about business, but it is unsafe for them to go out into local neighbourhoods

Note: TCB = Taking Care of Business.

Varies depending on item	At least 2.5 times cost price	At least 2.5 times cost price	At least 2.5 times cost price	At least 2.5 times cost price	2.5 times cost price	At least 2.5 times cost price
Supports child, niece, husband	Supports family (mother, children)	Supports children, nephew, sister	Supports children (aged 13 and 9 years), nephew, sister	Supports two children and one nephew, mother, sister	Supports five children; husband is unemployed	Supports family (husband, children)
800–1 500 rand	500 rand (cash) + 2 000–2 300 rand (credit)	1 000 rand (cash) or more	200 rand on an average day, 500 rand on a good day	1 000 rand or more	200 rand on average	Varies (80–700 rand)
Not enough, but improving	Not enough, but at least something	Not enough	No, though she is earning more than before; would like to be able to afford a house of her own and a car	Too little	Not enough	Business goes up and down
None	None	Yes, three government grants for children	None	Yes, three government grants for children	None	None
Report and update management when sick; husband helps when possible	No back-up plan when sick; husband can help if available	Necessary to report and show doctor's note if sick; husband helps when possible	No back-up plan when sick; husband can help deliver orders	Necessary to report and provide doctor's note if sick; husband can help with deliveries	Necessary to report and provide proof of sickness; children help with advertising	No back-up plan when sick; children help with business

7.4. Survey results: Construction sector

7.4.1. A brief characterization of the construction sector

The following discussion is based on the key statistics for the South African construction sector from 2018 to 2022, as summarized in table 7.5. The construction sector is a cornerstone of the country's economy, with substantial influence over both employment and economic output. In 2022 the sector exhibited a promising increase in the ratio of employment to output, signalling a potential growth trajectory. This suggests a favourable outlook for the construction industry in the coming years. Moreover, the stable ratio of remuneration to value added indicates efficiency in converting inputs into value-added output, reflecting the sector's robust performance.

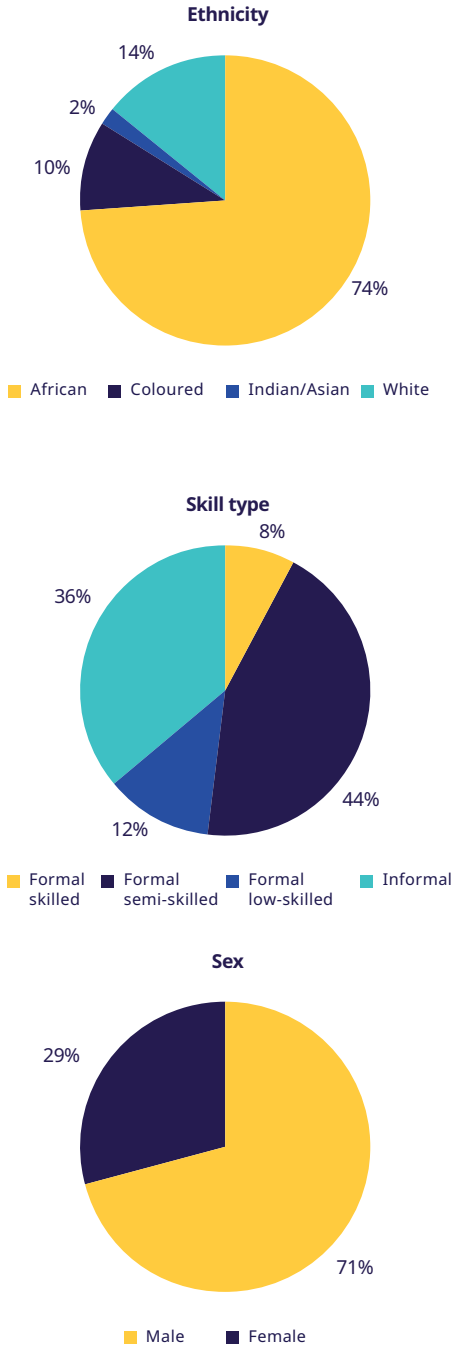
Table 7.5. Key statistics on the South African construction sector, 2018–22

Year	Ratio of employment to output	Ratio of remuneration to value added	Remuneration per employee (rand)	Unit labour cost (index 2015 = 100)	Formal employment (no. of employees)	Informal employment (no. of employees)	Gross value added at basic prices (million rand, 2023 prices)
2018	2.08	61.38	172 117	121.63	522 159	299 839	163 385.12
2019	1.95	60.99	159 174	125.58	556 116	228 779	165 682.24
2020	2.00	64.19	152 228	129.30	569 204	283 036	137 623.82
2021	1.78	63.35	161 823	135.98	613 392	337 707	142 387.82
2022	1.81	62.47	156 269	142.84	630 267	381 534	146 599.82

Source: Quantec EasyData Industry Service.

The construction sector is a major driver of employment in South Africa, its workforce numbering over 1 million individuals in 2022. The sector has a diverse demographic composition (figure 7.2). In terms of ethnicity, a majority of workers (74 per cent) are of African descent, followed by Whites at 14 per cent, Coloureds at 10 per cent, and Indians/Asians at 2 per cent of the total construction workforce.

Figure 7.2. Breakdown of employment in the South African construction sector by ethnicity, skill type and sex, 2022 (percentage)



Source: Quantec EasyData Industry Service.

The employment distribution by skill type reveals a hierarchical structure within the construction workforce, ranging from formal skilled workers to formal semi-skilled and low-skilled workers. Formal employment accounts for 64 per cent of the total workforce, highlighting the importance of skilled roles within the construction sector. Specifically, formal skilled workers comprise 8 per cent of total employment in the sector, while formal semi-skilled and low-skilled workers account for, respectively, 44 per cent and 12 per cent of the total. At the same time, informal employment, which accounts for 36 per cent of the construction workforce, contributes substantially to the overall employment landscape, reflecting the sector's adaptability and the existence of diverse roles that fall outside the formal structure. In terms of gender distribution, male workers make up 71 per cent of the construction workforce, while female workers account for 29 per cent.

Gauteng and KwaZulu-Natal are the leading provinces in terms of driving employment and output in the construction industry. With over 281,000 individuals employed in the sector, Gauteng emerges as the most influential region in this regard, followed by KwaZulu-Natal, which has more than 127,000 construction workers. Provinces such as the Northern Cape and the Free State have comparatively smaller construction sectors, reflecting their lower population densities and urban development levels.

The sector exhibits a diverse employment landscape that encompasses formal and informal workers. While formal employment offers stability and social protections, informal employment provides flexibility, albeit without such safeguards. Informal labour contributes significantly to the sector, with over 380,000 individuals participating in informal construction activities in 2022.

Notably, there is a great disparity in remuneration between the two categories of workers. In 2022 formal employees received an average remuneration of 156,269 rand, while their informal counterparts received considerably less – an average of 17,964 rand.

▸ 7.4.2. An insight into the construction sector industrial symbiosis network

The insights gained from analysis of employment patterns in the construction sector and its contributions to the economy offer a valuable framework for understanding the potential dynamics of industrial symbiosis (IS) networks, specifically among the informal workers surveyed for this study. A case in point is the IS relationship between local builders and suppliers of construction materials. In this network, both formal and informal workers play a crucial role as end users and collectors of waste materials. Builders benefit from a cost-effective source of construction materials, such as doors and windows, while waste collectors have access to a steady supply for their recycling efforts.

Analysis of the survey responses of informal construction workers, summarized in table 7.6, sheds light on the contextual factors that may be contributing to the observed difference in remuneration. For instance, respondent C-I-A, a 21-year-old South African man, operates in the construction sector as a secondary job while managing a spaza (a small unofficial shop): the flexibility and part-time engagement pursued may be behind the lower daily earnings that he reported. Respondent C-I-B, a 28-year-old Zimbabwean man, transitioned from his uncle's business to informal construction, illustrating the diverse backgrounds of informal workers. Respondent C-I-D, a 35-year-old South African woman, had a previous contract as a street cleaner with the City of Cape Town and engaged in sewing and business activities. Her lower daily earnings may be influenced by her practice of sharing income with her children, affecting her overall earnings. Additionally, the variable nature of her work may contribute to fluctuations in income.

Furthermore, the cases of workers such as respondent C-I-E, a 36-year-old South African man, and respondent C-I-F, a 39-year-old South African man, who are able to draw on their past experience in a shipping company and a security firm, respectively, highlight the influence of prior skills on the type of work undertaken in the informal construction sector. Significantly, the daily earnings of respondent C-I-G, a 22-year-old Malawian man who engages in various tasks related to collection, sorting and driving, demonstrate the potential for income variability within the sector.

The respondents in the survey came from diverse backgrounds and brought varying levels of experience to their current roles, ranging from newcomers to those who had worked for many years in various fields, including teaching and security work. Their skills were often acquired on the job or through informal training, as in the case of respondent C-I-C, who independently taught himself business management for his startup, or that of respondent C-I-B, who was able to apply record-keeping skills learned from his uncle. The start-up costs for these workers varied significantly, with some, such as respondent C-I-D, incurring minimal expenses, while others, such as respondent C-I-C, had to make a significant investment in materials and infrastructure.

The workers generally expressed job satisfaction, valuing the opportunity to work and achieve economic independence, despite facing challenges such as safety concerns, the need for better equipment and customer-related issues. Their incomes are highly variable, ranging from 100 to 8,000 rand per day, and many share their earnings with family members. Some also receive government grants for additional financial support. Support networks play a vital role, especially at times of sickness, when some workers have family members or colleagues to cover for them, while others, such as respondent C-I-G, rely on industry connections for replacements.

▶ Table 7.6. Summary of responses to the survey of informal workers in the South African construction sector, September–October 2023

Respondent	C-I-A	C-I-B	C-I-C	C-I-D	C-I-E	C-I-F	C-I-G
Demographics	21; male; South African	28; male; Zimbabwean	54; male; Zimbabwean	35; female; South African	36; male; South African	39; male; South African	22; male; Malawian
Job tenure	1.5 years	6 years	About 20 years	1 year	3 years	8 years	3 years
Previous work	Spaza shop	Uncle's business	Teacher	City of Cape Town (street cleaning)	Shipping company	Security company	Farming
Contract in previous job	No	Not formally employed	Yes	3-month contract	Yes	Yes	No
Skills used	Driving	Record-keeping	Business management	Sewing, business skills	Warehouse work, material collection	Security duties	Collection, sorting, driving
Learning experience	On the job with guidance	Learned from uncle	Started from scratch with savings	Learning at TCB	Similar to previous job	Experience in same field	Basic knowledge from farming
Start-up cost	Approx. 700 rand for licence	No initial cost	Initial materials cost (not specified)	Only transport costs	No specified initial cost	No	Purchased small car with brother
Job satisfaction	Satisfied, but unsure about future	Satisfied, but finds job challenging	Satisfied; busy but glad to be able to help his family	Enjoys the work, but has some safety concerns	Content with work	Satisfied, but has some safety concerns	Aiming to grow his business
Treated well at work?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Support infrastructure (equipment, etc.) is adequate?	No ownership of vehicle	Needs more computers	A new truck would help	Wants more machinery	May need a forklift	Safety equipment needed	Some equipment upgrades desired
Working hours	9–11 hours per day, Mon–Fri	7–9 hours per day, 5 days per week	12 hours per day, every day	7 hours per day, 5 days per week	10 hours per day, 5 days per week	Varies (up to 12 hours per day)	Varies (2–12 hours per day)
Type of waste collected	Doors, windows, etc.	Mostly timber	Doors, windows, etc.	Sells sewn items	Wood, tiles, etc.	Various construction materials	Woodchips, sawdust
Customers buying waste	Local buyers	Local carpenters	Local buyers	Community members	Builders, renovators	Builders, homeowners	Local community members
Pricing of waste sold	100–200 rand	100–1 500 rand	100–200 rand	100–300 rand	Varies by item	Not specified	20 rand/kg
Income shared with anyone?	No	Yes, shared	Yes, income is for family	Shared with children	Yes, shared	Yes, shared	Yes, shared
Daily earnings	Approx. 500 rand	Approx. 520 rand	Variable (up to 8 000 rand)	Variable (up to 400 rand)	Approx. 800 rand/day	Approx. 800 rand/day	Up to1 600 rand/day
Enough to live on?	No	Yes	No	No	No	No	No
Grants received	No	No	No	Yes, children receive grants	No	No	No
Sick leave	Continues working unless very sick	Yes, some pay cuts	Yes, but still works when sick	No response provided	Yes, seeks replacements	No response provided	Yes, seeks replacements

Note: TCB = Taking Care of Business.

7.5. Quantitative impact of industrial symbiosis on job generation

In certain instances, adjustments were necessary to address gaps and limitations in the survey data and the responses collected. This involved making inferences and using responses to related questions as proxies to perform accurate calculations.

The findings of this study demonstrate a notable positive quantitative impact of industrial symbiosis (IS) on job generation, as summarized in tables 7.7–7.10.

As shown in table 7.7, the overall impact of IS on job creation in South Africa's textile and construction sectors is notable. In the textile sector, while the IS network did replace 110 existing jobs, it led to a significant net increase of 605 jobs due to the substitution effect, which refers to the creation of new jobs resulting from the utilization of waste materials. While the activity effect, which refers to job creation stemming from increased economic activity within the sector, also contributed an additional 107 jobs, the dominant factor in the overall 25 per cent increase in total employment between 2018 and 2022 was the substitution effect. This highlights the economic potential of IS in generating new employment opportunities by repurposing waste materials in this sector.

Table 7.7. Impact of industrial symbiosis on total job creation in the textile and construction sectors, South Africa, 2018–22

Waste stream (type of company)	Textiles	Construction
No. of jobs replaced	110	26
Base employment	2 851	2 071
No. of jobs created through substitution effect	605	514
No. of jobs created through activity effect	107	57
Total impact (% increase)	25%	28%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

The construction sector experienced a similar trend, with the substitution effect creating 514 new jobs, significantly outweighing the 26 jobs that were replaced. The activity effect also played a substantial role, adding 57 jobs due to the increased economic activity associated with construction and infrastructure development. The combined impact of both effects resulted in a substantial 28 per cent increase in total employment during the same period. This demonstrates the positive influence of IS on employment generation in the construction sector, driven primarily by the substitution effect but also supported by the inherent job creation potential of the industry itself.

In both sectors, the substitution effect, stemming from the processes involved in repurposing waste materials, proved to be the primary driver of job creation. This highlights the economic potential of IS to generate new employment opportunities and contribute to overall economic growth in South Africa.

7.5.1. Direct effect

The IS networks in the textile and construction sectors in South Africa have been found to have a notable direct impact (table 7.8). In the textile sector, the IS network replaced 110 jobs in the base scenario, resulting in a base employment of 457 individuals. In this case, the substitution effect led to the creation of 84 direct jobs, while the activity effect added a further 18 direct jobs to the workforce. IS increased total employment in the textile sector by 22 per cent between 2018 and 2022.

Table 7.8. Impact of industrial symbiosis on direct job creation in the textile and construction sectors, South Africa, 2018–22

Waste stream (type of company)	Textiles	Construction
No. of jobs replaced	110	26
Base employment	457	319
No. of jobs created through substitution effect	84	26
No. of jobs created through activity effect	18	2
Total impact (% increase)	22%	9%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

In the construction sector, the direct impact was also significant. With 26 jobs replaced, the base scenario yielded an employment base of 319 workers. The substitution effect added 26 direct jobs to the workforce, while the activity effect contributed an additional 2 positions. IS led to a 9 per cent increase in total employment in the construction sector between 2018 and 2022.

7.5.2. Indirect effect

The positive indirect impacts of IS within the textile and construction sectors are evident, as indicated in table 7.9. The changes in production processes and increased overall activity translate into heightened expenditures along the value chain, subsequently leading to the creation of additional jobs. In the baseline scenario for the textile sector, the initial employment stands at 1,264 individuals. The substitution effect contributed an extra ten indirect jobs, complemented by an additional four positions through the activity effect. Consequently, IS brought about a 1 per cent increase in indirect employment between 2018 and 2022. These newly created indirect jobs in the textile sector encompass diverse activities throughout the value chain, such as weaving and the manufacture of cushions and carpets using collected waste materials.

Table 7.9. Impact of industrial symbiosis on indirect job creation in the textile and construction sectors, South Africa, 2018–22

Waste stream (type of company)	Textiles	Construction
No. of jobs replaced	–	–
Base employment	1 264	489
No. of jobs created through substitution effect	10	9
No. of jobs created through activity effect	4	13
Total impact (% increase)	1%	4%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

For the construction sector, the impact is also notable. With no specific number of jobs replaced provided, the base scenario yielded a base employment of 489 workers. The substitution effect added 9 indirect jobs, while the activity effect contributed an additional 13 positions. IS thus resulted in a 4 per cent increase in indirect employment between 2018 and 2022. The indirect jobs created in the construction sector are linked to specific activities along the value chain, such as the salvaging of materials, the collection of demolition waste and various other construction-related tasks.

7.5.3. Induced effect

The induced effect is a straightforward extension of the direct and indirect effects. It encompasses the additional jobs created as a result of increased economic activity generated by the initial employment boost. More specifically, the induced effect reflects the way in which an expanded demand for goods and services leads to further job opportunities across various sectors (table 7.10).

Table 7.10. Impact of industrial symbiosis in the textile and construction sectors on induced job creation in all sectors, South Africa, 2018–22

Waste stream (type of company)	Textiles	Construction
No. of jobs replaced	–	–
Base employment	1 129	1 264
No. of jobs created through substitution effect	511	480
No. of jobs created through activity effect	85	42
Total impact (% increase)	53%	41%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

In the case of the textile sector, the survey conducted and the approach used do not allow us to calculate the number of individuals replaced. The base employment stood at 1,129 workers. The substitution effect led to the creation of 511 induced jobs, while the activity effect contributed an additional 85 positions. This translates into a significant 53 per cent increase in induced employment between 2018 and 2022. The surge in textile demand as a result of IS triggers an economic cascade. The textile industry experiences heightened production and increased employment, with wholesalers playing a pivotal role in efficient distribution of the textiles. Retailers benefit from the upswing, witnessing increased sales and employment. The transport sector is in high gear, ensuring seamless logistics. Beyond the immediate players, companies in diverse business areas also enjoy heightened demand, highlighting the interconnected nature of industries. IS relationships thus foster economic growth as the induced effect weaves together the fortunes of the textile, wholesale, retail and transport sectors.

Similarly, in the construction sector, our methodology does not allow calculation of the number of individuals replaced. However, the base employment stood at 1,264 workers. The substitution effect here resulted in an impressive 480 induced jobs, while the activity effect contributed an additional 42 positions. This translates into a substantial 41 per cent increase in induced employment between 2018 and 2022. The construction sector's upswing reverberates across diverse industries. Mining experiences heightened demand for materials such as coal, iron ore and non-metallic minerals, leading to increased extraction activities. Manufacturing sees a surge in various outputs, from wood and paper to chemicals and metal products. Transport services thrive with the increased movement of construction materials. Wholesale and retail trade benefit from the construction sector's expansion, reflecting its central role in supply chains. By creating induced jobs in such sectors as agriculture, mining, manufacturing and services, the IS network's impact extends beyond direct construction-related activities and can help to promote a robust economic ecosystem.

7.6. Qualitative impact of industrial symbiosis on job generation

7.6.1. Composition effect

To further analyse the impact of industrial symbiosis (IS) on job creation, we examine the associated composition effect, using an approach similar to that of Abriata and Masut (2021), with a focus on equal opportunities. This involves evaluating the share of various socio-demographic groups in the employment changes resulting from IS. The qualitative indicators for the direct employment effects are based on measuring the proportion of women, individuals without secondary education, and women without secondary education in the total number of jobs created or destroyed. Since induced job creation operates primarily through consumption, we considered it less pertinent to analyse the composition of induced employment changes, which are expected to reflect the existing socio-demographic composition in the absence of IS.

Analysis of the employment effects of IS networks in the South African informal economy, specifically focusing on the provinces of Gauteng and the Western Cape, reveals notable disparities between the textile and construction industries (table 7.11). In the textile sector, a striking 87 per cent of the total jobs created or destroyed as a result of the implementation of IS were held by women. Moreover, 21 per cent of these positions were filled by individuals without a secondary education, which suggests that IS is an inclusive approach that provides opportunities for those with lower educational attainment.

Table 7.11. Composition of employment changes generated by industrial symbiosis in the textile and construction sectors; and characteristics of the regional labour market (Gauteng and Western Cape), 2022

Direct and indirect job creation	Textiles	Construction
Share of women in the total number of jobs created or destroyed	87%	31%
Share of individuals without secondary education in the total jobs created or destroyed	21%	0%
Share of women without secondary education in the total jobs created or destroyed	17%	0%
Characteristics of the regional labour market	**Gauteng**	**Western Cape**
Share of women in regional unemployment	47%	49%
Share of individuals without secondary education in regional unemployment	20%	17%
Share of women without secondary education in regional unemployment	9%	9%

Source: Authors' calculations based on the methodology of Abriata and Masut (2021).

The impact of IS on employment dynamics in the construction sector was quite different. Only 31 per cent of the total jobs created or destroyed were held by women, suggesting a comparatively low level of female participation in the workforce influenced by IS in that sector. Significantly, no jobs were created or eliminated for individuals without a secondary education in the construction sector, which may indicate that higher levels of education or specialized skills are required in that field.

To contextualize these findings, table 7.11 also provides some relevant information on the broader regional labour markets of Gauteng and the Western Cape, specifically on the proportion of unemployment in each province accounted for by women and individuals without a secondary education.

In summary, the findings presented here highlight the transformative impact of IS networks in the South African informal economy, particularly in the textile sector, where a substantial increase in employment opportunities for women and individuals without secondary education was observed.

7.7. Conclusions

- Industrial symbiosis (IS) networks have a positive impact on informal jobs and enterprises, giving rise to cases where individuals have been able to acquire valuable technical and entrepreneurial expertise.
- While such positive effects as stable employment, skills acquisition, job satisfaction and adequate remuneration through IS manifest themselves clearly, it is not so easy to identify the impact of IS on the formalization of informal jobs.
- The textile and construction sectors provide compelling narratives of how interconnected business relationships can pave the way for job creation and facilitate a shift from informal to formal economic activities. This is best exemplified by the Taking Care of Business (TCB) programme, which provides skills training supported by the application of IS in practice.
- While those enrolled in the TCB programme receive business training which could potentially lead to formalization, many participants still continue to operate their microenterprises informally. This shortcoming could be addressed through policy and regulatory changes.
- Our modelling suggests that, during the period 2018–22, the textile and construction sectors registered, respectively, a 25 per cent and a 28 per cent increase in employment generation as a consequence of IS.
- Given that informal workers account for 37 per cent of the construction sector's workforce, and given also the stark difference in average remuneration between formal and informal construction workers (156,269 rand versus 17,964 rand), it is essential that the government intervenes to promote formalization of the sector.

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Industrial symbiosis in developing countries

and productive job creation

Maria Sabrina De Gobbi

8.1. Introduction

The same research questions and themes presented in the Introduction to this volume were addressed in each of the country chapters, bringing different perspectives and instructive findings on specific issues. The following sections present and discuss emerging themes on the employment effects of industrial symbiosis (IS) in developing countries, which will lay the groundwork for policy conclusions.

Section 8.2 refers mainly to section 1.2 in the first chapter of this volume and examines the origins of IS networks in the countries studied. It also refers to section 1.3 and describes different institutional frameworks and policies, highlighting those that are most conducive to IS in emerging economies. Key actors and supporting entities are also considered.

Section 8.3 focuses on the quantity of jobs that IS can create or retain and on new enterprises that are set up. Findings from the analysis of individual firms of all sizes and of value chains in different sectors are presented. Direct, indirect and induced jobs created are measured using the two methodologies described in section 1.10. Some considerations on employment-generating mechanisms are presented with reference to section 1.4.

Two separate sections are devoted to the quality of jobs created in IS networks. Section 8.4 explores different aspects of decent work and decent work deficits, considering indicators such as gender, type of jobs created (without time limit, fixed-term, temporary, etc.), wages, working hours, occupational safety and health at work, and work accidents. Section 8.5 refers to section 1.7 of the first chapter and deals with a different aspect of job quality that is particularly relevant in poor countries. It examines the formal and informal dimension of jobs and enterprises, emphasizing the situations where IS has positive effects on formalization.

Section 8.6, referring to section 1.8 of the first chapter, briefly explores barriers to and enablers of the establishment and development of IS networks in poor countries. Section 8.7 refers to section 1.9 and describes skills needed in IS activities. Section 8.8 describes the role that governments, both national and local, and the social partners should play in supporting the creation and development of IS networks and employment in emerging economies.

8.2. Origins of industrial symbiosis and institutional framework

In parallel with the cases of Kalundborg in Denmark and of the Styria region in Austria, it is possible to find industrial symbiosis (IS) networks that are spontaneously created in emerging economies. Mapping the Argentinian territory, over 15 IS webs were identified. In Costa Rica three large enterprises involved in IS exchanges were uncovered. In the United Republic of Tanzania the main sugar companies have spontaneously engaged in the recycling of waste and by-products. Even in Colombia, where a programme supporting IS exists, a spontaneously created IS network started by an anchor enterprise before the launch of the programme was identified.

In the Colombian case, two important factors that led to the spontaneous creation of an IS web are strong corporate environmental responsibility, in particular with respect to waste disposal, and the perceived need to obtain certification for meeting internationally recognized environmental standards. Findings from Argentina show additional reasons why enterprises may spontaneously set up IS networks, including the solution of a logistical problem and making savings in marginal costs.

Evidence from our research reveals that, in less developed economies, the first and second creation models described in section 1.3 prevail: as a matter of fact, IS networks in these countries are typically either self-organized or emerge from serendipitous network processes, or they are the outcome of facilitation by individuals or organizations. Top-down planning, as exemplified by the industrial parks found in industrialized countries, is not the only or the most common way for IS webs to develop.

Geographical proximity is a typical characteristic of IS in industrial parks. With the exception of the Argentinian eco-industrial forest park, none of the country cases presented in this volume are characterized in this way. More precisely, Argentina covers a vast territory and enterprises are spread over large areas and located at considerable distances from one another. The Tanzanian case described in Chapter 3 illustrates a sectoral approach where sugar companies are found in different regions of the country. In the other four country cases, firms along the value chain of an

anchor enterprise may be located at remarkable distances from the other firms involved in an IS web.

As indicated in table 8.3, the prevailing sector where IS networks are established is agriculture, which is the dominant sector in developing economies. The food industry, or agro-industry, is another relevant sector, closely linked to agriculture.

Findings from the self-organized network in Colombia confirm the conclusion reached by Neves et al. (2019), according to which spontaneously created webs are characterized by exchanges occurring between firms that are connected by pre-existing commercial links or that are part of the same value chain. This can also be seen in the case of the whey value chain in Argentina and in the Costa Rican and Tanzanian IS webs. It is when IS networks are stimulated by external entities that firms can establish IS relations with unknown businesses. Such new linkages are initiated by various programmes, as explained in table 8.1.

Table 8.1. External support to set up industrial symbiosis networks in some emerging economies

Country	Programme/ model name	Starting year	Entities involved	Role
Argentina	Eco-industrial forest park in Corrientes province	2015	Local government and private sector	Plans the eco-industrial forest park; provides funding
Benin	Songhaï Centre	1985	NGO started by Father Godfrey Nzamujo	Provides skills to become farmer, artisan or entrepreneur in the agro-food sector
Colombia	RedES-CAR	2013	Local government and Universidad de los Andes	Invites anchor enterprises and SMEs in their supply chains to participate; organizes workshops where members design IS projects; checks project implementation 6 months later
South Africa	Western Cape Industrial Symbiosis Programme	2013	NGO called GreenCape	Identifies potential synergies between companies of varying size and from different sectors through workshops, meetings and industry events

Source: ILO IS Research Project 2024.

In a few of the country studies considered in this volume, external entities or support programmes have initiated the establishment of IS webs. In Argentina and Colombia different forms of public–private initiatives have been set up to that end, whereas in Benin and South Africa an NGO has promoted a large IS model. This latter finding confirms that in Africa, more than in Latin America, external stimuli play a key role in setting up IS webs (Olayide 2015). Table 8.1 briefly presents the characteristics of these external entities and initiatives corresponding to the second type of IS model described in section 1.3 of this volume.

In some instances reported in Argentina, some private engineering micro-businesses offering environmental engineering services have played a pivotal role in identifying synergies and creating IS webs. This approach corresponds to the second model of starting an IS network as described in section 1.3.

As anticipated in section 1.6, the three Latin American countries examined in this book have adopted plans, strategies and policies to promote a circular economy. The mention of IS in such policies and strategies is sometimes only implicit, but in the case of Colombia and Costa Rica, for instance, specific measures fostering IS are described. South Africa and the United Republic of Tanzania have also adopted policies promoting a circular economy, even if the focus remains on waste management. Table 8.2 sums up such plans, strategies, policies and legislation.

▶ Table 8.2. Plans, strategies, policies and legislation for a circular economy

Country	Policy/strategy/plan/legislation	Year
Argentina	National Circular Economy Plan for Waste Management	2023
	Provincial Strategic Plan of Waste Management towards a Circular Economy	2023
Benin	Interministerial Order No. 136/DHAB (on solid waste)	1995
Colombia	National Policy for the Integral Management of Solid Waste	2016
	Green Growth Policy	2018
	National Strategy for Circular Economy	2019
Costa Rica	National Comprehensive Waste Management Plan	2016
	National Decarbonization Plan	2018
	National Circular Economy Strategy	2022

South Africa	Waste Act	2008
	Waste Amendment Act	2014
	National Waste Management Strategy	2020
United Republic of Tanzania	Environmental Management (Solid Waste) Regulations	2022

Besides a conducive institutional and policy framework, several different actors and entities can play a role in the development of IS networks. They can be classified under the following main categories, examples of which can be found in the six country studies presented in this volume:

- **Employers' organizations.** Such bodies can start and/or enhance dialogue between companies and seek government support for the development of IS networks. Employers' associations have been active in supporting the participation of companies in the RedES-CAR programme and the creation of an eco-industrial park in Colombia, and in planning and developing an industrial forest park in Argentina.
- **Employees and workers' organizations.** As indicated by Schwarz and Steininger (1997), informal contacts between employees are important in supporting the development of IS networks. Employees should be trained, especially in small enterprises where only the owner tends to be involved in IS activity. In large companies, trade unions could actively support this process.
- **International agencies.** International public sector institutions, such as UNIDO, UNEP and the World Bank, are examples of international agencies that provide technical support for the establishment of IS webs in developing countries. UNIDO is particularly active in the design and implementation of eco-industrial parks, for instance in Argentina and Colombia.
- **Associations and NGOs.** Some of these entities are linked to international organizations, such as the International Solid Waste Association or the World Business Council for Sustainable Development. The GreenCape agency in South Africa also falls into this category. Other associations or NGOs are organized at national or regional levels, such as the Argentinian Petrochemical Institute or the Songhaï Centre in Benin, which has regional coverage in Africa. Associations encourage enterprises to establish linkages and create synergies with other firms through IS networks to increase revenue through the generation of new activities and to improve their reputation and visibility.

- **Research institutions and universities.** These entities can provide very useful technical support by identifying IS linkages between companies and providing training, as is the case with the Universidad de los Andes. These institutions can gain companies' trust, encouraging them to share data on their production with other firms and then helping them achieve economic, environmental and employment gains.

8.3. Quantity of jobs created

As noted in section 1.2, the main knowledge gap that this book seeks to fill concerns the employment effects of industrial symbiosis (IS). This section and the two subsequent ones address the first research question mentioned in the Introduction, focusing on the quantitative and qualitative employment effects of IS. This section, specifically, deals with the quantitative employment impacts, considering the direct, indirect and induced jobs that IS can generate.

The article by Martins and Harris (2018) is one of the few publications dealing with the employment effects of IS with a methodology that can be replicated to assess the number of direct jobs created and retained through IS. The geographical scope of this article is a region in Sweden. The studies on Benin, Colombia, Costa Rica and the United Republic of Tanzania contained in this book describe an application of this methodology, used with some adjustments, in developing countries. Data were obtained through semi-structured interviews with enterprise owners and managers.

In general, with the exception of Benin, no direct job losses due to IS were reported. In Benin the start of the Songhaï Centre led to the loss of 17 jobs, and the retention of 138 technicians (30.80 per cent), 121 skilled agricultural workers (27.01 per cent), 60 service and sales staff (13.39 per cent), 48 artisans/workers (10.71 per cent), and 81 department managers, machine operators and office workers (27, or 6.03 per cent, in each of the 3 categories). Jobs retained are those that could be kept thanks to new IS-related tasks. The highest shares of retained workers in Benin have sector-specific skills and a lower mobility level. In the same Benin case, a total of 480 new positions were opened, which corresponds to 58 per cent of employment growth in the surveyed enterprises (table 5.2). As reported in table 8.3, a few jobs were also retained in Colombia. No information is available on retained jobs per enterprise for the other countries considered in this volume.

Table 8.3 summarizes the results on new direct jobs created, presenting data per surveyed company in Benin, Colombia, Costa Rica and the United Republic of Tanzania. The percentage indicates the share of new jobs generated through IS activities as a proportion of total employment in that enterprise.

Table 8.3. Direct jobs created and retained through industrial symbiosis in Benin, Colombia, Costa Rica and the United Republic of Tanzania

Country	Jobs created (per company)	Jobs retained	Percentage of IS-created jobs per company	Company size	Company sector
Benin	1	n/a	2	Medium	Agriculture
	1	n/a	100	Micro	Agriculture
	0	n/a	0	Small	Agriculture
	0	n/a	0	Small	Agriculture
	0	n/a	0	Micro	Agriculture
	0	n/a	0	Micro	Agriculture
	34	n/a	63	Medium	Agriculture
	12	n/a	300	Small	Agriculture
	1	n/a	33	Micro	Agriculture
	0	n/a	0	Micro	Agriculture
	0	n/a	0	Micro	Agriculture
	19	n/a	127	Small	Agriculture
	0	n/a	0	Micro	Agriculture
	0	n/a	0	Small	Agriculture
	2	n/a	200	Micro	Agriculture
	3	n/a	30	Small	Agriculture
	407	n/a	1 071	Large	Agriculture
	0	n/a	0	Medium	Agriculture

Colombia	0	0	0	Large	Agro-food
	3	4	30	Micro	Recycling (paper, glass, compost)
	10	12	2.5	Large	Manufacturing
	20	0	0.6	Large	Agriculture
	0	2	0	Large	Agriculture
	0	10	0	Large	Construction
	0	0	0	Micro	Agriculture
Costa Rica	11	n/a	1.1	Large	Agro-food
	9	n/a	1.7	Large	Construction
	36	n/a	0.7	Large	Agro-food
	2	n/a	150	Micro	Agro-chemical
	6	n/a	133	Micro	Agro-food
	12	n/a	60	Small	Agro-chemical
	12	n/a	117	Small	Agro-chemical
United Republic of Tanzania	88	n/a	4.6	Large	Agro-industry
	63	n/a	4.2	Large	Agro-industry
	97	n/a	2.2	Large	Agro-industry

Note: n/a = not available.

Although in absolute values the highest numbers of jobs are created in large companies, the impact of IS is certainly greater in micro and small enterprises. The median value of the share of new jobs in large firms is only 1.1 per cent, whereas it is 30 per cent in all the others grouped together.

A few micro and small businesses are set up specifically with the objective of recycling the waste and by-products of large anchor enterprises. The studies on Colombia, Costa Rica and the United Republic of Tanzania report the establishment of new micro-businesses to meet the recycling needs of large companies. Other microenterprises are set up to provide consulting services to identify IS linkages between firms. Table 8.4 provides detailed information in this regard.

Table 8.4. Plans, strategies, policies and legislation for a circular economy

Country	Number of new enterprises established thanks to IS	Type of activity
Colombia	1	Works with recycled plastic ribbons for construction
Costa Rica	4	n/a
United Republic of Tanzania	7	n/a

Note: n/a = not available.

The studies of Colombia, Costa Rica and the United Republic of Tanzania shed some light on the most effective employment-generating mechanisms as described in section 1.4.

In the enterprises surveyed in Colombia, increased revenue, cost reduction and new activities (waste collection, classification, screening and processing) are the leading sources of new IS-related jobs. In Costa Rica the employment-generating mechanism that is most effective overall for large companies is increased revenue. Savings and new activities/production lines are also mentioned, and research and innovation create jobs, especially for women. Transport and waste treatment, collection, classification and cleaning are the principal IS-related activities that generate employment. For smaller businesses, increased production, higher revenue and establishment of the firm are the principal sources of new IS-related employment. Waste treatment and transformation are the IS-related activities that generate the highest number of new jobs in this type of firm. In the United Republic of Tanzania, new employment is created when IS activities are labour-intensive. New plants have a high automation level and are less intensive in terms of employment.

Direct, indirect and induced jobs (defined in section 1.4) along a whole value chain were measured for Argentina and South Africa, using a methodology developed by Abriata and Masut (2021). Two value chains per country were selected. Table 8.5 summarizes the results for the selected value chains.

▶ Table 8.5. Percentages of direct, indirect and induced jobs created through industrial symbiosis for selected value chains in Argentina and South Africa

Country	Value chain	Direct jobs (%)	Indirect jobs (%)	Induced jobs (%)	Total impact (%)
Argentina	Whey	19	20	19	19
	Wood	44	67	50	52
South Africa	Textiles	22	1	53	25
	Construction	9	4	41	28

Note: The percentages presented here correspond to direct, indirect and induced jobs created through IS and are additional to those that were available without the introduction of IS; for this reason, the sum of all shares does not add up to 100 per cent.

Although employment growth rates differ depending on the value chain considered, it is notable that the overall employment impact of IS per value chain is at least about 20 per cent, which is the proportion of jobs that would not have been generated had IS principles not been applied. This finding supports the view that IS is stronger in its effect on micro, small and medium-sized enterprises along the value chain, and less strong in the case of large anchor enterprises, where the median value of the share of new direct jobs is about 1 per cent.

Table 8.6 describes the types of direct, indirect and induced jobs created through IS in Argentina and South Africa. It should be noted that for South Africa the jobs described are largely informal.

▶ Table 8.6. Types of direct, indirect and induced jobs created through industrial symbiosis for selected value chains in Argentina and South Africa

Country	Value chain	Direct jobs	Indirect jobs	Induced jobs
Argentina	Whey	Full-time staff treating waste and by-products; part-time staff for logistical tasks	Jobs in transportation, energy consumption, industrial inputs towards acquisition of goods and services, spending in plant construction, metal structures and machines	Jobs stemming from direct and indirect workers' economic activities and spending

	Wood	Staff for bioenergy plant, operating and maintenance of chipping machines in sawmills, transportation and internal logistics	Jobs for new equipment, its operation and maintenance, transportation, plant construction, personal services, supplies, wood extraction	As above
South Africa	Textiles	Clothes selling, beadwork, repairing clothing, collecting old clothes	Weaving and manufacture of cushions and carpets using collected waste materials; jobs in textiles, wholesale, retail and transport	As above
	Construction	Collecting doors and windows from old houses; timber, wood and tiles; various construction materials; woodchips, sawdust	Salvaging of materials; collection of demolition waste and various other construction-related tasks; jobs in extraction, wood, paper, chemicals and metal products; transport, wholesale and retail trade	As above

Clearly, the quantitative impact of IS on employment creation is positive: IS generates jobs. But what kind of jobs? Does IS create decent work?

8.4. Decent work: The quality of jobs created through industrial symbiosis

Findings from enterprise surveys in Costa Rica and the United Republic of Tanzania reveal that workers employed both in large anchor companies and in smaller firms which are part of industrial symbiosis (IS) networks are formally employed and enjoy social protection, indicating that jobs created through IS are decent. However, some decent work deficits can be identified.

First of all, positions created through IS are largely occupied by men, revealing a major gender issue in IS-generated employment. Particularly interesting are findings from Costa Rica, where it is possible to observe that women's presence tends to prevail in research and innovation positions and in informal waste-screening activities. In the latter case, women can perform this work in between their other tasks (Wittmer 2021). Balancing professional and private life is often extremely important for female employees, and the two types of profession mentioned above are more compatible with that priority. Jobs in research and innovation certainly offer better working conditions, but only large companies like those surveyed in Costa Rica have research and innovation centres. The majority of enterprises involved in IS networks are small or micro-businesses which benefit from new technology developed by anchor firms. These smaller enterprises make more use of informal work, as indicated by the high informal employment levels recorded along value chains. More generally, findings from Costa Rica show that women mostly occupy IS-generated administrative and technical positions.

Second, in the United Republic of Tanzania, more than half of workers (54.4 per cent), especially those in charge of waste picking, cleaning and screening, are recruited only temporarily. Other employees, who have higher skill levels in IS-created jobs, have permanent or one-year renewable contracts and higher salaries. Furthermore, while there are occupational safety and health policies that give workers some amount of training, accidents do still occur.

Daily working hours are generally within the limits established by national legislation in both Costa Rica and the United Republic of Tanzania. As far as

salaries are concerned, they are above minimum wage in large Tanzanian companies. In Costa Rica a certain degree of dissatisfaction in this regard is recorded among employees in small and micro firms along the value chain. In Benin, despite employment remaining largely informal even after the start of the Songhaï Centre and IS, an increase in paid annual leave was recorded, as well as better salaries. In the United Republic of Tanzania, unionization rates are fairly high, at 70–80 per cent where data have been disclosed, indicating a good level of social dialogue within these companies.

Further information from Costa Rica about the quality of IS-created jobs in small enterprises along the value chain shows that employees are satisfied with career development perspectives, work–life balance, work environment, working conditions, training opportunities and access to technology. Anchor companies may have a positive impact on anti-discrimination and inclusion policies, which is the case reported in one small firm.

Some direct jobs are green, particularly when they are generated to improve energy efficiency or renewable energy, as in the bioenergy plant in the Argentinian eco-industrial forest park, or to preserve the environment, as in the case of micro-businesses using compost to fertilize fields for further food production. In other cases, though, direct and indirect jobs may not be green, as, for example, in the transport sector, where we do not know what type of vehicles are used. This latter consideration suggests that geographical vicinity in IS webs would certainly be desirable.

To conclude, while there is clear evidence that IS-created jobs may bring workers improved conditions and other benefits, they are neither always decent nor always green.

8.5. Formal and informal dimension of jobs and enterprises

To continue the analysis of the quality of the jobs generated by industrial symbiosis (IS), let us now consider the extent to which these new jobs are formal. The most positive finding in this regard is the formalization of microenterprises, which happens when large anchor companies intend to collaborate with businesses which are initially informal. This particular kind of formalization is reported in the studies of Colombia, Costa Rica and the United Republic of Tanzania. In Costa Rica the informal status of

micro firms is perceived as a barrier to the development of IS. This finding can be linked to the fact reported in section 8.3 that some small and micro firms are set up to meet the needs of anchor enterprises. When this is the case, newly created businesses must be formal. As observed in Chapter 1, Ibáñez-Forés et al. (2019) posit that informal workers can be formalized through the creation of associations or cooperatives. It is not possible to know whether the micro-businesses that are set up in relation to IS networks are cooperatives, but in some cases they may well be, in particular if they group together waste pickers.

Starting from a thorough analysis of secondary data, the Argentinian and Colombian studies reveal that informality is widespread in recycling and IS activity. Furthermore, it is reported that informality is a largely women-dominated field. The Argentinian research shows that IS leads to higher levels of informality for women in direct IS-related jobs. Findings on indirect employment generated by IS reflect the sectoral employment situation at a regional level. This finding confirms that some decent work deficits do exist in IS networks, especially in micro-businesses and SMEs along the value chain of large companies and with respect to the gender dimension. Importantly, it is estimated that over 70 per cent of the direct employment generated by the Argentinian IS network on the whey value chain contributed to the formalization of workers who were previously informal or unemployed. Sadly, however, women did not benefit from this positive impact of IS.

The study of South Africa focuses on informal employment, in order to try and better understand linkages between IS and formalization. Informal work represents a large proportion of employment in the two selected value chains: 18 per cent in textiles and 36 per cent in construction. In the latter case, male workers form a large majority, and informal employees earn less than formal ones. In both value chains, informal workers may shift from formal to informal jobs and may keep an informal job as a secondary one thanks to the flexible arrangements available. Despite clearly identifying the characteristics of informal workers, the study does not highlight any particular linkage between formalization and IS.

The study of Benin concerns informal employment, as only 19 per cent of all surveyed enterprises are formal. This means that the large majority of jobs created through IS are informal. Engaging with the Songhaï Centre and hence with IS has not resulted in any positive change in terms of enterprise or job formalization. Improvements due to IS include better wages and paid annual leave.

Both the South Africa and the Benin studies reveal that skills acquisition is a positive effect of IS for informal workers and businesses, thanks to training provided by specific programmes in South Africa and by the Songhaï Centre itself in Benin.

8.6. Barriers to and enablers of industrial symbiosis and productivity in developing countries

Table 8.7 summarizes the barriers to and enablers of industrial symbiosis (IS) as described in the country studies contained in this volume. The categories of barriers and enablers are the same as in table 1.1.

Table 8.7. Barriers to and enablers of industrial symbiosis in developing countries

Category	Barrier/enabler
Economic	Availability of funding
	Costs linked to heavy and slow bureaucracy
	Economies of scale, including through easy and convenient transport within IS web
	Market opportunities
	Competition promoting or hindering innovation
Technical	Presence of anchor enterprise
	Fluctuating supply of waste and by-products
	Informal status of some micro firms due to lack of incentives to formalize by local or national government or by large companies
	Information system showing supply and demand of recycling opportunities
	Availability of infrastructure
	High energy costs favouring IS

Organizational	Knowledge about IS, including training
	Engaging employees in IS activities
	Building capacity of employees involved in IS activities
	Space (including public) to build trust between enterprises
	Dialogue between enterprises to seek IS relations
	Good coordination within IS network and transparent information-sharing
	Availability of qualified labour force in remote areas
Social	Recycling culture in society
	Disseminating information about IS webs to encourage other enterprises to start or join IS webs and for a more efficient allocation of public resources and incentives
Policy/ institutional	Special official appreciation of enterprises engaged in IS
	Support and presence of universities and research centres
	Support of environmental public authority
	Presence or absence of public policies and IS strategies
	Economic, fiscal, environmental and social incentives
	Legislation on eco-industrial parks
	Strengthening municipalities through IS training to provide more support for enterprises
	Public support for/investment in recycling enterprises
	Fiscal incentives linked to eco-industrial parks
	Conflicting regulations and lack of specific legislation on IS

Note: It is assumed that each obstacle has a corresponding enabler (and vice versa) and hence that the description of one leads to an understanding of the other.

Source: Yang et al. 2022; Sellitto et al. 2021; Neves et al. 2019; Morales et al. 2019; Lombardi 2017; Bacudio et al. 2016; Golev, Corder and Giurco 2015; Johnsen et al. 2015; Schwarz and Steininger 1997.

Comparing table 1.1 and table 8.7 provides interesting insights into IS in developing countries.

In the Economic category of table 8.7, costs linked to bureaucracy and building economies of scale in relation to transport refer to typical situations in the context of developing countries. They are not mentioned in table 1.1. In particular, as mentioned in section 8.2, geographical vicinity – which is a key element in economies of scale – is not a characteristic of IS in the country cases considered in this volume. Promoting eco-industrial parks, as suggested in the Policy/institutional category of table 8.7, may be a good solution to building economies of scale and achieving geographical vicinity.

In the Technical category of table 8.7, the informal status of some firms, the need to have a structured system to identify IS opportunities, and the cost of energy are different from the barriers/enablers listed in table 1.1. Informality is certainly a widespread phenomenon in developing countries, as discussed in section 8.5, and we have seen how anchor enterprises become crucial for the formalization of some microenterprises. The need for a mechanism facilitating knowledge of IS relations may be linked to the lack of geographical vicinity between companies or to weaker institutional support compared with advanced economies. Lastly, in less developed countries, energy is an issue, both when its cost is high and favours IS, as is the case in the United Republic of Tanzania, and when it is simply not available and causes sudden electricity cuts that disrupt production.

In the Organizational category of table 8.7, the emphasis is on training and capacity-building much more than in table 1.1, where the focus is more on innovation and research. In a sense, these different elements represent two extremes of knowledge: in developing countries the prevailing need is to learn basic IS skills, whereas in advanced economies the need is for sophisticated knowledge and new ideas.

In the Social category, the list of barriers and enablers in table 8.7 is much shorter and of a more general character than in table 1.1. Societies in developing countries are less familiar with the notion of IS than in advanced economies, and basic ideas about sustainable production and consumption models still need to be more widely disseminated.

In the Policy/institutional category, the two tables have many barriers/enablers in common, indicating that in both cases institutional and policy support is key to the development of IS, as has already been noted by Neves et al. (2019). Industrial parks seem to be much more of a requirement in the context of developing countries than in that of advanced ones. Furthermore, the emphasis on research is more typical of advanced economies, as has already been observed in the comments on organizational barriers/enablers.

8.7. Skills needed for industrial symbiosis and productivity in developing countries

Industrial symbiosis (IS) requires both high and low skill levels – both employees with no or very little formal education and those with advanced university and post-university degrees. From the semi-structured interviews conducted in Argentina, Colombia and the United Republic of Tanzania, it seems that the skills needed to develop IS are available in national labour markets and do not differ from those needed in traditional industries. Additional training or retraining are deemed sufficient to meet IS needs.

The low-level skills required are those of operational staff and workers deployed in waste screening and classification, materials collection and preparation, driving vehicles, and loading and unloading. The high-level skills profiles required are those of environmental specialists, digital developers who can enhance an IS network by facilitating contacts between enterprises, chemical, metal, electronic and industrial engineers, and experts in research and innovation. Some specialized workers are also needed, for example, for the design of industrial machines for waste treatment or for new, specific technologies.

Some core soft skills that are necessary include leadership, negotiation capacity and environmental management. These core skills are in line with those described by the ILO as required for industrial green restructuring (ILO 2019, 2021) and considered earlier in section 1.9. For worker retention, learning to learn – the ability to learn new skills and absorb new knowledge – seems particularly relevant. Interdisciplinarity is also very important, as the country study on Argentina confirms (Circle Economy 2021); this is especially so for managers and professionals with expertise in economic management, including environmental and social aspects.

As for training, it is often specific to a given task related to waste management within a company. For instance, sawmills in Argentina train their staff in charge of wood crushers and slipways maintenance through courses and external technical support. The three surveyed companies in Costa Rica organize both internal training and training provided by external experts. Training materials and manuals are used, referencing

good practices. One enterprise organizes trips abroad to benchmark successful cases. Furthermore, the three firms offer induction training on IS to all new employees.

In the cases of Benin and South Africa, training is one of the most important elements of IS programmes. In Benin skills in recycling to reach zero waste represent a key feature of the Songhaï Centre. Technical experts who are regular staff members train local trainers, while farmers, artisans and entrepreneurs receive some basic training and periodical skills updates. Basic skills for technical staff are available in the national labour market, while the Songhaï Centre provides complementary training. In the informal textile sector in South Africa, an international training programme of The Clothing Bank (renamed Taking Care of Business) in Cape Town, Johannesburg and Durban trains unemployed mothers in recycling clothes. Other surveyed informal IS workers who do not benefit from any training rely on their professional experience, formal education and on-the-job training to acquire skills.

8.8. Role of national and local governments and the social partners in support of industrial symbiosis and productivity

The actions that national and local governments and the social partners should adopt are specific to the national or local situation, as described in the different country studies. Nonetheless, it is possible to highlight some common elements determining the role that each of the stakeholders mentioned can play in supporting the development of industrial symbiosis (IS) networks and employment in general. Table 8.8 provides an overview of such functions, which should contribute to overcoming the barriers to IS identified in table 8.7.

▶ Table 8.8. Role of national and local governments and the social partners in fostering decent work through industrial symbiosis

National government	Local government	Employers	Workers
Set economic (especially fiscal), environmental and social incentives	Facilitate dialogue on IS between national government and the private sector in a region	Spontaneously set up IS webs	Engage in IS activities in micro, small and medium-sized enterprises
Establish a specific department/ office focusing on IS	Promote IS locally	Push for formalization of micro, small and medium-sized enterprises	Engage in IS activities through trade unions in large firms
Be more proactive in formalization of micro, small and medium-sized enterprises	Promote the establishment of a digital system with supply and demand for waste and by-products	Provide IS training to employees	Promote gender inclusion, job security and social dialogue from within companies
Provide adequate infrastructure	Solve issues on conflicting local regulations	Promote women's participation in IS jobs	
Develop IS policies and strategies	Provide IS training to municipalities to better support enterprises		
Promote legislation on eco-industrial parks	Set up a local system or body to monitor the performance of IS webs, including employment indicators with gender disaggregation		
Solve issues on conflicting national regulations			

Promote policies and measures encouraging women's participation in jobs created through IS
Set up a national system or body to monitor the performance of IS webs, including employment indicators with gender disaggregation, collecting data from local databases

Clearly, most measures that are relevant to the development of IS should come from the government, especially at a national level. This finding is in line with the list of items in table 8.7 and with the observation by Neves et al. (2019) that institutional/policy IS enablers are the most relevant of all.

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Conclusions

The preceding chapters have all contributed in different ways to answering the research questions outlined in the Introduction to this volume. The research findings allow some conclusions to be drawn.

Industrial symbiosis (IS) does create employment, especially in micro and small businesses along the value chain of large anchor companies. Increased revenue, cost reduction and new activities/production lines are the main sources of employment generation. Waste treatment, collection, classification and cleaning are the IS-related activities requiring the largest shares of additional labour. Direct, indirect and induced jobs are generated. Sometimes, IS leads to the establishment of new micro-businesses, which clearly further contributes to job creation.

As for the quality of work, IS-created jobs are neither always decent nor always green. Some direct jobs are green, in particular when they are generated to improve energy efficiency or renewable energy, as in the bioenergy plant in the Argentinian eco-industrial forest park, or to preserve the environment, as in the case of micro-businesses using compost to fertilize fields for further food production.

Work is decent in large enterprises, where employees are formally employed and enjoy social protection with often permanent contracts. Worse conditions tend to exist in the micro and small enterprises along the value chain of anchor enterprises, where informal workers can be found. IS does not seem to have any positive impact on the formalization of individual employees. It is a business-to-business model and does not deal with individual workers or waste pickers (Buda and Ricz 2023). However, in

Colombia, Costa Rica and the United Republic of Tanzania, cases have been reported where anchor firms impose the formalization of micro and small businesses along their value chain, offering examples of good practices of formalization mechanisms. In some cases, individual informal employees can be formalized if they join together, creating a business that can also be a cooperative (Ibáñez-Forés et al. 2019).

Another major decent work deficit concerns women's scarce participation in employment created through IS. Sometimes this trend reflects that of the sector where specific IS activities occur, but in other cases the reasons are not clear. Findings from Costa Rica indicate that research and innovation is the most effective IS employment-creating mechanism for women.

As far as barriers to and enablers of IS development are concerned, the most relevant ones pertain to the Policy/institutional category. Policies and strategies on IS and the circular economy are key drivers of IS development, as reported in Chapter 2 on Colombia. To implement such strategies and policies, it is important to take formal steps to adopt the instruments they may include, such as incentives for enterprises and eco-industrial parks legislation. Resolving existing conflicts between laws and regulations and, if possible, passing specific legislation on IS are equally relevant.

Other key factors to promote IS include sharing and spreading knowledge about it, building trust and dialogue between enterprises seeking IS relations, and providing IS training to relevant stakeholders.

Both high- and low-level skills are needed, and such skills seem to be present in national labour markets. Low-level skills are mainly those involved in collection, screening, classification and cleaning of waste and by-products. High-level skills are those of environmental specialists, digital developers who can facilitate contacts and IS exchanges between enterprises, chemical, metal, electronic and industrial engineers, and experts in research and innovation. Some soft skills, such as leadership, negotiation capacity and environmental management, are also required.

Additional training or retraining can be used to meet specific IS skills needs. Such training is often provided internally by large anchor companies. NGOs provide training for informal workers and micro and small informal businesses.

Some policy recommendations are suggested by the actions described in Chapter 8 that national and local governments and the social partners should take in order to foster the creation of decent work through IS.

Adopting a circular economy or industrial symbiosis national strategy or policy

Our research findings make it clear that industrial symbiosis (IS) creates jobs. It is therefore important to foster IS on a national level. From the country studies presented in this book, it appears that IS is more likely to thrive where there are national strategies or policies setting out supportive measures for its development. Of those considered, the milder policies are general ones on solid waste management, as in South Africa and the United Republic of Tanzania, where a circular economy is mentioned and IS is intended to be part of it. Specific circular economy policies, such as those adopted in Colombia and Costa Rica, are more likely to refer explicitly to IS and are therefore more desirable.

Such policies and strategies should be formulated in close collaboration with employers' and workers' organizations. In general, employers' representatives are involved in the design and adoption of institutional frameworks for a circular economy and IS, as in the case of Argentina and Colombia. Less evident is the involvement of workers' associations, which is equally important as the role of employees in IS activities is key, as already indicated by Schwarz and Steininger (1997).

Such policies fostering IS, including eco-industrial parks, should envisage adequate funding measures or mechanisms, and consideration should also be given to contributions from the private sector and foreign investments.

Setting incentives for industrial symbiosis activities

One measure that the stakeholders surveyed in the country studies feel should be adopted is economic or fiscal incentives. Recycling often requires enterprises to invest, for example, in new machinery for waste treatment, and this may raise concerns over lost competitiveness. Remedies are therefore desirable. Incentives may be included in national circular economy policies or strategies, as is the case in Colombia and Costa Rica. However, a policy or strategy that does not contain legally binding measures will require some follow-up legal action. The issue here is that incentives may well be mentioned in a circular economy strategy or policy, but the necessary legal follow-up process to make such incentives real and effective takes too long to implement or is not implemented at all. It is therefore imperative that national and local governments ensure that the necessary legal steps are quickly implemented and regulations formally adopted.

Promoting women's participation in industrial symbiosis activities and newly created jobs

As revealed by the research findings, decent work deficits are reflected in the poor participation of women in industrial symbiosis (IS) employment. This is linked in part to the sectors where IS usually takes place and where the presence of women is traditionally weak. In this case, more should be done by national and local governments to promote active labour market policies supporting women's employment, especially in targeted sectors, and by the social partners. In the latter case, employers' organizations should sensitize their members towards the recruitment of female employees, and trade unions should actively look for female members to support female employees from within companies.

Harmonization of legislation to foster industrial symbiosis

The country studies reveal that there are often legal uncertainties and conflicting regulations that may deter industrial symbiosis activities. Different regions of the same country may have different rules concerning waste and the environment, and in some instances conflicting regulations can be found within the very same region. National governments must act promptly to solve all these existing uncertainties and conflicting rules.

Promoting recycling and waste commercialization

Findings from Colombia show that the share of enterprises engaged in recycling and waste commercialization – used as proxies for industrial symbiosis (IS) – is very low (8.5 per cent and 2.7 per cent, respectively). It is not expected that proportions in other countries are much higher. There is ample scope for governments and the social partners to promote these economic activities through training and other awareness-raising events. The objective should be to sensitize civil society in general. The social partners should sensitize their own members through similar activities. Furthermore, governments and public institutions should collect precise data on IS in order to better promote it and its positive effects with regard to both employment and the environment.

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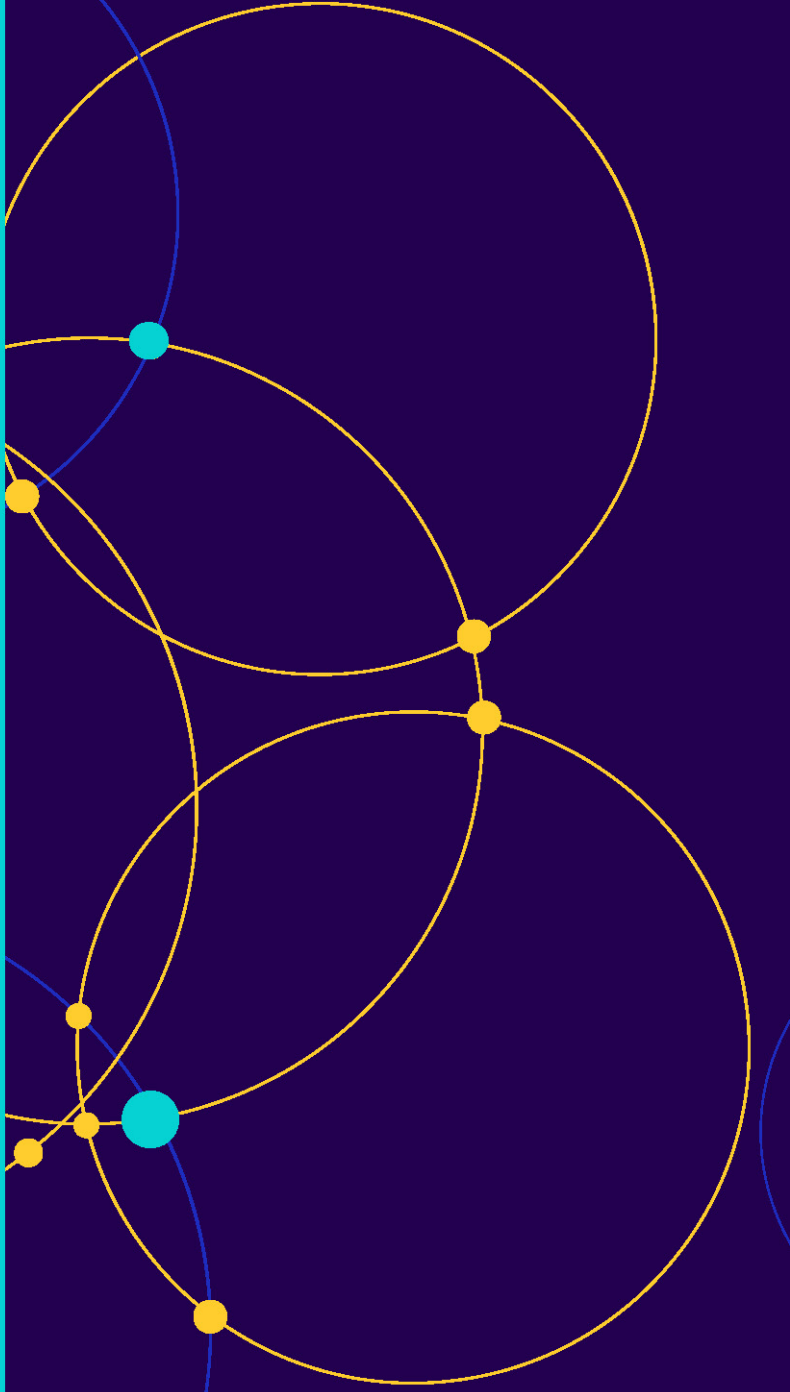

Contributors

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

ilo.org
International Labour Organization
Route des Morillons 4
1211 Geneva 22
Switzerland

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