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Designing regional industrial symbiosis networks: The case of Apulia region

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Abstract

Adopting industrial symbiosis (IS) is a key strategy for pursuing sustainable development and developing circular economy. In this regard, a powerful approach is promoting the development of regional business networks of IS relationships (ISNs), such as the well-known Kalundborg ISN in Denmark. Nevertheless, a formalized method supporting the development of effective ISNs at the regional level is still lacking in the literature and practice. This paper develops a methodology to support the design of regional ISNs, consisting of two steps: (1) building a waste-input relationship table, which can be used as a dictionary of the potential IS synergies implementable among couples of companies; and (2) identifying and selecting the potential symbiotic synergies that can be implemented among the companies belonging to a given regional area. The proposed methodology is tested for the case of Apulia region (Southern Italy), where more than 300 feasible IS synergies are identified. The method is useful both for companies interested to exploit IS benefits, and also for regional policymakers prone to develop IS in practice.

KEYWORDS
case study, circular economy, industrial symbiosis, industrial symbiosis network

1 | INTRODUCTION

Industrial symbiosis (IS) is a subfield of industrial ecology that engages separate industries in a collective approach to competitive advantage, involving physical exchange of materials, energy, and services (Chertow, 2000). Accordingly, materials, energy, and water generated as wastes by one production process can be used by other production processes instead of being discharged. Adopting such a practice, companies can reduce their production costs, thus achieving economic advantages, and generate environmental and social benefits for the entire collectivity (e.g., Jacobsen, 2006). For these reasons, IS is recognized as one of the best strategies to support the transition toward the circular economy (e.g., Govindan & Hasanagic, 2018).

To support the development of IS in practice, the European Commission explicitly recommends the establishment of Industrial symbiosis networks (ISNs) (European Commission, 2020; 2015). An ISN is a network of firms among which IS relationships exist (Fichtner et al., 2005). According to the 3–2 heuristic logic developed by Chertow (2007), an ISN is made up by at least three different firms exchanging at least two different types of waste. In ISNs, each company can be simultaneously involved in more symbiotic relationships with other companies. ISNs extend the concept of traditional supply chains because companies belonging to different industrial sectors (which might not cooperate in traditional business models) cooperate in the same network (Bansal & McNight, 2009; Geng & Côté, 2007; Herczeg et al., 2018; Jensen, 2016).

Industrial symbiosis networks are often characterized by a regional dimension (Domenech et al., 2019; Jensen et al., 2011; Taddeo et al., 2017; Vahidzadeh et al., 2021). Nevertheless, not many studies have specifically analyzed the regional ISNs and their effective design and application. One of the first contributions toward designing regional ISNs is provided by the National Industrial Symbiosis Network Programme (NISP) developed in the UK. Here, coordination bodies are in charge for identifying the potential symbiotic exchanges among the companies belonging to the region. According to Mirata (2004, p. 969), "Primary focus in addressing the informational issues, however, is placed on helping to identify complementarities among regional parties' needs and capacities that can form the foundations for collaborative partnerships. A major activity for doing this involves the analysis of the material, energy and water in- and out-puts of companies operating in the region, or that can potentially be based there. Such analyses help to uncover the possibilities for material exchanges, for cascading of energy and water, for development of more efficient and effective utility and waste management infrastructures, and for new businesses" (Mirata, 2004, p. 969). The key challenge for the success of this approach is to achieve information on the supply and (potential) demand of wastes into the region. According to Cutaia et al. (2014), who describe the case of the first ISN in Italy, this information can be collected by organizing plenary meetings among managers of companies located in the region, aimed at favoring the identification of potential symbiotic matches. However, they recognize the high difficulty in overcoming the distrust of companies in disclosing information regarding wastes produced and inputs required, since managers often repute them as highly sensitive. A further critical issue of this approach is the fact that "the participating companies can show more interest in offering their residues (outputs), rather than in demanding alternative inputs (e.g., waste to be used as raw materials) for their activities. This was certainly determined by the lack of knowledge, among the companies, on the technical chances to replace the supply of traditional raw materials with residues from other production cycles" (Luciano et al., 2016, p. 1013).

Despite the existence of regional initiatives and some studies, a consolidated methodology to support policymakers in designing successful regional ISNs is currently lacking (Vahidzadeh et al., 2021). One of the main barriers to the successful implementation of IS is still the knowledge of what symbiotic exchange can be employed based on the economic activities of a given region.

We thus propose a methodology to design regional ISNs aimed at overcoming this limitation. The method consists of two steps: (1) building a waste-input relationship table, which can be used as a dictionary of the potential IS synergies implementable among couples of companies; and (2) identifying and selecting the potential symbiotic synergies that can be implemented among the companies belonging to a given region. The proposed method is used to identify the potential IS synergies that can be implemented in the Apulia region, in South Italy.

The rest of the paper is organized as follows. Section 2 describes the theoretical background of the paper briefly presenting the features of the Regional ISNs and the main barriers to their implementation into practice. Section 3 describes the waste-input relationship table, as well as the procedure used to build such a table. Section 4 describes the procedure proposed to design ISNs at the regional level. Section 5 discusses the adoption of the proposed method in the Apulia region. The paper ends with conclusions in Section 5.

2 | THEORETICAL BACKGROUND

2.1 | Regional industrial symbiosis networks

Industrial symbiosis is considered a promising approach for the transition toward the circular economy, since it is able to reduce the environmental impact of production activities while creating economic advantages for companies (Jacobsen, 2006; Yazan et al., 2017; Yuan & Shi, 2009). In fact, one of the first driver motivating companies to explore the IS practice is the willingness to reduce their waste disposal costs and input purchasing costs (Esty & Porter, 1998). However, the operational costs to manage IS—that is, waste transportation costs, waste treatment costs, and transaction costs—erode the economic benefits achieved thanks to IS (Fraccascia et al., 2019). These costs arise at the level of IS relationships and have to be shared among the involved companies. In particular, the waste transportation costs drive the spatial level of IS relationships: in fact, IS relationships may arise among firms very distant from each other as far as they are economically convenient (Jensen et al., 2011; Lyons, 2007; Sterr & Ott, 2004). Nevertheless, geographic proximity is considered a potential facilitator for IS relationships because of economic (waste transportation costs are minimized when companies are in close proximity) and social issues (trust among companies might be enhanced) (Boons et al., 2017; Chertow, 2000; Tudor et al., 2007).

The network of firms among which IS relationships exist is referred to as IS network (ISN) (Fichtner et al., 2005). In ISNs, each company can be simultaneously involved in more symbiotic relationships with other companies. ISNs can be designed by using a top-down approach or, alternatively, emerge from the bottom, as the evolution of single IS relationships created between couples of companies. Examples of top-down ISNs are the eco-industrial parks, diffused in many countries such as China (Tian et al., 2014), South Korea (Park et al., 2016), Brazil (Elabras Veiga & Magrini, 2009). The ISN developed in the area of Kalundborg (Denmark) is the most famous case of self-organized ISN (Jacobsen, 2006; Jacobsen & Anderberg, 2005). Readers interested in deepening this issue are referred to a recent review by Neves et al. (2020).

The network dimension is beneficial for different reasons. First, companies belonging to an ISN gain additional advantages compared to operating single IS relationships, because they can easier exchange several wastes with multiple companies simultaneously (Jacobsen, 2006). This also may serve to enhance the economic feasibility of the symbiotic relationships, because of the higher quantity of waste available to be exchanged. Second, the network dimension facilitates, ceteris paribus, the match between supply and demand of wastes, which is considered as a key facilitator for IS because reduces the potential incentive misalignment among the companies[1] (Bansal & McNight, 2009; Fraccascia & Yazan, 2018; Herczeg et al., 2018). Furthermore, compared to single IS relationships, a network of IS relationships might also be characterized by higher resilience to disruptive events. Indeed, if one company producing/requiring a given waste decides to abandon the ISN, other companies producing/requiring that waste might exist into the network, available to maintain the waste exchange. Hence, the disruptive events would not correspond to the loss of the IS relationship. Readers interested in deepening the resilience of ISNs to disruptive events are referred to the following papers under brackets (Afshari et al., 2018; Ashton et al., 2017; Chopra & Khanna, 2014; Fraccascia et al., 2017; Kuznetsova et al., 2016; Li & Shi, 2015; Zhu & Ruth, 2013).

ISNs are often developed into a regional area (see the recent review by Vahidzadeh et al., 2021). Indeed, the regional dimension is considered to have an unique potential for the development of ISNs because allowing several advantages (Mirata, 2004; Sterr & Ott, 2004). First, companies can exploit the economic and social advantages of geographic proximity, which is considered one of the main facilitators for the adoption of the symbiotic approach (Chertow, 2000; Hewes & Lyons, 2008). In fact, companies located within the region are usually not much far from each other: this allows companies to pay low transportation costs for wastes and increases the chance of personal relationships among company managers. Second, the industrial region is usually characterized by a higher number and variety of companies than the industrial estate, and these companies are usually diverse enough, in terms of wastes produced and input required. Furthermore, a high level of redundancy might exist, that is, more than one company can produce/require the same waste. Ceteris paribus, these characteristics increase the chance to (quickly) find an appropriate partner. In fact, the diversity among companies (Korhonen, 2005) and the redundancy (Fraccascia et al., 2020) are recognized as important requisites for the IS practice and can also enhance the stability of the symbiotic network (Fraccascia et al., 2017). Third, regional areas might provide the necessary volumes of waste demand and supply to achieve the economies of scale required to ensure the economic profitability, which is a key driver motivating firms to implement the IS practice (Esty & Porter, 1998).

Furthermore, IS plays a critical role for regional development, since it can provide significative and positive contributions to the socio-economic status of the region, thanks to regional job creation and improved environmental performance at the regional level, in addition to the widely discussed economic advantages for companies (Ashton, 2009; Chertow et al., 2008; Kokoulina et al., 2019; Martin & Harris, 2018). Accordingly, several studies recently reported the rising number of ISNs at the regional level, especially in Europe (Domenech et al., 2019; Neves et al., 2020). However, facilitating the IS approach at the regional level is methodologically different from designing IS relationships at the inter-company level and, therefore, requires ad-hoc approaches, for instance specific policy measures (Paquin & Howard-Grenville, 2009; Vahidzadeh et al., 2021). Favoring the formation of effective ISNs is thus a priority for regional governments interested to fully exploit the opportunities coming from IS for sustainable development.

2.2 | Critical barriers to the development of effective regional ISNs

The literature has highlighted multiple barriers to ISNs formation and development at the regional level. They mainly include technical features, normative frameworks, and consumer behaviors. This section is not intended to be exhaustive of the topic but rather it would highlight the main barriers this paper contributes to overcome – for detailed information about the barriers to ISNs development, the reader is referred to Golev et al. (2015), Sakr et al. (2011), and Tudor et al. (2007), among the others.

Literature has highlighted that the formation and development of both top-down and bottom-up ISNs are limited by the lack of structured information on which companies located in a given region produce or require a given waste (Aid et al., 2017; Golev et al., 2015; Patricio et al., 2018). Although data about wastes are collected at a regional scale, companies are usually not prone to disclose information concerning the types and amounts of wastes produced and inputs required, since these are considered sensitive information and companies are scared that competitors would use them to their advantage[2]. Hence, identifying potential IS relationships becomes hard (Afshari et al., 2018; Boix et al., 2015; Yazdanpanah et al., 2019). This is associated with high transaction costs, especially due to the search for potential partners (Sterr & Ott, 2004). Furthermore, the lack of structured information contributes to exacerbating the mismatch between supply and demand of wastes, often indicated as a relevant problem. For example, within regional areas the demand for a given waste might exist but firms producing that waste might be not aware of it and vice-versa (Fraccascia & Yazan, 2018). As Golev et al. (2015, p. 150) highlight, "There is a need for more detailed environmental reporting for public interest, including regular summary reports for the whole area. The summary reports should include a database on existing waste streams in the area (and potentially future waste streams), also providing information on their current and possible reuse options. An agreed coordination mechanism (or body) for the environmental data sharing and analysis would help to facilitate this process.". Consistently, Sterr and Ott (2004) highlight the need of an information-sharing platform for inter-company communications.

A further critical variable concerns the legislation and regulatory frameworks. It may happen that they lack to be accordingly updated, failing to follow the speed of technological innovation and reducing the exploitation of symbiotic practices. In other words, a symbiotic exchange could be possible from a technical point of view, but could be not feasible in a given region due to the current legislation (Domenech et al., 2019). In this regard, legislation should not be limited to recognize the well-known waste reuse options, but also be open to the potential symbiotic opportunities (Golev et al., 2015).

3 | MATERIALS AND METHODS

The research was conducted following two main steps. First, we have carried a literature review collecting papers on IS practices and extrapolating information on the symbiotic exchanges in terms of waste exchanged, waste producer and waste user. Based on these results, we have built the waste-input relationship table of feasible IS exchanges. This table can be used as a dictionary of the potential IS synergies implementable among couples of companies. The procedure adopted to build the table is described in Section 3.1. Then, we have developed the methodology to design regional ISNs, which exploits the above-mentioned table to identify the potential symbiotic synergies that can be implemented among the companies belonging to a given region. The methodology is described in Section 3.2.

3.1 | Building the waste-input relationship table of feasible industrial symbiosis exchanges

From the technical point of view, IS relationship is established between two companies when a waste—for example, material, water, energy, heat—produced by a company (waste producer) is used to replace an input required by another company (waste user). Thus, any IS exchange can be described by means of three variables: (1) the waste exchanged between companies, (2) the company that produces the waste, and (3) the company that uses the waste.

Since the IS exchange requires that the waste produced is used in replace of an input, first it is needed to classify the feasible IS relationships on the basis of the current technological development. To this aim, we reviewed the literature to identify the possible IS exchanges, feasible from a technical point of view. Our goal is to develop a table of the current IS exchanges—that is, the waste-input relationship table of feasible IS exchanges—characterized in terms of the waste exchanged, the waste producer, and the waste user. This analysis is not intended to be exhaustive of all possible technical IS relationships but rather provides a current picture of most adopted IS practices. These are those where regional companies may find partners to carry out successful exchanges.

The wastes exchanged between companies are identified according to their European Waste Classification (EWC) code. Table A1 in Appendix A shows all the wastes identified from the above-mentioned literature review. Each EWC code is a 6-digit code combined in pairs: the first pair is called "chapter" and represents the general category that identifies the process that produced the waste (first column of Table 1), while the subsequent pairs allow a more precise identification of the waste type. The second column of Table 1 introduces a subcategory of wastes belonging to the "Chapter EWC code" on the same row; while the third column identifies the specific waste because it is reported the entire Code. For instance, considering the first row, the "wastes from stone working" have EWC Code 01.04.13. They belong to the subcategory 01.04 – wastes from chemical and physical treatment of nonmetallic minerals – that are included in the "Chapter" 01 – wastes from prospecting, mining, or quarrying, as well as from physical or chemical treatment of minerals.

Furthermore, wastes exchanged have been classified into five classes, corresponding to main resource categories characterizing IS: (1) metallic waste, (2) waste gas, (3) nonorganic waste, (4) organic waste, and (5) utilities. Table A2 in Appendix A shows the EWC codes for each of the above-mentioned category (please notice that the utilities, that is, cooling waters; wastewater, sulfur treated, steam, do not have a code according to the EWC).

The waste producers and the waste users have been classified according to the statistical classification of economic activities in the European Community (NACE). The NACE code is an alphanumeric combination that identifies an economic activity, whose format is made by one letter plus one to six numbers. The letter identifies the economic macro-sector while the numbers, from two to six digits (the higher the numbers, the higher the level of detail), represent the specific joints and subcategories of the sectors themselves. Table B1 in Appendix B shows the economic activities of waste producers and waste users that we have identified.

The full waste-input relationship table, developed based on the literature review, is characterized by 119 feasible matches and is depicted in Appendix C.

Table 1 shows part of the table built, for the sake of clarity. Each row of the table represents a feasible match between waste and input, thus suggesting an IS relationship between the waste producer and the waste user. The first two columns are related to the waste producer, showing (1) the NACE code of the waste producer and (2) the description of the waste producer. The following three columns are related to the waste exchanged, showing (1) the name of the waste, (2) the subcategory of waste, and (3) the EWC code of the waste. The following two columns are related to the waste user, showing (1) the description of the waste user and (2) the NACE code of the waste user. The last two columns denote the use of the waste and the academic reference. For instance, if we consider the first row of the table, we can see that the corn residues produced by companies cultivating cereals (classified under the NACE code 01.11.10), classified with EWC codes 02 01 03 and 02 04 99, can be used by biogas production plants (classified under the NACE code 38.21.09) as input for the biogas production. It can be noted that the same waste can be produced and used by companies belonging to different type of economic activities.

The table itself can be used by companies belonging to a given sector to retrieve information about potential symbiotic exchanges they can be developed. However, we aim at fostering the emergence of ISN and not only dyadic exchanges. As said above, the network dimension is fundamental for effective sustainable development.

3.2 | The procedure to design regional industrial symbiosis networks

This section describes the procedure that can be used to design an ISN in a given region. The proposed procedure consists of four steps:

1. *Identify the economic activities in the region*. This step consists in checking the existence of economic activities classified in the waste-input relationship table in the given area. This activity can be supported by data retrieved from national/regional databases of economic activities. The output of this step is a clear picture of which waste producers and users are present in the area and might be involved in IS synergies.
2. *Identify the number of companies per code of economic activity*. For each type of selected economic activity (both producers and users), the number of companies in the geographical area is identified, in order to quantify the size of each sector involved. Reaching a critical mass is in fact relevant for making economically beneficial the IS exchange.
3. *Select the corresponding rows in the waste-input relationship table*. This step consists in selecting: (1) the rows of the input-waste-output table displaying both waste producers and waste users

TABLE 1 Piece of the waste-input relationship table (the full table is depicted in Appendix C).

Waste producer			Waste exchanged			Waste user			
	NACE waste producer	Description waste producer	Waste	Subcategory wastes	EWC	Description waste user	NACE waste user	Use	References
A	01.11.10	Cultivation of cereals (excluding rice)	Corn residues	Organic	02 01 03	Biogas production plants	E 38.21.09	Input	(Regione Emilia Romagna, 2017a)
				organic	02 04 99				
	01.14.00	Farms: Cultivation of sugar cane	Wheat straw	Organic	02.04.99	Power plants	D 35.11.00	Biofuel	(Herczeg et al., 2018)
	01.2	Farms	Wheat straw	Organic	02 01 03	Power plants	D 35.11.00	Biofuel	
	01.23.00	Citrus cultivation	Citrus waste	Organic	02 01 03	Plant for making yarns and fabrics	C 13.20.00	Input to extract cellulose	(Cypriano et al., 2018)
	01.28.00	Growing of spices, aromatic and pharmaceutical plants (eucalyptus plantation)	Shrub scraps	Organic	02 01 03	Power plant	D 35.11.00	Vegetable charcoal as a substitute for black coal	(Chertow, 2007)
				Organic	02 01 07				
	01.50.00	Farms: Agricultural crops associated with animal breeding: mixed activity	Wheat straw	Organic	02 01 03	Power plants	D 35.11.00	Biofuel	(Herczeg et al., 2018)
	01.63.00	Farms: Activities following the harvest	Wheat straw	Organic	02 01 03	Power plants	D 35.11.00	Biofuel	
	03.21.00	Aquaculture in sea, brackish or lagoon water and related services (cultivation ponds)	Algae waste	Organic	02 01 03	Local farmers	A 01.13.20	Input for fertilizer	(Chertow, 2000)
B	08.91.00	Mineral extraction for the chemical industry and for the production of fertilizers (bromine production plant)	Used brine residual from the extraction of bromine	Nonorganic		Salt extractor plant	B 08.93.00	Input for salt extraction	(Liu et al., 2015)

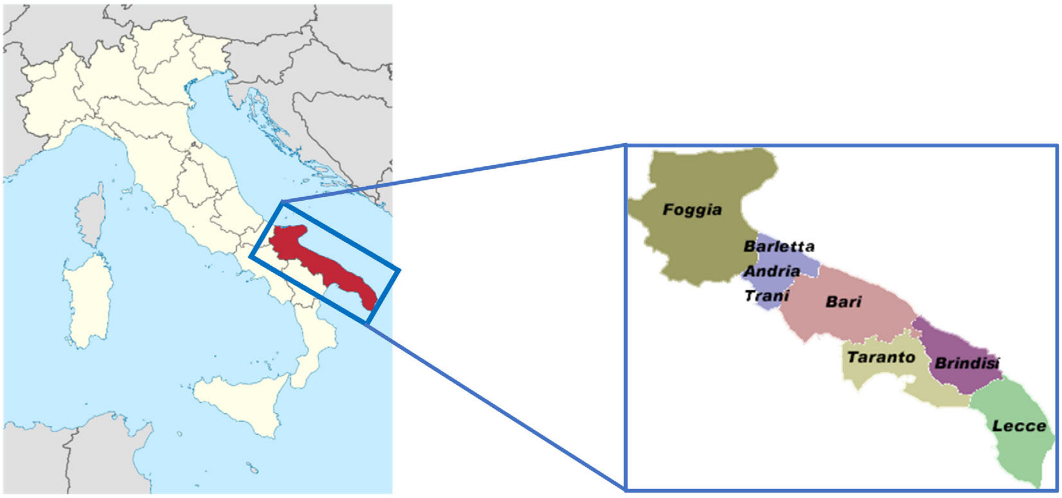

FIGURE 1 Map of Italy, where the Apulia region highlighted in red. The six provinces belonging to the Apulia region are highlighted on the right. [Colour figure can be viewed at wileyonlinelibrary.com]

localized into the region – these rows are representative of the feasible IS exchanges in the region; and (2) the rows of the input-waste-output table displaying at least one waste producer localized in the region while no waste users are localized in the region and, vice versa, the rows of the input-waste-output table displaying at least one waste user localized in the region while no waste producers are localized in the region – these rows are representative for the unfeasible IS exchanges in the region

4. *Mapping IS relationships*. Creating the network representation of the potential IS exchanges, where the node corresponds to economic activities and the direct link the waste exchange from the producer to the user.

4 | APPLICATION: THE CASE OF APULIA REGION

In this Section, the proposed procedure is adopted to identify the feasible IS relationships in the Apulia Region (Italy). Apulia Region is located in southern Italy, comprising 19,345 Km^2 and a population of more than 4 million people (Figure 1). The region is divided into six provinces: Foggia, BAT, Bari, Brindisi, Lecce, and Taranto.

The regional government is highly committed to supporting the implementation of circular economy strategies. Great effort has been devoted in the last years to urban wastes: in fact, the percentage of separate collection has more than doubled between 2013 (22.06%) and 2020 (54.50%) (ISPRA, 2021; 2019). However, more than 12 million tons of industrial wastes are yearly produced by the companies located in the region, corresponding to the 8.4% of the industrial wastes overall produced in Italy – Apulia Region is the fourth region Italy according to the amount of industrial wastes produced (ISPRA, 2022). In this regard, more than 1.6 million tons of industrial wastes are still disposed of in landfills every year, due to the fact that IS is not enough developed within the region. Furthermore, 135.000 tons of industrial wastes are even exported to other Italian regions, due to the fact that the annual capacity of Apulian landfills is not enough (ISPRA, 2020). This causes higher waste management costs for the companies belonging to the region. Hence, there is both the need to develop effective ISNs as well as the opportunities to exploit these wastes developing the regional economy.

We applied the procedure described in Section 3.2 to identify effective IS relationships. We first identified the sources for the required data. We used the database provided by the National Institute of Statistics (ISTAT) to retrieve data concerning the economic activities and the number of firms involved (steps 1–2) and the ISPRA Technical Report on Special Waste to collect data referring to the amount of wastes produced per economic activity and the ISPRA Technical Report on Special Waste per waste category (step 3).

Given the importance of geographical proximity for effective IS relationships, we decided to apply the methodology to each province. Thus, we performed step 1 and step 2 for the provinces of Bari, Brindisi, Lecce, Taranto, Foggia, and BAT. We searched for both the sectors that produce waste (waste-producer in Table 2) and the sectors that use waste (waste-user in Table 2), so obtaining a clear picture of the feasible IS relationships that can be potentially developed in Puglia. For the identified IS synergies, we then checked whether firms belonging to the user economic sectors are existing in the province (step 3). In this manner, we developed the six waste-input relationship tables, one for each province. Table 2 shows the table for the province of Bari.

Table 3 shows the number of feasible and unfeasible IS relationships in each province, identified thanks to the waste-input table. In the province of Bari 46 possible IS relationships have been identified, whether further six IS relationships are not feasible due to the unavailability of waste producers or waste users.

Finally, we drew a map of relationships by province (step 4), in order to graphically show the network of IS exchanges that can emerge via implementing the IS relationship identified. Noticed that, since an economic sector can simultaneously play the role of producer and user of wastes, a network of IS relationships emerge. This

TABLE 2 Part of waste-input table of Apulia region (it refers to the province of Bari). Unfeasible IS relationships are highlighted in italics

NACE code	Description of the manufacturer	N°	Refusal	EWC	NACE code	User company description	N°	Use
B 08.91.00	Mineral extraction for the chemical industry and to produce fertilizers	4	Used brine from bromine extraction	—	*B 08.93.00*	*Salt extraction*	*0*	*Input for salt extraction*
C 10.41.10	Production of olive oil from olives mainly not of own production	172	Wastewater from the mill	—	A 01.26.00	Agricultural cultivation and production of animal products, hunting and related services	149	Input
11.01.00	Distillation, rectification and mixing of alcohol	8	Isopropyl alcohol	02	C 10.51.10	Dairy industry, sanitation, milk storage	183	Input for features
11.05.00	Beer production	2	Wheat waste	02	A 01.30.00	Agricultural cultivation and production of animal products, hunting and related services	149	Mushroom growing substrate
17.12.00	Manufacture of paper and cardboard	5	Sludge	03	C 20.15.00	Manufacturing fertilizers and nitrogen compounds	4	Input
20.15.00	Manufacture of fertilizers and nitrogen compounds (excluding compost manufacture)	4	Steam condensation	—	D 35.11.00	Electricity production	101	Boiler feed input
20.16.00	Manufacture of plastic materials in primary forms	6	Condensation	—	D 35.11.00	Electricity production	101	Boiler feed input
20.59.90	Manufacture of other chemical products nec	1	Borlanda	02	A 01.19.90	Agricultural cultivation and production of animal products, hunting and related services	149	Input for forage production as fertilizer
			Organic by-products	16	E 38.21.09	Treatment and disposal of other nondangerous waste	9	Input to produce biogas
23.14.00	Manufacture of glass and glass products	74	Blast furnace slags	10	C 23.51.00	Concrete production	1	Input
23.31.00	Manufacture of ceramic tiles for floors and walls	4	Porcelain Gres sanding sludge	08, 10	C 23.32.00	Brickmaking, tiles and other terracotta building products	4	Replacement clay input for bricks
23.62.00	Manufacture of plaster products for construction	3	Chalk scrap	10, 17	A 01.61.00	Agricultural cultivation and production of animal products, hunting and related services	149	Fertilizer to improve land quality
23.70.10	Sawing and processing of stones and marble	158	Granite polishing residues	01	C 23.32.00	Brickmaking, tiles and other terracotta building products	4	Input for foundation material
23.70.30	Cutting, shaping and finishing of stones	198	Blast furnace slags	10	C 23.51.00	Concrete production	1	Input
24.10.00	Iron and steel industry - Manufacture of iron, steel and ferro-alloys	4	Demineralized water		D 35.11.00	Electricity production	101	Input
			Processing slags	10	C 23.51.10	Concrete production	1	Input
					23.52.00	Lime production	1	Input
			Powders		*24.43.00*	*Production of lead, zinc and tin and semi-finished*	*0*	*Input for the zinc electro-extraction process*
			Exhausted gas		D 35.11.00	Electricity production	101	Input for electricity and steam production

(Continues)

TABLE 2 (Continued)

NACE code	Description of the manufacturer	N°	Refusal	EWC	NACE code	User company description	N°	Use
			Slag of iron oxides, calcium, silicon	12	C 19.20.40	Manufacture of bitumen, tar and road emulsions	3	Input for asphalt production
24.53.00	Casting of light metals	1	Caustic Soda	10	C *24.42.00*	*Aluminum and semi-finished production*	*0*	*Input*
			Rejection of silica, alumina, fluoride		C 23.51.00	Cement production	1	Fuel
24.54.00	Casting of other nonferrous metals	2	Sulfur dioxide gas	10	C *24.43.00*	*Production of lead, zinc and tin and semi-finished*	*0*	*Input*
D 35.11.00	Electricity production	105	Cold salted water	—	A 03.21.00	Aquaculture in seawater, brackish or lagoon and related services	2	Input
			Steam	—	C 20.15.00	Manufacturing fertilizers and nitrogen compounds	4	Input
					20.13.09	*Manufacturing of other inorganic basic chemicals*	*0*	*Input*
					20.16.00	Manufacture of plastics in primary forms	6	Input
			Ashes	10	23.51.00	Concrete production	1	Input
					19.20.40	Manufacture of bitumen, tar and road emulsions	3	Input per aggregate for Road Construction
					23.52.10	Lime production	1	Input
			Chalk	06	23.62.00	Manufacturing of plaster products for construction	3	Natural chalk replacement input
			Sulfur Treaty		23.62.00	Manufacturing of plaster products for construction	3	Natural chalk replacement input
			Pretreated steam	—	21.20.0	Manufacture of medicines and pharmaceutical preparations	1	Input
E 37.00.00	Collection and purification of wastewater	42	Treated wastewater	—	D 35.11.00	Electricity production	101	Cooling water
					C *24.42.00*	*Aluminum and semi-finished production*	*0*	*Water for washing sludge*
					23.51.00	Concrete production	1	Process or cooling water
			Waste sludge	19	A 01.61.00	Agricultural cultivation and production of animal products, hunting and related services	149	Input for bio-soil remediation
			Organic waste	16	E 38.21.09	Treatment and disposal of other nondangerous waste	9	Input to produce biogas
38.21.09	Treatment and disposal of other nonhazardous waste	5	Steam	—	C 20.16.00	Manufacture of plastics in primary forms	6	Input
			Ashes	10, 19	23.51.00	Cement production	1	Input
			Organic waste	16	20.15.00	Manufacturing fertilizers and nitrogen compounds	4	Input

TABLE 2 (Continued)

NACE code	Description of the manufacturer	N°	Refusal	EWC		NACE code	User company description	N°	Use
38.32.10	Recovery and preparation for the recycling of metal waste and scrap	38	Mixed Plastic	16, 19	E	38.32.20	Recovery and preparation for the recycling of plastic slathering to produce plastic raw materials, synthetic resins	10	Input
			Processed plastic		C	23.61.00	Manufacturing of concrete products for construction	16	Input
38.32.20	Recovery and preparation for the recycling of plastic material to produce plastic raw materials, synthetic resins	10	Plastic	16,17,19,20	C	24.10.00	Steel – Iron, steel and iron steel fabrication	4	Alternative coal blast furnace fuel
						20.15.00	Manufacturing fertilizers and nitrogen compounds	4	Fuel
						23.51.00	Cement production	1	Fuel
			Plastic powder	12		22.21.00	Manufacture of plastics	120	Input
38.32.30	Recovery and preparation for recycling of municipal, industrial and biomass solid waste	25	Sludge	03	C	23.51.00	Cement production	1	Input
			Biomass residues	02	D	35.11.00	Electricity production	101	Fuel
			Oil extracted from biomass		C	20.41.10	Manufacture of soaps and detergents, cleaning and polishing products	5	Input
			Dried coffee grounds	16		13.30.00	Textile finishing	23	Fuel for boilers
						23.43.00	Manufacture of insulators and ceramic insulation pieces	1	Fuel for boilers

TABLE 3 Number of feasible and unfeasible IS relationships per province

Province	Number of feasible IS relationships	Number of unfeasible IS relationships (due to unavailability of waste producers or waste users)
Bari	46	6
Foggia	23	4
BAT	3	5
Brindisi	3	1
Taranto	14	9
Lecce	24	6

increases the value of the proposed methodology, which is not limited to identifying potential dyadic IS relationships between sectors, but to showing the network of IS relationships potentially existing within an area.

Figure 2 shows the possible relations related to the province of Bari. In particular, the outgoing red arrows indicate that a feasible IS relationship exists with a waste user of another province (the name of the receiving province is shown on the arrow itself). The ongoing blue arrows indicate that a feasible IS relationship exists with a waste producer of another province. The maps of the IS feasible and potential relationships in the other provinces are shown in (Appendix Figure A1–A5).

5 | DISCUSSION

Designing effective regional ISNs is a critical task to support the transition toward a sustainable economy (e.g., Cutaia et al., 2015; Luciano et al., 2016). However, designing regional IS networks is not an easy task, mainly because of the unavailability of information among the wastes produced by companies located into the region (e.g., Aid et al., 2017; Fraccascia & Yazan, 2018; Golev et al., 2015; Sakr et al., 2011), which is crucial to identify the symbiotic exchanges that can be exploited based on the economic activities of a region.

Compared to the currently available approaches, we proposed a method that can be used by both companies and public administrations, consistent with both a top-down and bottom-up design of the ISN. Rather than developing a sophisticated but time-consuming method—which requires to (effectively) collect precise data about type and quantity of wastes produced and required, by means of large and detailed questionnaires filled by each company belonging to the regional area—we developed an approach based on secondary data, which are collected by national institutions at national and regional levels and therefore already available to be used, able to quickly capture the opportunities of multiple symbiotic relationships in a given region. Our approach does not need to collect sensible information provided directly by companies. In fact, since companies are often not prone to disclose them, the currently available methods, even though more precise, fail to be applied. Thus, the merit of our approach is to improve the practical efficacy of the methodology rather than its precision.

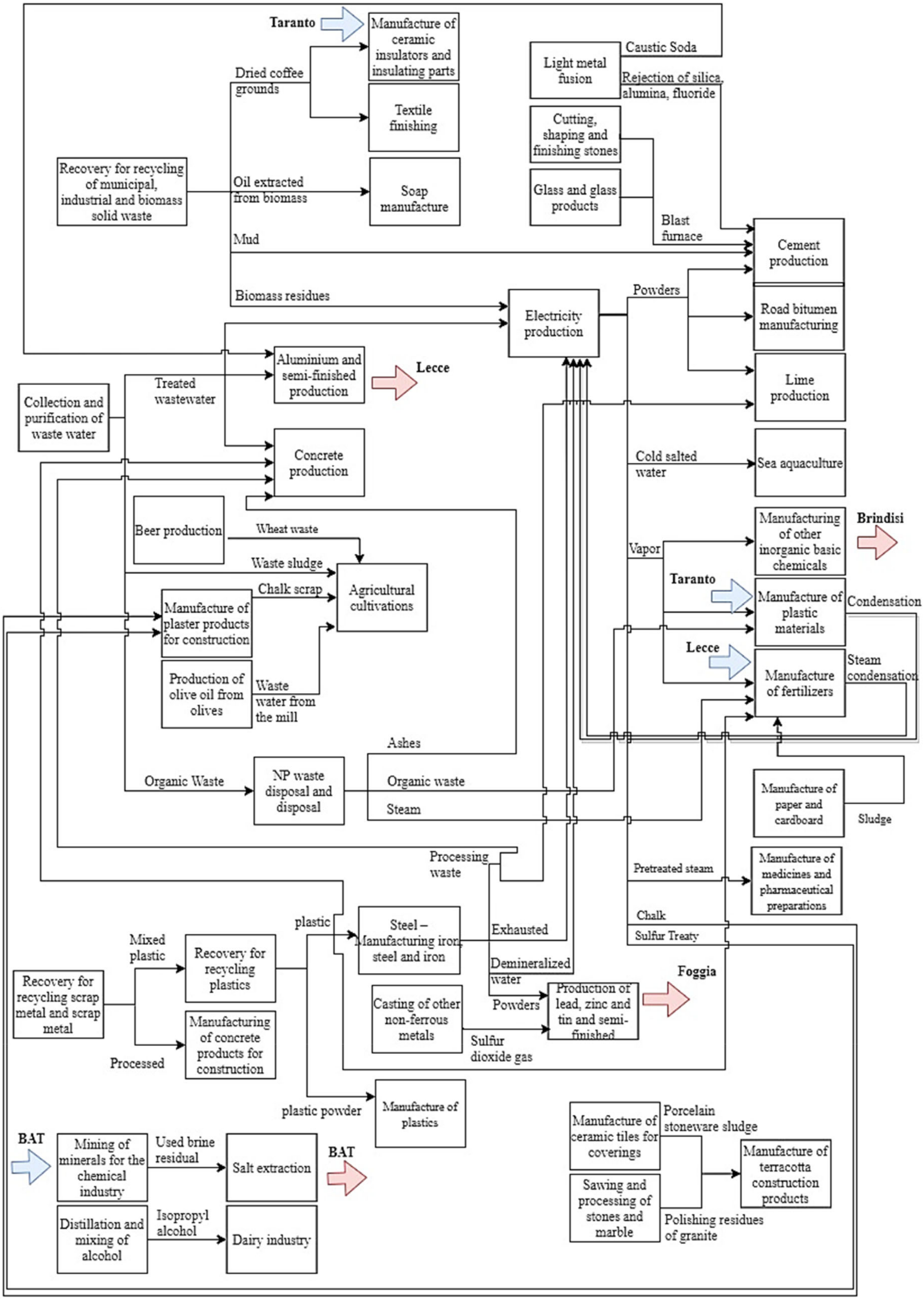

FIGURE 2 Map of possible IS relationships in Bari province and the related ISN. [Colour figure can be viewed at wileyonlinelibrary.com]

The proposed method can be applied by both companies and policymakers.

Companies can use the method to discover feasible IS opportunities based on the economic activities carried out in the region, since the method captures the existence of companies buying the waste they produce or producing wastes that they can buy, thus replacing raw materials. In doing so, our method, even in its simplicity, contributes to design complex IS relationships according to a bottom-up approach, since multiple IS exchanges can be activated by the same companies by themselves, once the information about potential IS partners is discovered and available. This permits to reduce the transaction costs associated with IS relationships, helping to overcome this critical barrier limiting the effective implementation of IS practices.

Furthermore, note that the method provides the number of companies producing and requiring the different wastes in a given regional area. This is an important piece of information for companies involved in establishing IS relationship, because the number of companies affects the contractual power (Costantino & Di Gravio, 2009; Giannoccaro & Pontrandolfo, 2009) during the negotiation of the economic terms (i.e., how to share the operational costs and the waste exchange price) of IS relationships. For example, when few producers of a given waste exist but many companies require that waste, waste producers have a higher contractual power than waste users, ceteris paribus, and could exploit such a power by playing an opportunistic behavior aimed at gaining the greater part of the economic benefits while leaving a scant part to the symbiotic partners (Yazan et al., 2020).

Policymakers can use the method to identify the IS synergies to promote via ad-hoc policy measures (e.g., Tao et al., 2019). Incentive policy mechanisms can be developed to support the emergence of IS relationships between regional companies. Similarly, policymakers may financially support the location eco-industrial parks in a given region based on the knowledge of the existence of effective IS exchanges that can be activated in a given area.

The method can be also applied to discover unexplored IS opportunities in a given region due to the mismatch between demand and supply of wastes, that is, the cases when: (1) a given waste is produced by companies belonging to the region but there are no companies requiring that waste; a given waste is produced by companies belonging to the region but there are few companies requiring that waste; (3) a given waste is required by companies belonging to the region but there are no companies producing that waste; and (4) a given waste is required by companies belonging to the region but there are few companies producing that waste. In such a case, policymakers could implement additional policy measures aimed at attracting specific waste producers/users in the region.

The method can also support strategic regional economic planning. The identification of IS networks can help assess the environmental benefits associated, for example by quantifying the reduction of wastes disposed in landfills, the critical raw materials usage, and the greenhouse gas emissions (GHG).

Finally, policymakers can also use the method to guarantee a better alignment between technically and regulatory feasible IS relationships. Since the method is able to capture the IS relationships potentially feasible in a given region, based on the level of technological development, the policymakers can check if the IS relationships identified can be carried out according to the regional legislative and regulatory frameworks. If not, they can promote the modification and update of current frameworks so as to foster the development of IS practices in the region.

6 | CONCLUSIONS

This paper has been aimed at proposing a simple and replicable procedure to design ISNs at the regional level. This method can be used to investigate whether, in a given region, there are opportunities to develop IS synergies among companies belonging to that area and to show them using a network approach. The proposed methodology has been tested for the case of Apulia region (South Italy), where more than 300 feasible IS synergies emerge that can be implemented.

In doing so, the methodology proposed contributes to support the development of regional ISNs identified as an effective strategy to promote the regional sustainable development. The regional level provides in fact interesting advantages. It permits to exploit cost benefits associated with geographical proximity among companies implementing IS practices. It permits to guarantee diversity, since the practices are implemented at a meso scale, so improving the resilience of ISN (Fraccascia et al., 2017), but at the same time improving efficiency thanks to the possibility to exploit scale economy. It also reduces transaction costs, since companies may share similar cultural and environmental features.

The paper presents some limitations. First, our method is based on a table identifying the potential IS synergies referring to the current literature and technological advance. This means that the table should be continuously updated to be aligned with the current technological state of the art. Indeed, new IS opportunities thanks to technological development should be periodically integrated into the table, in the forms of new rows, to preserve the full efficacy of the tool. Furthermore, in a given area there could certainly be other activities, not considered by the method, which have the potential to produce or require wastes. Second, the efficacy of the method proposed relies on the data collected by the public administration. In this regard, notice that the number of economic activities belonging to a given region might change over time, since new companies can start their activity or, alternatively, existing companies can end their activity. Hence, these data should be periodically updated by public administrations.

However, we believe that losing some opportunities is justified by the simplicity and effectiveness of our methods, which can be easily adopted by companies and policy-makers to identify the most promising IS practices in a given regional area, having high efficacy to be implemented, without complex and time-consuming procedures.

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ENDNOTES

[1] The actual amount of waste exchanged also depends on the frequency in production and demand of wastes, which is able to critically affect the match between supply and demand.

[2] Many reasons drive the low willingness of companies to disclose information, which might include personal and cultural issues apart business ones – see, for example, Corvellec et al. (2021).

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APPENDIX A: EWC codes used in IS relationships

TABLE A1 Explanation of EWC code used into IS relationships

Category EWC CODE	Subcategory EWC CODE	EWC CODE	Description
01 – Waste from prospecting, mining or quarrying, as well as from physical or chemical treatment of minerals	01.04 – Wastes from chemical and physical treatment of nonmetallic minerals	01.04.13	Wastes from stone working
02 – Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food processing and preparation.	02.01 – Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing.	02.01.03	Plant tissue waste
		02.01.07	Forestry waste
		02.01.99	Wastes not otherwise specified
	02.02 – Wastes from the preparation and treatment of meat, fish and other food of animal origin	02.02.99	Wastes not otherwise specified
	02.03 – Wastes from the preparation and treatment of fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco; the production of canned food; the production of yeast and yeast extract; of the preparation and fermentation of molasses	02.03.99	Wastes not otherwise specified
	02.04 – Wastes from sugar refining	02.04.99	Wastes not otherwise specified
	02.07 – Wastes from the production of alcoholic and nonalcoholic drinks (except coffee, tea and cocoa)	02.07.02	Wastes from the distillation of alcoholic beverages
03 – Wastes from wood processing and the production of panels, furniture, pulp, paper and cardboard.	03.03 – Wastes from pulp, paper and cardboard production and processing	03.03.01	Bark and wood waste
		03.03.02	Sludge from the maceration baths (green liquor)
		03.03.05	Sludges from deinking processes in paper recycling
		03.03.09	Waste sludges containing calcium carbonate
		03.03.10	

TABLE A1 (Continued)

Category EWC CODE	Subcategory EWC CODE	EWC CODE	Description
			Fiber and sludge waste containing fibers, fillers and coating products generated by mechanical separation processes
		03.03.11	Sludges from on-site effluent treatment
05 – Wastes from oil refining, natural gas purification and pyrolytic treatment of coal	05.01 – Wastes from oil refining	05.01.11	Wastes from base fuel purification
		05.01.16	Sulfur-containing wastes from petroleum desulphurisation
		05.01.99	Wastes not otherwise specified
06 – Wastes from inorganic chemical processes	06.06 – Wastes from the production, formulation, supply and use of sulfur-containing chemicals, sulfur chemical processes and desulphurization processes	06.06.99	Wastes not otherwise specified
08 – Wastes from the manufacture, formulation, supply and use of coatings (paints, varnishes and glazes), adhesives, sealants and printing inks	08.01 – Wastes from the production, formulation, supply and use and removal of paints and varnishes	08.01.19	Aqueous suspensions containing paints and varnishes containing organic solvents
		08.01.20	Aqueous suspensions containing paints and varnishes
	08.02 – Wastes from the production, formulation, supply and use of other coatings (including ceramic materials)	08.02.02	Aqueous sludges containing ceramic materials
10 – Wastes from thermal processes	10.01 – Wastes from thermal power plants and other thermal plants	10.01.01	Bottom ash, slag and boiler dust
		10.01.02	Coal fly ash
		10.01.03	Fly ash from peat and untreated wood
		10.01.15	Bottom ash, slag and boiler dust from co-incineration
		10.01.99	Wastes not otherwise specified
	10.02 – Wastes from the iron and steel industry	10.02.01	Wastes from slag treatment
		10.02.02	Untreated slag
		10.02.10	Lamination flakes
		10.02.99	Wastes not otherwise specified
	10.03 – Wastes from aluminum thermal metallurgy	10.03.22	Other powders and particulates (including those produced by ball mills), other than those of referred to in the entry
		10.03.30	Wastes from salt and black slag treatment
		10.03.99	Wastes not otherwise specified
	10.05 – Wastes from zinc thermal metallurgy	10.05.99	Wastes not otherwise specified
	10.06 – Wastes from copper thermal metallurgy	10.06.99	Wastes not otherwise specified
	10.08 – Wastes from thermal metallurgy of other nonferrous minerals	10.08.04	Dust and particulates
		10.08.09	Other slags
		10.08.16	Flue gas dust
		10.08.18	Sludges and filter cakes from flue gas treatment
	10.09 – Wastes from casting of ferrous materials	10.09.10	Dust from the combustion gasses
	10.12 – Wastes from manufacture of ceramic, brick, tile and building materials	10.12.13	Sludges from on-site effluent treatment
	10.13 – Wastes from manufacture of cement, lime and plaster and products made from these materials	10.13.04	Calcination and lime hydration wastes
		10.13.06	Dust and particulates

(Continues)

TABLE A1 (Continued)

Category EWC CODE	Subcategory EWC CODE	EWC CODE	Description
12 – Wastes from processing and physical and mechanical surface treatment of metals and plastics	12.01 – Waste produced by the processing and physical and mechanical surface treatment of metals and plastics	12.01.01	Filing and shavings of ferrous materials
		12.01.02	Powders and particulates of ferrous materials
		12.01.03	Filing and shavings of nonferrous materials
		12.01.04	Powders and particulates of nonferrous materials
		12.01.13	Welding waste
16 – Wastes not otherwise specified in the list	16.01 – End-of-life vehicles belonging to different modes of transport (including nonroad mobile machinery) and waste produced by dismantling end-of-life vehicles and vehicle maintenance	16.01.19	Plastic
	16.03 – Off-specification and reject materials	16.03.06	Organic waste
17 – Waste from construction and demolition operations (including soil from contaminated sites)	17.02 – Wood, glass and plastic	17.02.03	Plastic
	17.08 – Gypsum-based construction materials	17.08.02	Gypsum-based construction materials
19 – Wastes from waste treatment plants, off-site wastewater treatment plants, as well as from water purification and its preparation for industrial use	19.01 – Wastes from incineration or pyrolysis of waste	19.01.12	Bottom ash and slag
		19.01.14	Fly ash
	19.08 – Wastes from wastewater treatment plants, not otherwise specified	19.08.05	Sludges from urban wastewater treatment
	19.10 – Wastes from crushing operations of metal-containing wastes	19.10.01	Wastes from iron and steel
	19.12 – Wastes from mechanical waste treatment (e.g., sorting, shredding, compacting, pelletizing) not otherwise specified	19.12.04	Plastic and rubber
20 – Municipal waste (domestic and similar waste produced by commercial and industrial activities as well as by institutions) including waste from separate collection	20.01 – Separately collected fractions of waste	20.01.39	Plastic

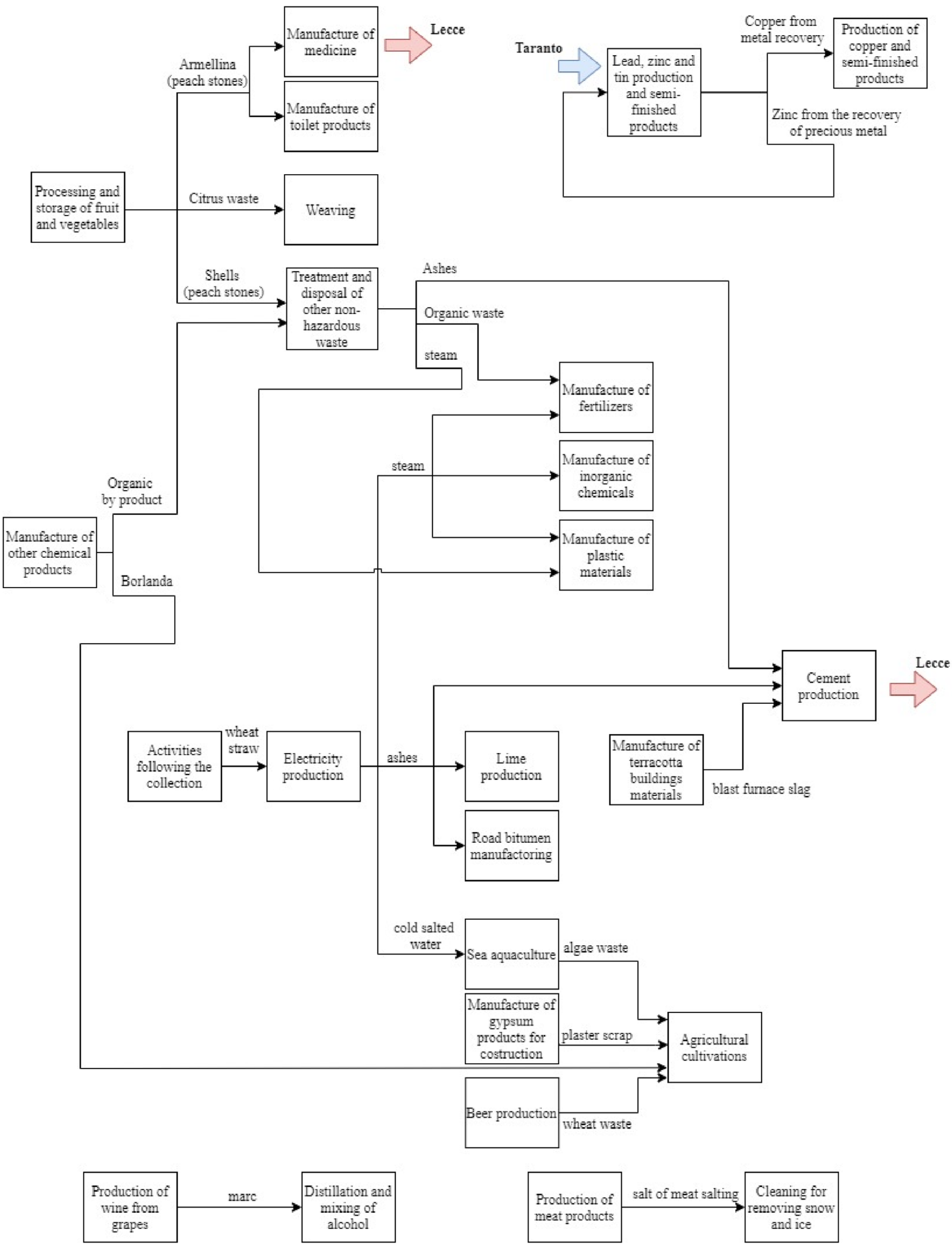

FIGURE A1 Map of feasible and potential IS relationships in the province of Foggia. [Colour figure can be viewed at wileyonlinelibrary.com]

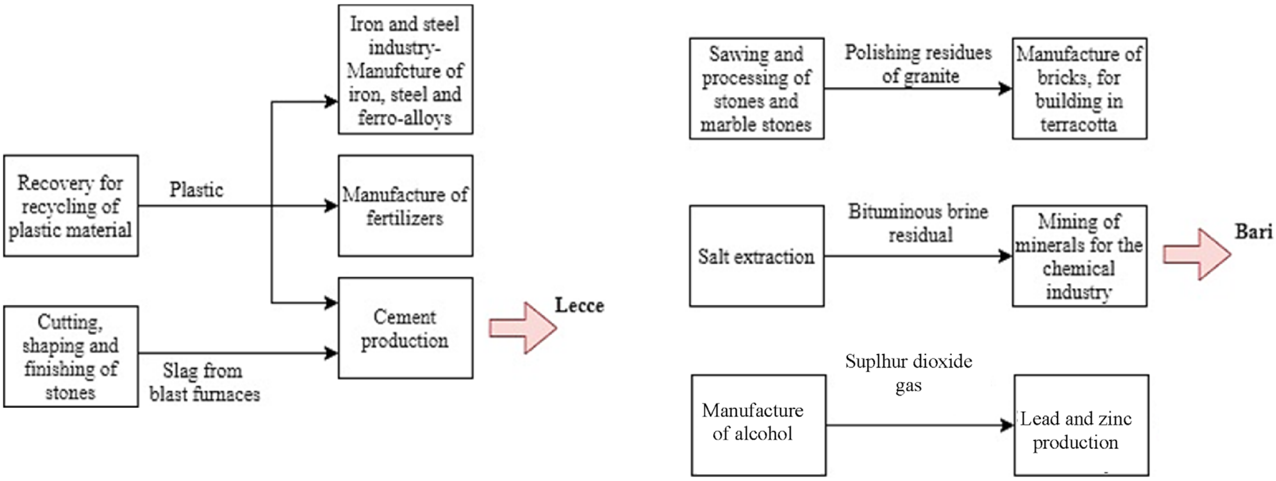

FIGURE A2 Map of feasible and potential IS relationships in the province of BAT. [Colour figure can be viewed at wileyonlinelibrary.com]

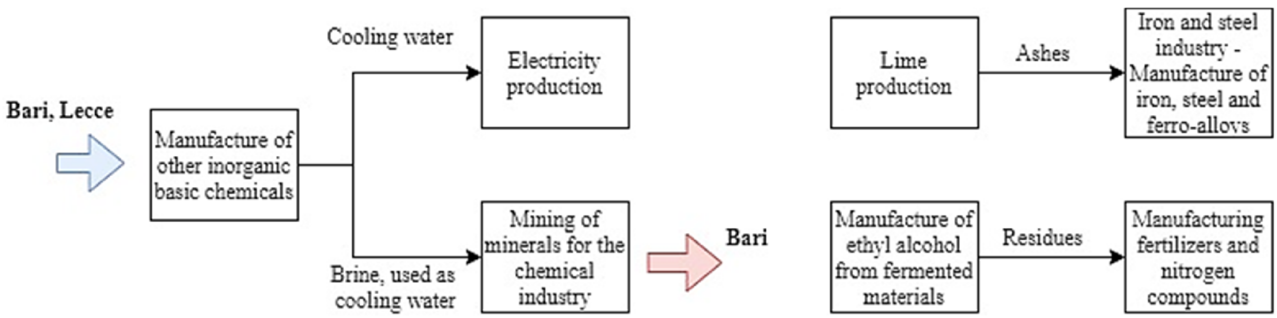

FIGURE A3 Map of feasible and potential IS relationships in the province of Brindisi. [Colour figure can be viewed at wileyonlinelibrary.com]

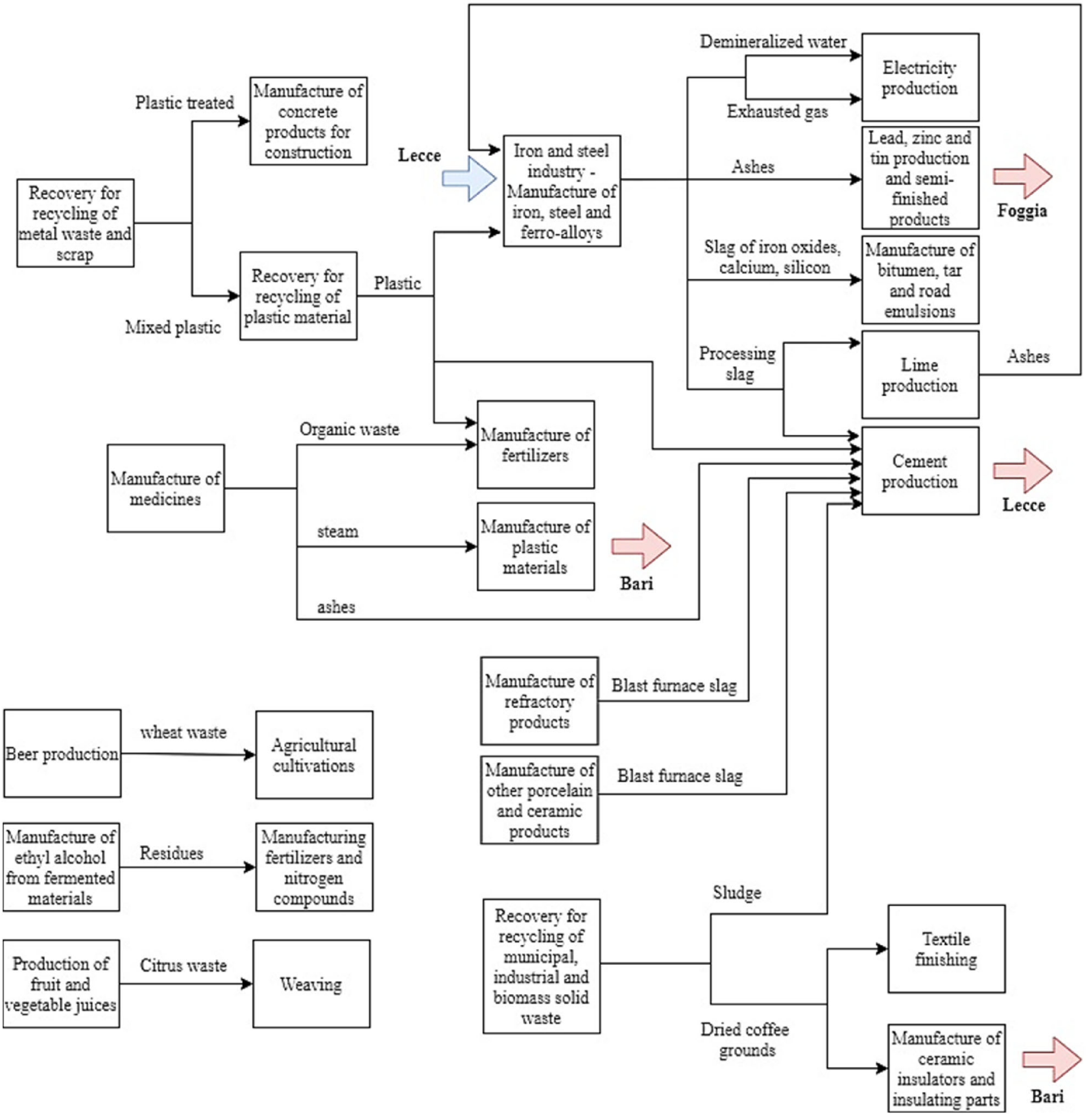

FIGURE A4 Map of feasible and potential IS relationships in the province of Taranto. [Colour figure can be viewed at wileyonlinelibrary.com]

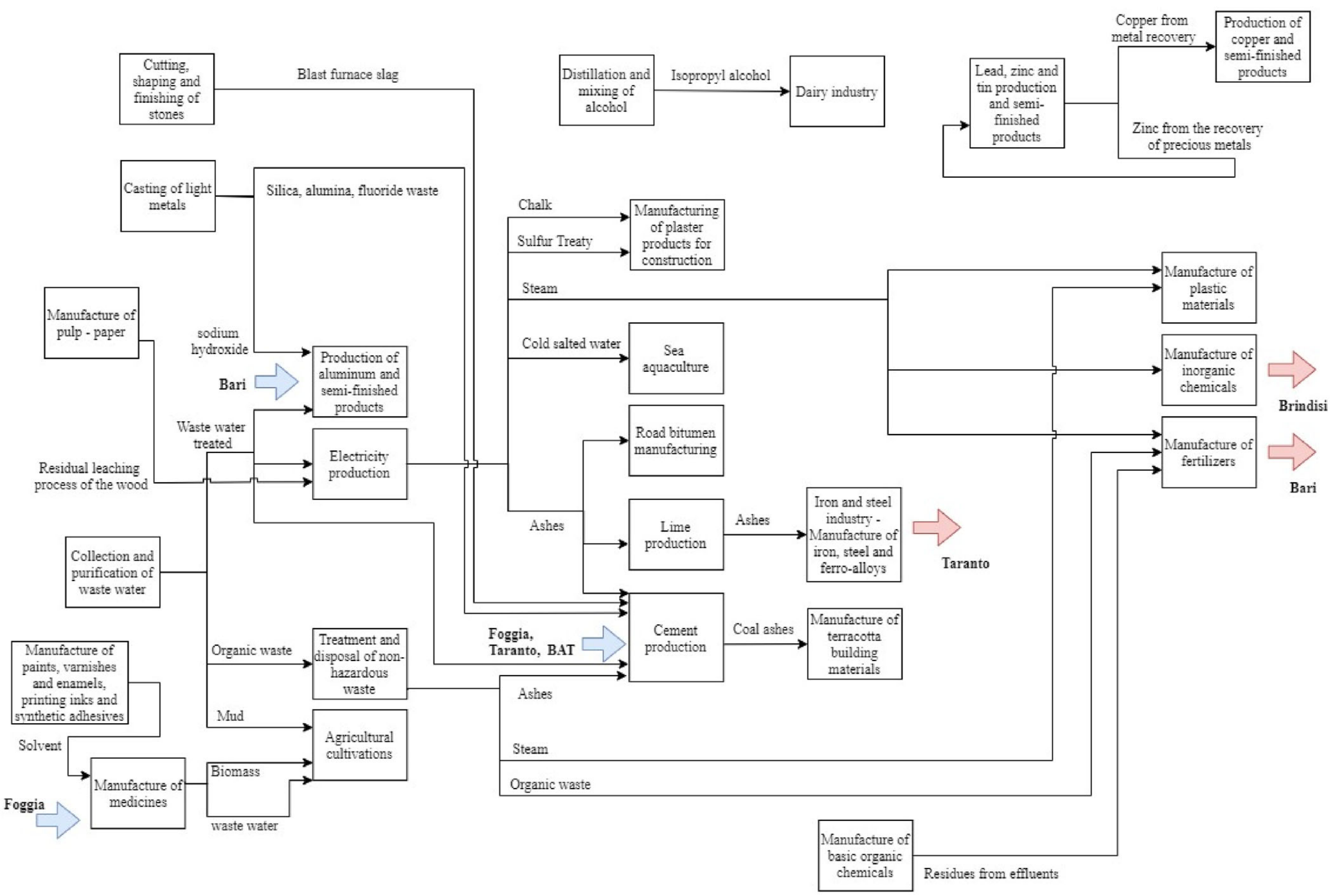

FIGURE A5 Map of feasible and potential IS relationships in the province of Lecce. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE A2 Classification of wastes exchanged into IS relationships

EWC					
Metallic waste	**Nonorganic waste**				**Organic waste**
10 03 22	01 04 13	10 01 01	10 08 18	17 08 02	02 01 03
10 03 30	02 02 99	10 01 02	10 09 10	19 01 12	02 01 07
10 03 99	03 03 01	10 01 03	10 12 13	19 01 14	02 01 99
10 05 99	03 03 02	10 01 15	10 13 04	19 08 05	02 03 99
19 10 01	03 03 05	10 02 01	10 13 06	19 12 04	02 04 99
Waste gas	03 03 09	10 02 02	12 01 01	20 01 39	02 07 02
02 07 02	03 03 10	10 02 10	12 01 02		16 03 06
05 01 16	03 03 11	10 02 99	12 01 03		
05 01 99	06 06 99	10 03 30	12 01 04		
10 01 99	08 01 19	10 08 04	12 01 13		
10 02 99	08 01 20	10 08 09	16 01 19		
10 06 99	08 02 02	10 08 16	17 02 03		

APPENDIX B: NACE codes of waste producers and waste users in IS relationships

TABLE B1 NACE codes of waste producers and waste users in IS relationships

Sections – NACE code	Division – NACE code	Description – NACE code
A – Agriculture, forestry and fishing	01: Agricultural cultivations and production of animal products, hunting and related services	A 01.11.01: cultivation of cereals (excluding rice). A 01.13.20: cultivation of vegetables (including melons) in leaf, drum, fruit, roots, bulbs and tubers in protected cultures (excluding sugar beet and potatoes). A 01.14.00: cultivation of sugar cane. A 01.19.20: cultivation of flowers in protected cultures. A 01.23.00: citrus cultivation A 01.26.00: cultivation of oily fruits. A 01.28.00: growing of spices, aromatic and pharmaceutical plants. A 01.50.00: agricultural cultivations associated with animals breeding: mixed activity. A 01.61.00: support activities for vegetable production. A 01.63.00: Activities following the harvest.
	03: Fishing and aquaculture	A 03.21.00: Aquaculture in sea, brackish or lagoon water and related services
B – Mineral extraction from quarries and mines	08: Other mineral extraction activities from quarries and mines	B 08.91.00: Mineral extraction for the chemical industry and for the production of fertilizers B 08.93.00: Salt extraction
C – Manufacturing activities	10: Food industries	C 10.13.00: Production of meat products (including poultry meat) C 10.32.00: Production of fruit and vegetable juices C 10.39.00: processing and preservation of fruit and vegetables (excluding fruit and vegetable juices). C 10.41.10: Production of olive oil from olives mainly not of own production. C 10.51.10: milk hygienic treatment. C 10.81.00: Sugar production C 10.83.01: Coffee processing.
	11: Beverage industry	C 11.01.00: Distillation, rectification and mixing of alcohol C 11.02.20: production of sparkling wine and other special wines. C 11.05.00: Beer production
	13: Textile industries	C 13.20.00: Weaving
	17: Manufacture of paper and paper products	C 17.11.00: Pulp manufacturing C 17.12.00: Manufacture of paper and cardboard
	19: Manufacture of coke and deriving products from the refining of oil	19.20.10: Oil refineries 19.20.40: Manufacture of bitumen, tar and binder emulsions for road use
	20: Manufacture of chemical products	C 20.13.09: Manufacture of other inorganic basic chemicals C 20.14.01: Manufacture of ethyl alcohol from fermented materials C 20.15.00: Manufacture of fertilizers and nitrogen compounds (excluding the manufacture of compost) C 20.16.00: Manufacture of plastic materials in primary forms C 20.30.00: Manufacture of paints, varnishes and enamels, printing inks and synthetic adhesives C 20.41.14: Manufacture of other organic basic chemicals C 20.59.90: Manufacture of other chemicals
	21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	C 21.20.09: Manufacture of medicines and pharmaceutical preparations
	22: Manufacture of rubber items and plastic materials	C 22.21.00: Manufacture of plastic plates, sheets, tubes and profiles.
	23: Manufacture of other products from the processing of nonmetalliferal minerals	C 23.14.00: Manufacture of glass fibers. C 23.20.00: Manufacture of refractory products. C 23.31.00: Manufacture of ceramic tiles for floors and walls

(Continues)

TABLE B1 (Continued)

Sections – NACE code	Division – NACE code	Description – NACE code
		C 23.32.00: Manufacture of bricks, tiles and other building products in terracotta. C 23.43.00: Manufacture of ceramic insulators and insulating parts C 23.44.00: manufacture of other ceramic products for technical and industrial use. C 23.51.00: Cement production C 23.52.10: Lime production C 23.62.00: Manufacture of plaster products for construction C 23.70.10: Sawing and processing of stones and marble C 23.70.30: crushing of various stones and minerals not in connection with the extraction.
	24: Metallurgy	C 24.10.00: Iron and steel industry – Manufacture of iron, steel and ferro-alloys C 24.43.00: Production of lead, zinc and tin and semi-finished products C 24.44.00: Copper and semi-finished production C 24.53.00: Casting of light metals C 24.54.00: Casting of other nonferrous metals
D – Electricity, gas, steam and air conditioning supply	35: Electricity, gas, steam and air conditioning supply	D 35.11.00: Production of electricity
E – Water supply; sewerage networks, waste management activities and recovery	37: Management of sewerage networks	E 37.00.00: Collection and purification of wastewater
	38: Collection, treatment and disposal of waste; recovery of materials	E 38.21.09: Treatment and disposal of other nonhazardous waste E 38.32.10: Recovery and preparation for the recycling of metal waste and scrap E 38.32.20: Recovery and preparation for the recycling of plastic material for the production of plastic raw materials, synthetic resins E 38.32.30: Recovery and preparation for recycling of municipal, industrial and biomass solid waste
N – Rental, travel agencies, business support services	81: Service activities for buildings and landscape	N 81.29.91: Cleaning and washing of public areas, removal of snow and ice
	82: Support activities for office functions and other business support services	N 82.92.10: Food packaging and packaging

APPENDIX C: Waste-input relationship table of feasible IS exchanges

Waste producer			Waste exchanged			Waste user				
NACE 1		Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
A	01.11.10	Cultivation of cereals (excluding rice)	Corn residues	organic	02 01 03 02 04 99	Biogas production plants	E	38.21.09	Input	(Regione Emilia Romagna, 2017a)
	01.14.00	Farms: Cultivation of sugar cane	Wheat straw		02.04.99	Power plants	D	35.11.00	Biofuel	(Herczeg et al., 2018)
	01.2	Farms	Wheat straw		02 01 03	Power plants	D	35.11.00	Biofuel	
	01.23.00	Citrus cultivation	Citrus waste		02 01 03	Plant for making yarns and fabrics	C	13.20.00	Input to extract cellulose	(Cypriano et al., 2018)
	01.28.00	Growing of spices, aromatic and pharmaceutical plants (eucalyptus plantation)	Shrub scraps		02 01 03 02 01 07	Power plant	D	35.11.00	Vegetable charcoal as a substitute for black coal	(Chertow, 2007)
	01.5	Farms: Agricultural crops associated with animal breeding: mixed activity	Wheat straw		02 01 03	Power plants	D	35.11.00	Biofuel	(Herczeg et al., 2018)
	01.63.00	Farms: Activities following the harvest	Wheat straw		02 01 03	Power plants	D	35.11.00	Biofuel	
	03.21.00	Aquaculture in sea, brackish or lagoon water and related services (cultivation ponds)	Algae		02 01 03	Local farmers	A	01.13.20	Input for fertilizer	(Chertow, 2000)
B	08.91.00	Mineral extraction for the chemical industry and for the production of fertilizers (bromine production plant)	Used brine residual from the extraction of bromine	non organic		Salt extractor plant	B	08.93.00	Input for salt extraction	(Liu et al., 2015)
	08.93.00	Salt extractor plant	Bituminous brine residue from salt extraction			Plant producing potassium sulfate	B	08.91.00	Input for the extraction of potassium sulfate	

(Continues)

Waste producer			Waste exchanged			Waste user				
NACE 1		Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
C	10	Food processing plants	Ashes	non organic	10 01 01	Local brick producers	C	23.32.00	Input	(Bain et al., 2010)
					10 01 02					
					10 01 03					
			Food residues, mainly coffee grounds	organic	02 04 99	Oil extractor plant	E	38.32.30	Input to extract oil as biomass fuel	
	10.13.00	Production of meat products - including poultry meat - (Agri-Food Sector)	Salt deriving from the salting of the meats	non organic	02 02 99	Cleaning activity	N	81.29.91	Road anti-ice	(Regione Emilia Romagna, 2017b)
	10.39.00	Processing and preservation of fruit and vegetables (excluding fruit and vegetable juices)	Peach stone armellina	organic	02 01 03	Pharmaceutical and Cosmetic Industry			Input	(Regione Emilia Romagna, 2017b)
					02 01 99		C	21.20.09		
					16 03 06			20.42.00		
			Peach shells		02 01 03	Biogas production plants	E	38.21.09	Input	
					02 01 99			38.21.09		
					16 03 06			38.21.09		
	10.32.00	Production of fruit and vegetable juices (Citrus-fruit juice chain)	Citrus waste	organic	16 03 06	Plant for making yarns and fabrics	C	13.20.00	Input to extract cellulose	(Cypriano et al., 2018)
	10.41.10	Oil production company: production of olive oil from olives which are not own production	Crusher waste water	utilities		Farms: cultivation of oily fruits	A	01.26.00	Input	(Notarnicola et al., 2016)
	10.81.00	Sugar production	Filtered sludge as waste from the sugar refining process	non organic	02 03 01	Cement production	C	23.51.00	Input	(Zhu & Cote, 2004)
		Sugar production	Filtered sludge as waste from the sugar refining process		02 04 03	Cement production	C	23.51.00	Input	

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
		Bagasse, long residual fibers of sugar cane	organic	02 04 99	Cogeneration plant	D 35.11.00	Fuel to produce electricity	
		Bagasse, long residual fibers of sugar cane		02 04 99	Paper production plant	C 17.12.00	Input for paper production	
		Molasses		02 04 99	Distillery	11.01.00		
				02 04 99	Alcohol production	20.14.01	Input	
	Sugar production	Marrow of the barrel		02 04 99	Cogeneration power station	D 35.11.00	Fuel	
		Black liqueur, or refusal of the bagasse crushing process		02 04 99	Alkali recovery plant	C 20.13.09	Input	
10.83.01	Processing of coffee	Food residues, mainly coffee grounds		02 04 99	Oil extractor plant	E 38.32.30	Input to extract oil as biomass fuel	(Bain et al., 2010)
11.01.00	Distillation, rectification and mixing of alcohol	Isopropyl alcohol	nonorganic		Dairy industry: milk hygienic treatment	C 10.5.101	Input for processing	
		CO2	waste gas	02 07 02	Compression plant for bottling	N 82.92.10	Input	
11.02.20	Wine producer	Marc	organic	16 03 06	Distillery	C 11.01.00	Input	(Cypriano et al., 2018)
11.05.00	Beer production	Spent grain		02 01 03 02 04 99	Local farmes	A 01.30.00	Substrate for mushroom cultivation	(Chertow, 2000)
17.11.00	Pulp manufacturing	Residual leaching process of the wood	nonorganic	03 03 01 03 03 02 03 03 10 03 03 11	Power plant	D 35.11.00	Fuel	(Regione Emilia Romagna, 2017d)
17.12.00	Manufacture of paper and cardboard (paper mill)	Sludge		03 03 02 03 03 09	Fertilizer company	C 20.15.00	Input	(Bain et al., 2010)

(Continues)

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
				03 03 11				
19.20.10	Oil refineries	Sulfur	waste gas	05 01 16	Plant producing acid-fertilizers	C 20.15.00	Input	(Herczeg et al., 2018)
		Combustible gasses		05 01 99	Power plant	D 35.11.00	Input	(Cypriano et al., 2018)
		Cooling water; waste water	utilities		Cooling waters; waste water		Water for boiler supply; Cooling water for the desulphurization process	(Jacobsen, 2006)
		Well water; steam condensation			Power plant		Input; Cooling water	(Cypriano et al., 2018)
20.13.09	Manufacture of other inorganic basic chemicals (soda production plant)	Brine, used as cooling water	nonorganic		Bromine production plant	B 08.91.00	Input for the extraction of bromine	(Liu et al., 2015)
		Liquid ammonia waste			Calcium chloride plant	C 20.13.09	Input for extraction	
	Chemical industry	Plaster as a waste from the production of phosphoric acid (i.e., calcium sulfate)		06 09 99	Plasterboard manufacturer	C 23.62.00	Input	(van Beers et al., 2007)
				06 09 99	Aluminum refinery	C 24.42.00	Input	
	Plant producing soda; Calcium chloride plant	Cooling water; steam condensation	utilities		Thermal power plant	D 35.11.00	Water to feed the boilers	(Liu et al., 2015)
20.14.01	Manufacture of ethyl alcohol from fermented materials (alcohol production)	Residues	organic	02 07 02	Fertilizer production	C 20.15.00	Input for the production of fertilizers	(Zhu & Cote, 2004)
20.15.00	Manufacture of fertilizers and nitrogen compounds – excluding the manufacture of compost – (potassium sulfate producing plant)	Steam condensation	utilities		Thermal power plant	D 35.11.00	Boiler power input	(Liu et al., 2015)
20.16.00	Manufacture of plastic materials in primary forms	Condensation			Cogeneration plant	D 35.11.00	Steam input	(Chertow et al., 2008)
20.30.00	Manufacture of paints, varnishes and enamels,	Solvent	nonorganic	08 01 19	Pharmaceutical industry	C 21.20.09	Input for drugs	

Waste producer		Waste exchanged			Waste user				
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
	printing inks and synthetic adhesives (paint manufacturer)			08 01 20					
20.59.90	Manufacture of other chemicals (Ethanol production plant)	Borlanda, organic by-product	organic	02 03 99	Animal breeders	A	01.19.90	Input for the production of forage as a fertilizer	(Jacobsen, 2006; Mirata et al., 2017)
		Organic by-products (waste edible oil)		16 03 06	Biogas production plants	E	38.21.09	Input for biogas production	
		Pure CO2 from fermentation	waste gas	02 07 02	CO2 plant	C	20.11.00	Input to produce liquid carbonic acid, biogenic product	
21.20.09	Manufacture of medicines and pharmaceutical preparations (pharmaceutical Industry)	Waste water	utilities		Farm	A	01.13.20	Fertilizer	(Chertow et al., 2008)
		Biomass	organic	16 03 06	Local farmers	A	01.61.00	Fertilizer to improve the quality of the soil	(Jacobsen, 2006)
23.14.00	Mineral processing: manufacture of glass fibers	Blast furnace slag	nonorganic	10 08 04	Cement production	C	23.51.00	Input	(van Beers et al., 2007)
23.20.00	Mineral processing: Manufacture of refractory products	Blast furnace slag		10 08 09	Cement production	C	23.51.00	Input	
23.31.00	Production of Reggio and Modena porcelain stoneware	Porcelain stoneware sludge		08 02 02 10 12 13	Plants for the production of bricks	C	23.32.00	Replacement clay input	(Rambaldi et al., 2007)
23.32.00	Mineral processing: manufacture of terracotta building materials	Blast furnace slag		10 08 16	Cement production	C	23.51.00	Input	(van Beers et al., 2007)
23.44.00	Mineral processing: manufacture of other ceramic products for technical and industrial use	Blast furnace slag		10 08 18	Cement production	C	23.51.00	Input	
23.51.00	Cement production	Coal ashes		10 01 02 10 01 03	Construction companies	C	23.32.00	Input	(Cypriano et al., 2018)
23.52.10		Lime kiln dust			Cast iron production	C	24.10.00	Input	

(Continues)

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
	Lime production: Kilns for lime production			10 13 06				(van Beers et al., 2007)
23.62.00	Manufacture of plaster products for construction: Plasterboard production plant	Plaster scrap		10 13 04 10 13 06 17 08 02	Local farmers	A 01.61.00	Fertilizer to improve the quality of the soil	(Jacobsen, 2006)
23.70.10	Sawing and processing of stones and marble: Granite polishing plants	Polishing residues of granite		01 04 13	Local construction company	C 23.32.00	Input for foundation material	(Bain et al., 2010)
23.70.30	Mineral processing: Crushing of various stones and minerals not in connection with the extraction	Blast furnace slag			Cement production	C 23.51.00	Input	(van Beers et al., 2007)
24.10.00	Iron and steel industry – Manufacture of iron, steel and ferro-alloys: Electric arc furnace for the production of steel bars	Slag of iron oxides, calcium, silicon		12 01 01 12 01 02 12 01 03 12 01 04 12 01 13	Asphalt production	C 19.20.40	Input	(ENEA, 2017)
	Iron and steel industry – Manufacture of iron, steel and ferro-alloys: Steel Production Process	Blast furnace slag		10 02 01 10 02 02 10 02 10	Cement production	C 23.51.00	Input	(Cypriano et al., 2018)
	Iron and steel industry – Manufacture of iron, steel and ferro-alloys: Chemical refining of steel	Slag		10 02 01 10 02 02	Lime production	C 23.52.10	Input	(ENEA, 2017)

Waste producer			Waste exchanged			Waste user				
NACE 1		Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
					10 02 10					
		Iron and steel industry – Manufacture of iron, steel and ferro-alloys: Electric arc furnace for the production of steel bars	Steel powders containing zinc		10 02 99 10 09 10 12 01 02	Zinc producer	C	24.43.00	Input for the electro extraction process of zinc	
		Iron and steel industry – Manufacture of iron, steel and ferro-alloys: Steel production process		utilities		Power plant	D	35.11.00	Input	(Cypriano et al., 2018)
			Exhausted gas	waste gas	10 02 99				Input for electricity production	
				utilities		Industrial gas producer	D	35.21.00	Input	
	24.43.00	Production of lead, zinc and tin and semi-finished products: Lead and zinc refinery	Zinc from the recovery of precious metals	metallic waste	10 05 99	Zinc refinery	C	24.43.00	Input	(Park et al., 2008)
			Copper from the recovery of precious metals		10 05 99	Copper refinery	C	24.44.00	Input	
	24.44.00	Copper and semi-finished production: Copper production plan	Steam	utilities		Paper production plant	C	17.12.00	Input	
	24.53.00	Casting of light metals: Aluminum foundry	Silica, alumina, fluoride waste	metallic waste	10 03 22 10 03 30 10 03 99	Plant Production of cement clinker	C	23.51.00	Fuel	(van Beers et al., 2007)
				non organic	10 03 30			24.42.00	Input	
	24.54.00	Casting of other nonferrous metals: Copper production plant by melting	Sulfur dioxide gas	waste gas	10 06 99	Zinc and lead refinery	C	24.43.00	Input to produce sulfuric acid	(Park et al., 2008)
D	35.11.00	Production of electricity: Cogeneration plant	Ashes	non organic	10 01 01 10 01 02 10 01 03	Local farmers	A	01.61.00	Soil leveling product	(Bain et al., 2010)

(Continues)

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
	Production of electricity: Cogeneration plant	CO2	waste gas	10 01 99	Serre	A 01.19.20	Input	(Herczeg et al., 2018)
	Production of electricity: Combustion of the electricity production plant	Sulfur treated	utilities			A 03.21.00	Input	(Chertow, 2007)
	Production of electricity: Power plant	Pretreated steam			Plasterboard production plant	C 19.20.10	Input	(Jacobsen, 2006)
	Production of electricity: Combustion filtering process	Ashes	nonorganic	10 01 01	Aggregate manufacturer for road construction	C 19.20.40	Input	(Zhu & Cote, 2004)
	Production of electricity: Coal Cogeneration Plant; Combustion filtering process; Power plant	Ashes; Ashes from coal combustion		10 01 02	Aggregate manufacturer for road construction	C 19.20.40	Input by aggregate; input	(Chertow, 2000; Jacobsen, 2006; Zhu & Cote, 2004)
	Production of electricity: Combustion filtering process; Power plant	Ashes; ash from coal burning		10 01 03	Aggregate manufacturer for road construction	C 19.20.40	Input	(Jacobsen, 2006; Zhu & Cote, 2004)
	Production of electricity: Thermal Power Plant	Steam	utilities		Calcium chloride plant; Soda production plant	C 20.13.09	Input	(Liu et al., 2015)
	Production of electricity: Thermal Power Plant	Steam			Plant producing potassium sulfate/ fertilizer	C 20.15.00	Input	
	Production of electricity: Cogeneration plant	Steam			Petrochemical industry	C 20.16.00	Input	(Chertow et al., 2008)
	Production of electricity: Power plant	Pretreated steam			Pharmaceutical plant	C 21.20.00	Input	(Jacobsen, 2006)
	Production of electricity: Thermal Power Plant; combustion filtering process	Ashes	nonorganic	10 01 01	Cement production [3]	C 23.51.00	Input for cement production; input	(Liu et al., 2015; Zhu & Cote, 2004)
		Ashes; ash from coal burning; fly ash		10 01 02				
		Ashes; ash from coal burning		10 01 03			Input	
	Production of electricity: Coal-fired power station	Fly ash		10 01 03	Cement and lime producer	C 23.52.1	Additive	(van Beers et al., 2007)

Waste producer			Waste exchanged			Waste user				
NACE 1		Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
		Production of electricity: Desulphurization process in the power plant	Industrial plaster		06 06 99	Plasterboard production	C	23.62.00	Replacement input to natural plaster	(Jacobsen, 2006)
		Production of electricity: Combustion of the electricity production plant	Scrubbed sulfur	waste gas	10 01 99	Plasterboard production plant	C	23.62.00	Gypsum wallboard	(Chertow, 2007)
		Production of electricity: Coal Cogeneration Plant	Ashes	non organic	10 01 02 10 01 03	Industrial landfill	E	38.32.30	Stabilizer for waste	(Chertow et al., 2008)
		Production of electricity: Thermal power plants	Heat; steam	utilities		Industrial processes	C	All	Energy avoiding on-site production	(Herczeg et al., 2018)
E	37.00.00	Collection and purification of wastewater: Wastewater treatment plant; Purifier	Waste sludge; gypsum	non organic	19 08 05	Local farmers	A	01.61.00	Input for soil bioremediation; input to reduce soil acidity	(Jacobsen, 2006; Zhu & Cote, 2004)
		Collection and purification of wastewater: Treatment plant	Waste water treated	utilities		Cement production	C	23.51.00	Process water; cooling water	(Hashimoto et al., 2010)
		Collection and purification of wastewater: Treatment plant	Waste water treated			Aluminum refinery	C	24.42.00	Water for washing sludge	(van Beers et al., 2007)
		Collection and purification of wastewater: Purification plant; Wastewater treatment plant deriving from the pharmaceutical industry	Wastewater; treated wastewater			Combined cycle gas plant; Cogeneration plant	D	35.11.00	Cooling water	(Chertow, 2000; Chertow et al., 2008)
		Collection and purification of wastewater: Wastewater treatment	Organic waste	organic	16 03 06	Biogas production plant	E	38.21.09	Input biogas	(Mirata, 2004)
	38.21.09	Treatment and disposal of other nonhazardous	Synthetic solvent-based fuel; tires	nonorganic	05 01 11	Plant Production of cement clinker	C	23.51.00	Fuel	(van Beers et al., 2007)

(Continues)

Waste producer		Waste exchanged			Waste user				
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2		Use	References
	waste: hazardous and combustible wastes								
	Treatment and disposal of other nonhazardous waste: Biogas production plant	Organic waste	organic	16 03 06	Special chemicals industry	C	20.15.00	Fertilizer input	(Park et al., 2008)
	Treatment and disposal of other nonhazardous waste: Incineration plant	Steam	utilities		Petrochemical industry	C	20.16.00	Input	
	Treatment and disposal of other nonhazardous waste: Local incinerators	Ashes	nonorganic	19 01 12 19 01 14	Cement production	C	23.51.00	Input	(Hashimoto et al., 2010)
	Treatment and disposal of other nonhazardous waste: Treatment plant	Semi-finished product from incinerator slag treatment			Cement production	C	23.51.00	Input	(Barberio & Morabito, 2013)
	Treatment and disposal of other nonhazardous waste: Incinerator	Heavy slag		10 01 15 19 01 12	Treatment plant	E	38.21.0	Input for semi-finished products	
38.32.10	Recovery and preparation for the recycling of metal waste and scrap: Paper recycling plant	Metal waste	metallic waste	19 10 01	steelworks	C	24.10.00	Input	(Hashimoto et al., 2010)
	Recovery and preparation for the recycling of metal waste and scrap: Appliance recycling plant	Plastic treated	nonorganic	19 12 04	Production of concrete formwork	C	23.61.00	Input	
	Recovery and preparation for the recycling of metal waste and scrap: WEEE treatment plant	Mixed plastic		16 01 19 19 12 04	Plastic pulverization plant	E	38.32.20	Input	(Marconi et al., 2018)
38.32.20	Recovery and preparation for the recycling of plastic material to produce plastic raw materials, synthetic	Plastic	nonorganic	16 01 19 17 02 03	Ammonia production	C	20.15.00	Fuel	(Hashimoto et al., 2010)

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
	resins: Plastic recycling plant			19 12 04				
				20 01 39				
	Recovery and preparation for the recycling of plastic material to produce plastic raw materials, synthetic resins: Plastic pulverization plant	Plastic powder	nonorganic	12 01 13	Plant producing plastic compounds	C 22.2	Input	(Marconi et al., 2018)
	Recovery and preparation for the recycling of plastic material to produce plastic raw materials, synthetic resins: Plastic recycling plant	Plastic	nonorganic	16 01 19	Cement production	C 23.51.00	Fuel	(Hashimoto et al., 2010)
				17 02 03				
				19 12 04				
				20 01 39				
				16 01 19	Steel production	24.10.00	Alternative blast furnace fuel to coal	
				17 02 03				
				19 12 04				
				20 01 39				
38.32.30	Recovery and preparation for recycling of municipal, industrial and biomass solid waste: Oil extractor plant	Residual coconut	organic	16 03 06	Farm – Dairy cattle breeding	A 01.41.00	Cattle feeding ingredient	(Bain et al., 2010)
					Farm – Breed–ng of other cattle and buffaloes	A 01.42.00		
					Farm – Breeding of horses and other equines	A 01.43.00		
					Farm – Camel and camelid breeding	A 01.44.00		
						A 01.45.00		

(Continues)

Waste producer		Waste exchanged			Waste user			
NACE 1	Description firm 1	By-product	Subcategory wastes	EWC	Description firm 2	NACE 2	Use	References
					Farm – Breeding of sheep and goats			
					Farm – Pig breeding	A 01.46.00		
					Farm – Poultry breeding	A 01.47.00		
		Dried coffee grounds		16 03 06	Clothing company and manufacturer of thermal insulators	C 13.30.00	Fuel for boilers	
		Oil extracted from biomass such as coffee grounds, coconut and sawdust		02 04 99	Soap maker	C 20.41.10	Input	
		Dried coffee grounds		16 03 06	Garment company and manufacturer of thermal insulators	C 23.43.00	Fuel for boilers	
	Recovery and preparation for recycling of municipal, industrial and biomass solid waste: Organic products treatment plant	Biomass residues such as rice husk, coffee grounds, coconut shells and peanut shells	nonorganic	03 03 05	Cogeneration plant of the paper mill	C 23.51.00	Input	
				03 03 11	Cement production		Replacement clay input	
			organic	02 01 03	Cogeneration plant of the paper mill	D 35.11.00	Fuel to produce electricity	
				02 04 99				

APPENDIX D: Feasible IS exchanges in the provinces of Foggia, BAT, Brindisi, Taranto, and Lecce

	Waste producer				Waste exchanged		Waste user				
Province	NACE code		Description of the manufacturer	N°	Refusal	EWC code	NACE code		User company description	N°	Use
Foggia	A	01.63.00	Activities following the harvest	108	Wheat straw	02	D	35.11.00	Electricity production	105	Biofuel
		03.21.00	Aquaculture in sea, brackish or lagoon water and related services	57	Seaweed waste	02	A	01.13.20	Agricultural cultivation and production of animal products, hunting and related services	285	Input for farmers as fertilizer
	C	10.13.00	Production of meat products (including poultry meat)	11	Salt from salting meat	02	N	81.29.91	Cleaning and washing public areas, removing snow and ice	15	Road anti-ice
		10.39.00	Processing and storage of fruit and vegetables	77	Fishing hazelnut shells	02, 16	E	38.21.09	Treatment and disposal of other nondangerous waste	6	Input to produce biogas
					Citrus waste	02, 16	C	13.20.00	Weaving	2	Input to extract cellulose
					Armellina hazelnuts fishing	02, 16		21.20.09	Manufacture of medicines and pharmaceutical preparations	0	Input for drugs
								20.42.00	Manufacture of toiletries: perfumes, cosmetics, soaps and the like	8	Input
		11.02.20	Production of wine from grapes	98	Marc	16	C	11.01.00	Distillation, grinding and mixing alcohol	3	Input
		11.05.00	Beer production	2	Wheat waste	02	A	01.30.00	Agricultural cultivation and production of animal products, hunting and related services	285	Mushroom growing substrate
		20.14.01	Manufacture of ethyl alcohol from fermented materials	1	Sulfur dioxide gas	10	C	24.43.00	Production of lead, zinc and tin and semi-finished	2	Input
		20.59.90	Manufacture of other chemical products nec	1	Borlanda	02	A	01.19.90	Agricultural cultivation and production of animal products, hunting and related services	285	Input for forage production as fertilizer
					Organic by-products	16	E	38.21.09	Treatment and disposal of other nondangerous waste	6	Input to produce biogas
		23.32.00	Manufacture of terracotta building materials	15	Blast furnace slags	10	C	23.51.00	Concrete production	0	Input
		24.43.00	Lead, zinc and tin production and semi-finished products	1	Zinc from the recovery of precious metals	10	C	24.43.00	Production of lead, zinc and tin and semi-finished	2	Input

(Continues)

Province	Waste producer				Waste exchanged		Waste user					
	NACE code		Description of the manufacturer	N°	Refusal	EWC code	NACE code		User company description	N°	Use	
		23.62.00	Manufacture of plaster products for construction	3	Chalk scrap	10, 17	A	01.61.00	Agricultural cultivation and production of animal products, hunting and related services	285	Fertilizer to improve land quality	
	D	35.11.00	Electricity production	105	Cold salted water		A	03.21.00	Aquaculture in seawater, brackish or lagoon and related services	57	Input	
					Steam		C	20.15.00	Manufacturing fertilizers and nitrogen compounds	2	Input	
								20.13.09	Manufacturing of other inorganic basic chemicals	2	Input	
								20.16.00	Manufacture of plastics in primary forms	3	Input	
					Ashes	10	C	23.51.00	Concrete production	0	Input	
								19.20.40	Manufacture of bitumen, tar and road emulsions	2	Input per aggregate for Road Construction	
								23.52.10	Lime production	1	Input	
					Chalk	06		23.62.00	Manufacturing of plaster products for construction	3	Natural chalk replacement input	
					Sulfur Treaty			23.62.00	Manufacturing of plaster products for construction	3	Natural chalk replacement input	
	E	38.21.09	Treatment and disposal of other nonhazardous waste	5	Steam		C	20.16.00	Manufacture of plastics in primary forms	3	Input	
					Ashes	19		23.51.00	Concrete production	0	Input	
					Organic waste	16		20.15.00	Manufacturing fertilizers and nitrogen compounds	2	Input	
BAT	B	08.91.00	Mineral extraction for the chemical industry and for the production of fertilizers	4	Used brine from bromine extraction		B	08.93.00	Salt extraction	0	Input	
	B	08.93.00	Salt extraction	1	Remaining targoum from salt extraction		B	08.91.00	Mineral extraction for the chemical industry and fertilizer production	0	Input	
	C	20.14.01	Manufacture of ethyl alcohol from fermented materials	1	Sulfur dioxide gas	10	C	24.43.00	Production of lead, zinc and tin and semi-finished	0	Input	
		23.70.30	Cutting, shaping and finishing of stones	187	Blast furnace slags	10	C	23.51.00	Concrete production	0	Input	
		23.70.10	Sawing and processing of stones and marble	167	Granite polishing residues	01	C	23.32.00	Brickmaking, tiles and other terracotta building products	1	Input for foundation material	

	Waste producer				Waste exchanged		Waste user				
Province	NACE code		Description of the manufacturer	N°	Refusal	EWC code	NACE code		User company description	N°	Use
	E	38.32.20	Recovery and preparation for the recycling of plastic material for the production of plastic raw materials, synthetic resins	10	Plastic	17,19,20	C	24.10.00	Steel - Iron, steel and iron steel fabrication	1	Alternative coal blast furnace fuel
								20.15.00	Manufacturing fertilizers and nitrogen compounds	3	Fuel
								23.51.00	Concrete production	0	Fuel
Brindisi	C	20.13.09	Manufacture of other inorganic basic chemicals	3	Cooling water		D	35.11.00	Electricity production	29	Water for boiler feeding
					Brine, used as cooling water		B	08.91.00	Mineral extraction for the chemical industry and fertilizer production	0	Input for bromine extraction
		20.14.01	Manufacture of ethyl alcohol from fermented materials	1	Residues	02	C	20.15.00	Manufacturing fertilizers and nitrogen compounds	1	Input for fertilizer production
		23.52.10	Lime production	9	Powders	10	C	24.10.00	Steel - Iron, steel and iron steel fabrication	1	Input for cast-iron production
Taranto	C	10.32.00	Production of fruit and vegetable juices	3	Citrus waste	02, 16	C	13.20.00	Weaving	1	Input to extract cellulose
		11.05.00	Beer production	2	Wheat waste	02	A	01.30.00	Agricultural cultivation and production of animal products, hunting and related services	65	Mushroom growing substrate
		20.14.01	Manufacture of ethyl alcohol from fermented materials	1	Residues	02	C	20.15.00	Manufacturing fertilizers and nitrogen compounds	1	Input for fertilizer production
		23.20.00	Manufacture of refractory products	2	Blast furnace slags	10	C	23.51.00	Concrete production	0	Input
		23.44.00	Manufacture of other porcelain and ceramic products	56	Blast furnace slags	10	C	23.51.00	Concrete production	0	Input
		23.52.10	Lime production	7	Powders	10	C	24.10.00	Steel - Iron, steel and iron steel fabrication	1	Input for cast-iron production
		24.10.00	Iron and steel industry - Manufacture of iron, steel and ferro-alloys	4	Demineralized water		D	35.11.00	Electricity production	27	Input
					Processing slags	10	C	23.52.10	Lime production	7	Input
								23.51.00	Concrete production	0	Input
					Powders			24.43.00	Production of lead, zinc and tin and semi-finished	0	Input for the zinc electro-extraction process
					Exhausted gas		D	35.11.00	Electricity production	27	Input for electricity and steam production
					Slag of iron oxides, calcium, silicon	12	C	19.20.40	Manufacture of bitumen, tar and road emulsions	2	Input for asphalt production

(Continues)

Province	Waste producer				Waste exchanged		Waste user				
		NACE code	Description of the manufacturer	N°	Refusal	EWC code		NACE code	User company description	N°	Use
	E	38.21.09	Treatment and disposal of other nonhazardous waste	5	Steam		C	20.16.00	Manufacture of plastics in primary forms	0	Input
					Ashes	19		23.51.00	Concrete production	0	Input
					Organic waste	16		20.15.00	Manufacturing fertilizers and nitrogen compounds	1	Input
		38.32.10	Recovery and preparation for the recycling of metal waste and scrap	38	Mixed Plastic	16, 19	E	38.32.20	Recovery and preparation for the recycling of plastic slathering for the production of plastic raw materials, synthetic resins	4	Input
					Processed plastic		C	23.61.00	Manufacturing of concrete products for construction	10	Input
		38.32.20	Recovery and preparation for the recycling of plastic material for the production of plastic raw materials, synthetic resins	10	Plastic	17,19,20	C	24.10.00	Steel - Iron, steel and iron steel fabrication	1	Alternative coal blast furnace fuel
								20.15.00	Manufacturing fertilizers and nitrogen compounds	1	Fuel
								23.51.00	Concrete production	0	Fuel
		38.32.30	Recovery and preparation for recycling of municipal, industrial and biomass solid waste	25	Sludge	03	C	23.51.00	Concrete production	0	Input
					Dried coffee grounds	16		13.30.00	Textile finishing	6	Fuel for boilers
								23.43.00	Manufacture of insulators and ceramic insulation pieces	0	Fuel for boilers
Lecce	C	11.01.00	Distillation, rectification and mixing of alcohol	8	Isopropyl alcohol	02	C	10.51.10	Dairy industry, sanitation, milk storage	43	Input for features
		17.11.00	Pulp manufacturing	2	Remaining wood litusing process	03	D	35.11.00	Electricity production	97	Fuel to produce electricity
		20.30.00	Manufacture of paints, varnishes and enamels, printing inks and synthetic adhesives	17	Solvent	08	C	21.20.09	Manufacture of medicines and pharmaceutical preparations	2	Input for drugs
		20.41.14	Manufacture of other organic basic chemicals nec	1	Effluent residues	10	C	20.15.00	Manufacture of fertilizers and nitrogen compounds (excluding compost)	0	Input for fertilizer production
		21.20.09	Manufacture of medicines and pharmaceutical preparations	2	Wastewater		A	01.13.20	Agricultural cultivation and production of animal products, hunting and related services	114	Fertilizer used by farms
					Biomass	16		01.61.00	Agricultural cultivation and production of animal products, hunting and related services	114	Fertilizer to improve land quality

Province	Waste producer			Waste exchanged		Waste user			
	NACE code	Description of the manufacturer	N°	Refusal	EWC code	NACE code	User company description	N°	Use
	23.51.00	Cement production	2	Coal ash	10	C 23.32.00	Brickmaking, tiles and other terracotta building products	1	Input
	23.52.10	Lime production	8	Powders	10	C 24.10.00	Steel - Iron, steel and iron steel fabrication	0	Input for cast-iron production
	23.70.30	Cutting, shaping and finishing of stones	204	Blast furnace slags	10	C 23.51.00	Concrete production	2	Input
	24.43.00	Lead, zinc and tin production and semi-finished products	1	Copper from precious metals recovery	10	C 24.44.00	Copper and semi-finished production	0	Input
				Zinc from the recovery of precious metals		24.43.00	Production of lead, zinc and tin and semi-finished	1	Input
	24.53.00	Casting of light metals	1	Caustic Soda	10	C 24.42.00	Aluminum and semi-finished production	11	Input
				Rejection of silica, alumina, fluoride		23.51.00	Concrete production	2	Fuel
	D 35.11.00	Electricity production	105	Cold salted water		A 03.21.00	Aquaculture in seawater, brackish or lagoon and related services	2	Input
				Steam		C 20.15.00	Manufacturing fertilizers and nitrogen compounds	0	Input
						20.13.09	Manufacturing of other inorganic basic chemicals	0	Input
						20.16.00	Manufacture of plastics in primary forms	2	Input
				Ashes	10	23.51.00	Concrete production	2	Input
						19.20.40	Manufacture of bitumen, tar and road emulsions	1	Input per aggregate for Road Construction
						23.52.10	Lime production	8	Input
				Chalk	06	23.62.00	Manufacturing of plaster products for construction	2	Natural chalk replacement input
				Sulfur Treaty		23.62.00	Manufacturing of plaster products for construction	2	Natural chalk replacement input
	E 37.00.00	Collection and purification of waste water	42	Treated wastewater		D 35.11.00	Electricity production	97	Cooling water
						C 24.42.00	Aluminum and semi-finished production	11	Water for washing sludge
						23.51.00	Concrete production	2	Process or cooling water

(Continues)

	Waste producer			Waste exchanged		Waste user				
Province	NACE code	Description of the manufacturer	N°	Refusal	EWC code	NACE code		User company description	N°	Use
				Waste sludge	19	A	01.61.00	Agricultural cultivation and production of animal products, hunting and related services	114	Input for bio-soil remediation
				Organic waste	16	E	38.21.09	Treatment and disposal of other nondangerous waste	5	Input to produce biogas
	38.21.09	Treatment and disposal of other nonhazardous waste	5	Steam		C	20.16.00	Manufacture of plastics in primary forms	2	Input
				Ashes	19		23.51.00	Concrete production	2	Input
				Organic Scraps -F138: F145	16		20.15.00	Manufacturing fertilizers and nitrogen compounds	0	Input