A European Vision for Industrial Symbiosis:

Recommendations for a successful European IS strategy

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Abstract

The study tries to examine the steps that need to be taken in order to achieve a European strategy for industrial symbiosis (ESIS). Conclusions are drawn upon a large pool of scientific studies on the topic as well as best practices. Important factors being discussed are benefits of industrial symbiosis and obstacles that hinder its creation, as well as social factors and networking. The study presents the development of industrial symbiosis in Europe and highlights the UK "National Industrial Symbiosis Programme" (NISP) as an innovation and promising best practice for the widespread implementation of industrial symbiosis across Europe. This is why the study argues that the EU has to take the role of a *coordinator of coordinators* by following a subsidiary approach, promoting the implementation of national industrial symbiosis programs in all Member States and generally focusing on the creation of a context in which IS network can sprout bottom-up through self-organization. Concrete measures include turning into law provisions from the 2015 Circular Economy (CE) Package and taking inspiration from the 2009 Chinese CE law, plus clearing regulatory issues concerning the waste status of by-products. The EU should assist Member States in providing their national IS programs with sufficient budget and provide a European database containing knowledge, information and material stream data, which businesses interested in IS ventures can make use of.

Key words: industrial symbiosis, widespread implementation, European strategy, NISP, middle-out approach, obstacles, organization

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List of acronyms

CCC- Competitive-cum-cooperative

CE - Circular Economy

DG - Directorate General

EIP(s)- Eco-industrial park(s)

ERDF - European Regional Development Fund

ESIS - European Strategy for Industrial Symbiosis

IE- Industrial Ecology

IS - Industrial Symbiosis

MS(s) - European Union Member State(s)

NISP- National Industrial Symbiosis Programme

SMEs - Small and medium-sized enterprises

TFEU - Treaty on the Functioning of the European Union

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1. Introduction

Resource scarcity, Europe’s dependency on energy from unstable regions, environmental pollution and climate change are challenges that require innovative approaches to conservation and cooperation in the industrial sector. One of these innovations is industrial symbiosis (IS),[1]which is a concept within the framework of industrial ecology and circular economy thinking. Industrial symbiosis features the exchange of by- and waste products, making one firm's output another firm's input, thus fostering resource efficiency and a stable flow of energy among the participating industries, and ultimately yielding environmental as well as economic benefits.This study tries to make concrete policy recommendations that aim at the creation of a European Strategy for Industrial Symbiosis (ESIS). ESIS is supposed to promote the widespread implementation of industrial symbiosis in Europe.

1.1 Background and relevance

There has been a lot of research on the concept of industrial symbiosis since the turn of the millennium. Scholars tried to map the pro and contra of IS, resulting in a large amount of papers praising its benefits, with saving valuable resources like energy, water and raw materials and reducing waste production being the most cited ones.The majority of studies, however, have focused on the reasons for the emergence of industrial symbiosis networks and the question why there are so few examples of successfully implemented IS networks if IS really is such a promising concept.

Chertow (2000) defined IS as the collaboration of "traditionally separate industries" that benefit each other through the physical exchange of materials, water, energy and by-products, and this definition has been cited commonly in literature addressing this topic. In 2012, Lombardi and Laybourn proposed to the academic community an updated definition of the concept, which broadened some previously narrowly defined requirements for successful IS development (Lombardi and Laybourn, 2012). They claimed that geographic proximity is neither a necessary nor a sufficient factor for the emergence of IS networks. According to the scholars, “IS engages diverse organizations in a network to foster eco-innovation and long-term culture change” (Lombardi and Laybourn, 2012). They also claimed that networking serves the creation and sharing of knowledge, leading to “mutually profitable transactions for novel sourcing of required inputs and value-added destinations for non-product outputs” while enhancing technical processes and business management (Lombardi and Laybourn, 2012). The academic community describes IS as a beneficial concept, from both an

[1] Industrial symbiosis is a concept originating from industrial ecology that implies a collective engagement of traditionally separate industries towards business and environmental management while including exchanges of materials, by-products, energy or water (Chertow, 2000). While I am aware that the abbreviation ‘IS’ is not restricted in its scope to industrial symbiosis, but also employed in different contexts, I follow the convention common in industrial ecology literature of using ‘IS’ as the abbreviation for industrial symbiosis.

environmental and economic point of view. Additionally, studies found that roughly 70% of all synergies included innovative technologies or production processes and 20% involved new R&D (EREP, 2014). Hence, any study contributing to the exploration of this concept can be regarded as relevant to societal welfare. The European Union showed great interest in IS's job-creating potential and in its capability to foster eco-innovation and green growth. There is, however, yet no clear outlook on the role the EU could play in the European scale development of the concept. In order to achieve the vision of large scale industrial symbiosis, experts of the field argue that they require the support of institutions with worldwide reach. While there have been studies on the role of coordination bodies within IS networks, the responsibility of the European Union and the benefits yielded by a European industrial symbiosis network are yet relatively untouched by scientific research and this study argues that the EU could assume the role of the actor required in order to deliver large scale IS. This study aims at advancing the state of knowledge in this regard by making concrete proposals on how to foster a European vision for industrial symbiosis through ESIS.

A problem that yet remains in IS research is how to govern cross-border symbioses in industrial regions that transcend national borders, such as in the Gulf of Bothnia Region, described by Salmi, Hukkinen, Heino et al. (2011). As this study addresses the ways in which the European Union can promote a Pan-European industrial symbiosis network, it may contribute to providing solutions for this problem.

1.2 Research Question

Research and stakeholders reached consensus in regarding industrial symbiosis as a favorable way of doing business and as an accelerator of green growth. Hence, the question that remains is how to enable the rapid and large scale industrial transition (International Synergies, 2016). As mentioned when discussing the scientific relevance of this study, there is yet no clear path for the EU to follow in order to achieve a European industrial symbiosis network. This study proposes the way towards a European industrial symbiosis strategy and in doing so, tries to identify concrete measures that can be undertaken by the EU in order to approach such a strategy. Therefore, the overall research question of this paper is:

How can the European Union enable a rapid and large scale industrial transition towards IS?

As was outlined in the introduction, there seems to be a set of obstacles keeping industrial symbiosis networks from emerging in a larger quantity than the few empirical examples known to researchers of industrial ecology. This study includes a collection of common barriers to IS development, which is a necessary step because only if the barriers are known, concrete counteraction by the EU can be proposed. Consequently, the study tackles the following sub-question:

Which obstacles for the implementation of industrial symbiosis exist in Europe in 2016?

The theory section will point out the issue of organization and coordination with regard to industrial symbiosis networks, and networks in general. Hence, the way how a Pan-European IS network would have to be organized and actually look like requires clarification, as well.

How would a Pan-European industrial symbiosis network have to be organized?

2. Theoretical foundation of the analysis

The concept of industrial symbiosis is embedded within the studies on the transition towards a circular economy. The Circular Economy involves a restructuring of the traditional way of conducting business and industrial processes, which is where the implementation of industrial symbioses tries to provide a contribution. The Circular Economy promotes the importance of reverse cycle logistics, that is, processes that manage "reuse, refurbishing, remanufacturing and recycling" (Ellen MacArthur Foundation, 2013). In this respect, the continuous development of industrial symbiosis or symbiotic structures can yield valuable insights.

The study is a contribution to the research on industrial symbiosis, which in itself is a sub-category among studies on industrial ecology. Industrial ecology, as introduced by Frosch and Gallopoulos (1989) is a field of study that postulates that the efficiency of the current industrial system could be improved if it were oriented more strongly towards naturally occurring biological ecosystems. Industrial symbiosis makes use of this biological sphere and transfers the interaction within biological ecosystems to interactions among firms (Chertow 2000). Lombardi and Laybourn (2012) define IS as "a phenomenon where organizations engage in non-traditional transactions to find beneficial uses for underutilized resources (in particular, materials, by-products water and energy) with environmental or economic benefit". Whereas Chertow (2000) held that geographic proximity and the exchange of physical resource be necessary conditions for symbiotic structures, Lombardi and Laybourn (2012) backpedaled from these narrow definitions and rejected them as indispensable factors, while, however,not neglecting the facilitating feature of geographic proximity. The researchers developed further the idea of creating symbiotic structures through non-physical exchanges (while also including physical exchanges in their study). Industrial symbiosis thus can be understood as a modular concept, that is, different layers of inter-relational ties that add up and eventually become a full-fledged industrial system of inter-related companies, where the removal of one contributor may result in great harm to the whole system.

The wider approach of understanding towards industrial symbiosis promises to provide networking opportunities with regard to non-physical collaboration. For instance, Simboli et al. (2013), find inefficiencies in current waste disposal mechanisms of the network they analyzed.

Instead of each industry having their own location for waste disposal, firms could collaborate and gather waste in a joint spot. A necessary condition for this opportunity to be enabled certainly is that at least two of the firms being analyzed produce wastes of a similar kind.As mentioned earlier, Chertow (2000) views heterogeneity as an indispensable trait. Nevertheless, especially with regard to joint waste management, heterogeneity could rather be regarded as an impediment. In addition to that, homogeneity of industries within a network promotes the use of secondary materials, for the probability of compatible material inputs and outputs is greatly increased.In this context, the term 'cascading' becomes important. According to Chertow (2008), cascading describes repeatedly using a resource in different applications, whereas in every continuous step, the resource will be of lower quality and lower value. However, this lower value of a resource has to be seen objectively, for from a subjective point of view, a firm might actually value the cascaded resource higher than the original resource.

In Chertow's (2007) study "Uncovering Industrial Symbiosis" the scholar examines a total of 27 industrial symbiosis projects with regard to their feasibility and success story. As was alsoconcluded by Simboli et al. (2013), Chertow finds planned IS projects to be less successful than those that emerge from self-organization, that is, due to opportunistic business decisions (mostly based on the prospect of long-term economic profit and stability) of the firms involved.She argues that firms engage in inter-firm relations in the prospect of economic benefits, that is, cost reduction, resource security, and eventually, profit maximization. Based on such "kernels of symbiosis" (Chertow, 2007), efforts could then be made to raise the already existing relationships to an even higher level of cooperation such as symbiotic networking. Here is where policy makers and planners come into play and where the design stage begins. The 'IS from scratch' method skips that first crucial step, and whereas free market dynamics are inherent to the evolution method, the designed IS would eventually collapse under the conditions of a free market. However, although Chertow (2007) and others have found empirical evidence for this scenario, Chertow also makes clear that there can be exceptions in which designed symbioses actually thrive. Such exceptions usually apply to those symbioses that center on chemical or petrochemical industry as their 'champion' (Chertow, 2007; Hewes & Lyons, 2008). Consequently, the focus should be on "uncovering" existing symbiotic structures rather than planning and building eco-industrial parks (EIPs) from scratch. Once they have been uncovered, efforts can be made to foster integration and strengthen these structures (see *figure 1*). Chertow (2007) then defines a three-step policy approach to the implementation of successful symbioses. The first step is to identify industrial areas that feature some form of symbiotic basis, such as the exchange of materials. These "kernels of cooperative activity" ought to be discovered and described. As a second step, technical or financial assistance should be provided in order to enhance interactions qualitatively and/or quantitatively, that is, the development of such kernels should be assisted. Thirdly, the kernels that have been supported should be used as bridges to realize the transition towards full-fledge symbioses.

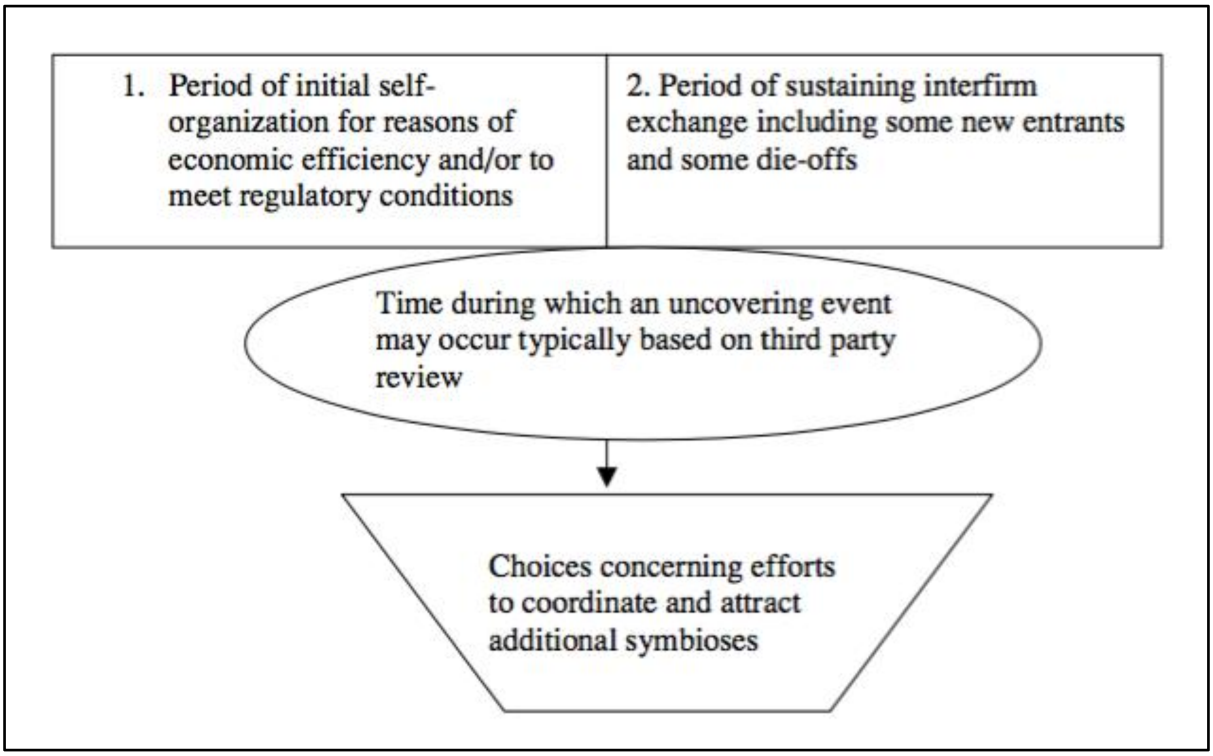

Figure 1: "Empirical findings of industrial symbiosis progression" (Source: Chertow, 2007)

2.1 The benefits of engagingin industrial symbiosis networks

In theory, industrial symbiosis is verybeneficial from an economic as well as environmental viewpoint. Due to the creation of a highly efficient loop system, firms save valuable resources and create less waste, which in turn saves costs, as the burden of waste management is lowered.These theoretical benefits have been confirmed empirically in various cases. Chertow and Lombardi (2005) tried to quantify the economic and environmental benefits of IS in a project in Guayama, Puerto Rico. The benefits were estimated "by measuring the changes in consumption of natural resources and in emissions to air and water" in the symbiotic arrangement. The researchers found a 99,5% reduction in SO_2 emissions and water savings of 4 million gallons per day. The local power station has savings of 1,2 million US-Dollars per year while the symbiosis' petrochemical company exhibits greatly decreased operating costs. Similarly, the UK's "National Industrial Symbiosis Programme" (NISP) helped achieve cost savings of over one billion GBP, while saving millions of tons of water and preventing millions of tons of carbon emissions from polluting the air (*please find more detailed results in table 4 and chapter 4.1.2*).The economic benefits of the famous Kalundborg symbiosis were calculated by Ehrenfeld and Gertler (1997). According to the researchers, the water savings account to 1,2 billion liters, while the use of coal and oil is reduced by 30.000 tons and 19.000 tons, respectively. Additionally, the various symbioses of the Kalundborg system account for the prevention of 130.000

tons of carbon dioxide, 1 billion liters of water treatment sludge and 2000 tons of sulfur dioxide wastes.

Next to cost savings and environmental good practice, IS networks are supposed to create a harmonious business environment based on trust and intimacy (Hewes and Lyons, 2008). Such networks aim at fostering reliable long-term structures, which in turn, lead back to cost savings through decreased transaction costs (Ehrenfeld and Gertler, 1997). Companies also want to increase competitive advantage by strengthening their 'green' profile, which opens the door to new markets.

2.2 Obstacles to industrial symbiosis

After the previous paragraph has provided an overview of the benefits of industrial symbiosis, one might ask why it has not yet been implemented across sectors all around the globe. If it is such a promising concept, why are there so few examples of successfully implementedsymbiotic networks? This paragraphwill shed some light on the obstacles to IS implementation as well as valid reasons why interdependence may not always be the superior option to independence.

Obstacles to IS development can be allocated into six different categories: 1) communicational barriers, 2) lack of trust, 3) individualism, 4) political/regulatory barriers, 5) technical barriers and logistics and 6) economic barriers. The absence of communication is a major issue and even occurs among companies linked through commercial relationships. Those companies that operate within highly competitive markets often are constrained by strict communication policies that interdict the sharing of valuable information with neighboring companies or external agents due to the fear of the competitor gaining competitive advantages over the own company. Such information might be input and output streams, however, it is exactly this kind of information that is required in order to reveal potential symbioses, so this is a real problem. The absence of communication inevitably leads to a lack of trust among the companies. Yet, as Hewes and Lyons (2008) point out, trust is the major enabler of network creation.A purely competitive environment may lead to companies not trusting each other, as revealing vital business details may always lead to being taken advantage of by the competitor. Hence, a coordination body may be required in order to foster communication and trust and its effectiveness has already been shown empirically (Chertow & Ehrenfeld, 2012; Ehrenfeld & Gertler, 1997; Mirata & Pearce, 2006). The predominance of an individualistic management approach, in parts caused by the former two obstacles, leads to the nonexistence of a common vision. The general assumption is that one firm's waste streams are not complementary with another firm's needs. Thus, they are literally regarded as wastes and disposed of individually or through a bilateral contract with a waste management firm. Again, the presence of a coordination body might improve this situation. Chertow (2008) identifies various regulatory obstacles such as restrictions of the free market tied with current environmental regulation. For instance, the free market exchange of by-products may be forbidden, for current environmental rules might only focus on disposal rather than the possibilities for reuse and recycling within another industry's production cycle. Issues regarding the definition of waste havealready been documented in empirical research. One example from 2002 is a Finnish industry complex, which faced severe bureaucratic problems when trying to replace the waste statusof a product with a by-product status in order to be able to trade it. The legal process eventually lasted over 6 years, which hints at another problem being such long and complex administrative processes (Salmi, Hukkinen, Heino et al., 2011). Furthermore, there may be an evident lack of stimulus on the part of the state, since despite recognized economic and environmental benefits for the respective firms, missing government incentives such as tax reductions or financial aid required to establishthe required infrastructure lead to restrained development of symbiotic structures among industrial networks. Instead of tax reductions on IS related activities, theory also suggests the other way round. An increased level of taxes levied from unsustainable practices, for instance, could also be a promising option. Technical barriers to IS generally refer to the quantity of waste streams, as large waste streams are required in order to generate exchanges that meet the demand of the exchange partners. In addition to issues of quantity, issues of quality may occur, as the chemical composition of the output stream needs to match the properties of the other firm's input stream. In a free market setting, a lack of quality will result in the buyer searching for a supplier that better suits its needs. In order to enable the transfer of material and energy, the firms need to provide the necessary infrastructure Transportation may also pose an impediment to IS and its impeding effective generally increases the farther apart the partners are located. When dealing with hazardous waste, the transport costs may exceed the eventual benefits due to having to comply with regulatory issues. Ultimately, there are economic impediments, which generally relate to the lack of profitability through cost savings created by exchanges and the "inability to generate additional value beyond the actual cost/benefit of the transaction", as firms fail to capitalize on environmental gains (Domenech Aparisi & Davies, 2009). That is, when symbiotic relationships are beneficial only from an environmental perspective and yield no increased economic benefit, then the firm will very unlikely sacrifice its independence to seek IS. Furthermore, transaction costs rise as firms have to comply with regulatory requirements and face increasing transport costs. Consequently, firms have to consider short term costs and benefits as well as long term costs and benefits in order to make the right decision. Some companies even fail to recognize the profitability of enhanced environmental performance, which, as mentionedin the previous paragraph, leads to the accession intonew markets.

2.3 The issue of interdependence

The inevitable result of industrial symbiosis arrangements is a certain degree of interdependence, which may vary according to the degree of connectedness and depth of the network. Interdependence is a crucial factor in the development of symbioses, since its positive and negative effects on doing business have to be weighed up against each other and there is not always a clear prevalence of advantages nor disadvantages resulting from interdependency but instead sort of a trade-off. There are obvious disadvantages to interdependency, such as lock-in scenarios in which firms find themselves stuck in a worse deal than they might strike with a third party from outside the network. For the sake of the common interest which the network considers more important than individual desires,firms have to refrain from switching suppliers for purchasing cheaper materials. Another aspect worth considering is the total dependency of one's production capacity on another company, as well as the dependency on another company taking one's output.If one part of such a perfectly complementary system is removed, the whole system mightcollapse unless quick counteractive action istaken. However, if interdependency is embedded in long term oriented stable structures,being part of an interdependent network also holds valuable benefits for individual companies. First of all,company A will not need to worry about selling its by-products or waste since company B is dependent on company A inasmuch as A is on B (or another company of the network) and hence, company B will stay a certain customer. In theory, interdependency creates a perfect loop. Company A wants to keep producing, but in order to continue its production it may be dependent on another company's resource, which, in turn, is dependent on company A keeping up the production. Vendors do not break away, creating sort of a safety net for each producer as well as overall economic growth. The existence of interdependent networks also leads to the sharing of responsibilities and facing problems as a united actor rather than a mere individual.One could compare being part of an IS network to being a Member of the EU. A membership yields undeniable benefits which are, however, paid for by losing sovereignty. One has to abide by the rules, respect the needs of the others and decide about important matters as a collective. After having been integrated, it is impossible to return to the status quo ante without causing harm for both sides, the individual and the network.

However, it has to be mentioned that this view on interdependence is, in fact, an individualist point of view. While from an individualist point of view, interdependence decreases independence, it increases independence when a collectivist view is applied. Moving somewhere between transitioning towards green energy solutions and decreasing its dependence on Russian and Middle Eastern energy sources, Europe finds itself in the middle of a discussion on how to achieve energy autonomy. The concept of industrial symbiosis is capable of contributing a big deal to reaching energy autonomy, at least in the industrial sector, which however, represents a quarter of final energy consumption in Europe (Statistical Pocketbook, 2015). Depending on the savings on transportation achieved through direct material exchange in symbiotic arrangements, IS's impact on energy autonomy could be even greater (Statistical Pocketbook, 2015). Consequently, there will have to be a shift to a new, more collectivist mindset with regard to conducting business in a resource scarce economy.

2.4 *Social factors and the role of champions*

Although industrial symbiosis may appear to be a highly technological enterprise, most studies found social factors to be playing the more important role in its development. When referring to the way towards successful networking, the literature often mentions the concepts of trust and social embeddedness. Trust refers to the literal concept of trust, i.e., a high degree of trust among business leaders (and public sector actors) is regarded as an accelerator or even enabler of industrial symbiosis, whereas a lack thereof impedes the creation of any interdependent relationship whatsoever. Trust is vital to cooperative business, as it transforms uncertainty into risk (Yap & Devlin, 2016). Domenech Aparisi & Davies (2009) identify four conditions that allow trust to emerge: firstly, all participants must believe in their actions being based on common values. These common values require translation into common goals that ought to be achieved. Thirdly, the network needs a common sense of solidarity that is in accordance with the members' expectations. Ultimately, trust must be reinforced by past action and empirical evidence. There are other factors that can positively affect trust among network members, such as the homogeneity of a group and the degree of connectedness (Chertow, 2000; 2007; Domenech Aparisi & Davies, 2009). The size of a network seems to exert a negative effect on trust because homogeneity and connectedness tend to be reduced. Furthermore, the sharing of a common history is an important enabler of trust and an empirically proven accelerator of integration in symbioses that feature waste and by-product exchange (Domenech Aparisi & Davies, 2009). By trying to address these social factors, the partners contribute to increasing mental proximity, that is, they ideally end up thinking as a collective actor rather than different individuals, mostly in terms of goal achievement and collective decision-making (Ehrenfeld & Gertler, 1997; Gertler, 1995). Increasing mental proximity requires a steady flow of extensive information about the project and each other.

According to Domenech Aparisi & Davies (2009), the embeddedness of networks can be defined using three main features: trust, extensive information transfer and joint problem solving. Embedded networks are more flexible and can adapt faster to a changing business environment. Consequently, they gain competitive advantages over other forms of governance.

Moreover, theory suggests that deeply integrated networks cannot come into existence without the presence of so-called champions. Hewes & Lyons (2008) define champions as "leading advocates of industrial symbiosis", that is, highly proficient experts of the field that have gathered experience in how to implement symbiotic networks in a successful fashion. Valdemar Christensen who managed the Asnaes Power Plant in Kalundborg and who played a major role in the development of the world famous Kalundborg industrial symbiosis and later helped develop IS projects in Ukraine, as well as Peter Lowitt who worked as the town manager of Londonderry, New Hampshire, and who pushed the development of the Londonderry EIP were exemplified as two champions in Hewes & Lyons (2008). Their paper emphasizes the role champions play in the development of IS, arguing that while champions may leave the project at an advanced stage with the project being continued anyway, champions are essentialin getting a project started in the first place. The projects initiated on the basis of the Kalundborg experience in Ukraine and New Hampshire are not the only empirically reported champion-led projects. More modern examples include the NISP in the UK as well as its copies that have sprouted in more than 30 countries across the globe and show resilient growth. This leads to the notion that a Pan-European IS strategymay also require the guidance of one or even multiple champions in order to be a promising project.

Mirata and Pearce summarized a set of interrelated factors that emerge from different areas as well as their potential impact on industrial symbiosis networks.

Category	Elements constituting the factors	Potential implications for IS networks
Informational	- Hesitance to disclose information - Availability of timely and reliable information from a wide spectrum of areas to the right parties - An information management system systematically monitoring changing dynamics and assessing the desirability and feasibility of options	- Possibilities to identify synergies - Possibilities to operationalize synergies - Risk perception of companies
Organizational & motivational	- Trust - Openness to each other and to new ideas - Risk perception - Intensity of social interaction - Mental Proximity - Decision power - Organizational history	- Presence/creation of the necessary institutional framework for collaboration - Development of synergies - Maintenance of synergies
Political	- Overarching environmental policies - Nature of laws and regulations - Taxes, fees, fines, levies - Subsidies, credits	- Incentives to develop and adopt environmentally desired technologies and practices, and to form symbiotic linkages
Technical	- Physical, chemical and geographic attributes of in- and output streams - Processing, utility (energy & water), logistics, and managerial needs & capacities - Availability of reliable and cost efficient technologies to enable synergies	- Number and diversity of potential symbiotic linkages - Extent of environmental, economic and social gains synergies may provide - Extent of investment & effort required to develop and maintain synergies
Economic & Financial	- Cost of virgin inputs, economic values of waste & by-product streams and the impact of political elements - Cost savings, revenue generation potentials - Amount of necessary investment and cost of maintaining synergies (including transaction and opportunity costs)	- Extent of economic advantage and competitiveness gained - Decisions of private companies - Necessity for alternative source of finance

Table 1: "Factors influencing the development and operational characteristics of IS networks" (Data source: Mirata & Pearce, 2006)

2.5 Organization of IS networks

IS networks can be regarded as a special form of industrial networks, but they are subject to the same theoretical models, nonetheless. The following chapter maps different types of governance and coordination mechanisms that can be found in organizational networks.

Okada (2000) differentiates three types of governance and their respective types of interaction. The two extremes are market governance (spot interaction) and hierarchical governance (internalized interaction) with competitive-cum-cooperative (CCC) governance (vertical/horizontal CCC interaction) striking a balance between the two. Spot interaction describes interactions that are based on a zero-sum game, not exerting any influence,whatsoever, on the next interaction. The frequent occurrence thereof results in interfirm relations and practices that fit into market governance, such as contract-oriented transactions, for instance, short-term contracts, auctions and self-liquidating sales, (Okada, 2000). Hierarchical governance refers to an organizational type in which intra-firm relations, measures and practices shaped by "the bureaucratic principles of control and coordination" harmonize a set of semi-independent actors (Okada, 2000). Hierarchical governance can be found in both vertically-integrated and horizontally-integrated companies, as well as in conglomerates. Long term relations between companies are found between the previously shown extremes and involve CCC interaction, which can be described as "a set of mutually influencing actions" that mix both cooperation and competition (Okada, 2000).

The author further distinguishes between horizontal and vertical CCC interactions, with the former being characterized by partial corporate interlocks in order to stabilize streams of resource and capital, stable long term contracting as well as continuous business transactions. Okada (2000) emphasizes the need for complementary companies or competitors to strike valuable alliances in a CCC governance setting. The latter, vertical CCC interactions, involves subcontracting systems, long-term relationships between large-sized enterprises and SMEs, as well as vertical keiretsu[2] (the keiretsu model is explained in more detail below*)*. The Japanese business culture features a high degree of human-relations-oriented social norms, that is, concepts such as trust are deeply integrated the organizational culture. Given the empirically proven importance of trust in the development of industrial symbiosis, models from the Japanese organizational culture may hence serve as best practices.

[2] The keiretsu is an organizational structure that comprises a set of interdependent companies. Whereas the horizontal keiretsu is characterized by power-symmetric interfirm relations, in which loosely bound large-sized companies of diverse complementary backgrounds cooperate, the vertical keiretsu features a power-asymmetric organization large-sized companies and SME foster close cooperation (Okada, 2000).

Types of governance	Types of interaction	Examples
A. Market governance		
	• Spot interaction	- Short term contracts - Spot-market contracts - Self-liquidating sales
B. CCC governance		
	• Horizontal CCC interaction	- R&D alliances - Franchise contracts - Corporate interlocks - Stable contracting - Joint ventures - Interfirm agreements - Licensing - Production alliances - Public ventures' contracts with private sector - Long term relationships between power-symmetric organizations
	• Vertical CCC interaction	- Subcontracting - Long term relationships between power-asymmetric organizations
C. Hierarchical governance		
	• Internalized interaction	- Vertically integrated companies - Horizontally integrated companies - Conglomerates

Table 2: Types of governance and interaction and their features (Data source: Okada, 2000)

The industrial symbiosis literature also discusses the importance of coordination mechanisms,focusing on symbiotic systems. According to Ehrenfeld and Gertler (1997), organizational arrangements among firms occur because of efforts to minimize transaction costs for each individual party. The Kalundborg symbiosis, for instance, developed through contracting and alliances that required little or no institutional intervention at all. In contrast to a pure market setting, such an organizational arrangement yields the benefits of long term certainty and stability.IS networks could be closer integrated by introducing the concept of common ownership in parts of the production process (Ehrenfeld and Gertler, 1997). Common ownership may, for instance, contribute to the facilitation of waste exchanges. If wastes that constitute vital exchange streams to the system are attributed common ownership instead of being one individual firm's responsibility, the exchange thereof could be safeguarded, as challenges such as providing sufficient infrastructure for material streams could be solved collectively (Salmi, Hukkinen, Heino et al., 2011). The Japanese *keiretsu*is mentioned as an example of such a cross-ownership organization in the exchange of by-products (Ehrenfeld and Gertler, 1997).The keiretsu ("grouping of enterprises" (The Economist, 2009)) is a cluster of interdependent companies in which the member companies hold parts of the shares in each other's company and which is centered on a core bank. In the Japanese economy, this organization is supposed to shield the companies from stock market fluctuations as well as takeover attempts, which creates a stable environment for long term projects and innovation (The Economist, 2009). Translated into the realm of industrial ecology, the keiretsu system could shield the members of the symbiosis from raw material price fluctuations and foster cooperative strategic planning among the parties.The mutual shareholding might also increase the general level of trust, as shareholding and vertical integration lead to more openness and insight into each other's plans. The core bank could constitute the coordination body of the symbiosis.

The concept of the highly integrated keiretsu isfamiliar to what Salmi, Hukkinen, Heino et al. (2011) refer to as common pool resource (CPR) governance. The idea of CPR governance is to decrease the risks posed by being exposed to open markets as well as waste management through a high degree of interdependency. CPR requires clearly defined physical and membership margins in order to establish a border between the actual members and third parties and should also apply proportional cost-benefit equivalence (Salmi, Hukkinen, Heino et al., 2011).Since the uncertainty about the distinction between waste and non-waste by-products is a major problem present in industrial ecology, CPR brings the potential remedy of a joint definition among the participating firms, which in turn decreases waste management risks and fosters by-product exchange streams.Additionally, CPR seeksto enhance the participation of the member industries in collective decision-making, hence fostering a more cooperative business culture in general. Market governance, however, implies being exposed to global markets in terms of volatile raw material prices and uncertainty about whether or not a certain material counts as a waste or rather an exchangeable by-product (Salmi, Hukkinen, Heino et al., 2011). Exposure to global markets is considered a threat to long term stability because thecrashing market price of an alternative natural resource can put a sudden end to material reuse on the part of the buyer and simultaneously cause the immediate need for extensiveby-product storage on the part of the seller. By joining the CPR governed IS network, the members would be able to share the risks posed by global markets and waste management, while at the same time enjoying the benefits that result from mutual by-product reuse and waste management (Salmi, Hukkinen, Heino et al., 2011). For the case treated in their study, the authors endorse "voluntary databases for by-products, long-term recycling contracts, by-product retailing, waste stock market arrangements, site-based waste retailing, tradable pollution permits" as well as natural resource banking as measures to share costs (risks) and benefits. Besides, they promote the understanding of a natural resource bank as an insurance type company, which provides an insurance against harmful future developments in exchange for a deposit. Alike the core bank in the Japanese keiretsu, the common insurance company could also serve as a coordination body. While the authors promote applying CPR for the Finland case treated in their study, they argue that CPR may not always be the preferable option and that the right coordination mechanism always depends on the individual case.

The importance of the role of the coordination body in symbiotic arrangements is widely acknowledged in the literature and has been subject to examination (Chertow & Ehrenfeld, 2012; Mirata, 2004; Mirata and Pearce, 2006;). The coordination body is the network entity that thinks beyond short term economic opportunities and plans ahead future developments of the network, thus creating long term sustainability (Mirata, 2004) and in most of the cases that have been analyzed empirically, the coordination body was either an industry association or a state agency, such as local authorities or municipalities (Yap & Devlin, 2016; Hatefipour, 2012). Such long term planning may include promoting the application of IE principles, such as increasing the share of renewables in the energy input, reducing environmental damage caused by production processes, etc. (Ellen MacArthur Foundation, 2013). Despite slightly deviating descriptions, the literature equally identifies three main areas of coordination body activity: a) the promotion of the IS concept and the exchange of information thereof through, e.g., network meetings, workshops and online data, b) the identification and implementation of synergies and cooperation, c) the creation of an institutional framework that facilitates cooperation and waste flows (Domenech Aparisi, 2010). It is vital for the coordination body to have the capacities necessary to channel its fellow member companies and to implement its ideas. Perhaps even more importantly, the coordination body needs to enjoy a certain degree of legitimacy and prestige among the members of the network in order to make decisions that are respected by the others rather than disregarded (Domenech Aparisi, 2010).

2.6 The middle-out approach of IS development

The middle-out approach was described by Costa and Ferrão (2010) in their case study on the IS development in Chamusca, Portugal. The aim of the middle-out concept is to create a favorable context[3] in which industrial symbiosis can thrive. This is achieved via the industry, governmental and academic institutions as well as other potential partners joining forces and creating a positive feedback process on the basis of successive interventions at different levels influencing different context factors (Costa and Ferrão, 2010). The concept is based on authors such as Mirata (2005) who pointed out the nature of the context as a highly influential factor in the development of spontaneous networks. According to Mirata (2005), the context can be affected via mindful interventions on the part of different agents, which usually take the form of coordinative measures and policies. The

[3] Context can be regarded as the socio-economic, technical and political conditions embedded in a geographical setting (Costa and Ferrão, 2010). If these factors are favorable to exchanges of waste and by-products, then the development of symbioses is considered to be more promising.

former is regarded as a short term tool and usually is provided for by academic institutions or business associations. The latter, policy, is a strong long term tool capable of influencing all context conditions across geographical areas (Mirata, 2005). There is, for instance, empirical evidence that the implementation of strong national environmental regulations incentivizes companies to develop solutions that meet regulatory objectives while simultaneously gaining competitive and economic advantages (Mirata, 2005).A major tool in this approach is monitoring, which is used in order to observe and analyze the effects of the interventions, with the information being fed back to agents, who in turn readjust their current plan or come up with further actions. The basic idea behind the approach is to integrate common bottom-up and top-down approaches, by facilitating the "uncovering process" (Chertow, 2007), since synergies in spontaneous networkstend to be "masked as normal commercial transactions" (Costa and Ferrão, 2010).

2.7 Major findings from the literature

So what can we draw from the literature presented in this chapter? The benefits of the IS concept are clear and can be quantified via thorough analysis of the individual projects (Chertow and Lombardi, 2005). Environmental damage can be prevented and costs can be saved in various domains, for instance, due to the cost advantage of recycled raw materials over virgin raw materials, reduced transaction costs and a declining cost burden associated with waste management and environmental pollution in the long term. Complex barriers, however, restrict the concept from being widespread and implemented more often. These barriers can be categorized as communicational barriers, lack of trust, individualism, political/regulatory barriers, technical barriers and logistical issues as well as economic obstacles. While interdependent networks may bring about considerable benefits, there can also be raised legitimate concerns about the issue of interdependence. Less flexibility, the shift from individual decision-making to collective decision-making as well as short term economic loss are factors that make enterprises question the suitability of IS for their business and prefer short term profits over long term stable growth. Social factors outweigh political and economic factors in their capability to enable industrial network creation. Trust among the cooperating firms and being embedded in social structures of the local community are aspects that can make the differencebetween success and failure of an IS venture. More importantly, trust cannot be created top-down, but grows from below and reifies in cooperative activities. Symbiotic relationships hence are not the peak of trust, but merely an illustration of trust and a condition through which trust can continue to thrive. IS literature also places a great deal of emphasis on the key role played by champions. Projects that are guided or led by experienced IS champions follow a much more clearlydefined strategy and have better prospects of success than projects that do not rely on the expertise of champions. Important theoretical input can also be drawn from the organizational structure of IS networks, the specific characteristics of which exert great influence on transaction cost and trust (Ehrenfeld and Gertler, 1997). Okada (2000) describes competitive-cum-cooperative (CCC) governance patterns that steer a middle course between hierarchical governance and market governance, and which aim at fostering long term alliances among firms.Coordination bodies are assigned a decisive purpose in IS networks. They foster the promotion of IS and the exchange of information through network meetings, workshops, online data and other instruments. They also assist networks with the identification and implementation of synergies and cooperative business strategies. Thirdly, they construct an institutional framework facilitating cooperation and the management of waste flows (Domenech Aparisi, 2010). Ultimately, there is the middle-out approach of IS as described by Costa and Ferrão (2010). The middle-out approach is characterized by successive interventions (mostly coordinative activities and policies) that aim at fostering a favorable context for IS network creation. These interventions represent a compromise between rigid top-down planning (EIPs) and the laissez-faire approach. Monitoring constitutes an important tool of this strategy, as interventions are monitored with regard to their effectiveness, and information feedback loops created among policymakers, academia and enterprises. As will be explained further below, this approach is of great interest for EU policymaking directed at an ESIS, since it combines purposeful interventionist policy with the traditional European ideal of a free market.

3. Research approach

The study is based on secondary research. The theoretical input provided by the industrial symbiosis literature presented in the previoussection serves as the groundwork for this study and for concrete recommendations that ought to help the European Union at promoting a European industrial symbiosis network. It includes mostly peer-reviewed scientific studies and European Union intelligence. The research is then conducted partly on the basis of the scientific framework and best practicesstemming both from relevant academic literature and online sources.

The theory has been selected according to its adequacy and value for policy recommendations to the EU. IS's benefits have been included in order to display why it makes sense for the EU to strive for an organized overarching IS network in the first place. The literature also provides an overview of common obstacles to IS implementation in order to obtain a guideline on what to look for when examining current obstacles IS development is facing in Europe in 2016. The issue of interdependency and the role of social factors such as trust and embeddedness both constitute crucial factors, as they - next to the previously mentioned obstacles - can be seen as the reasons for why IS hasyet been so rare despite its economic and environmental benefits. Consequently, including them becomes indispensable from a methodological perspective.The organization of IS networks is a very important aspect because organization and coordination concern the very heart of any industrial network and it is important to study the special dynamics of industrial symbiosis networks if one is to give valid advice on how to promote their formation. The middle-out approach by Costa and Ferrão

(2010) serves as the theoretical basis for the nature of the recommended EU actions. This is because, according to the literature, top-down planning is not much of a promising approach, and while it may in fact work in economies like China, it can hardly be expected to perform well in a border transcending economy such as the European common market. Since government bodies, nonetheless, are capable of accelerating IS network sprout through intelligent intervention and are well-advised to do so, this approach - out of the literature available on this topic - exhibits the best prospects of effectively realizing the EU's goal. This assessment can be stressed further when considering the importance of social factors to network creation and the observation that trust and embeddedness cannot be imposed from above but have to prosper from below, from a solid foundation which in turn, can be cherished by (EU)policymakers.

The analysis is conducted in three steps. Firstly, the development of the industrial symbiosis concept is presented. This chapter examines three European developments, beginning with the symbiosis in Kalundborg, Denmark, which is regarded as the first symbiotic industrial network ever and a focal point for much research on the topic.In order to fully understand the dynamics of industrial symbiosis development, the Kalundborg case must be referred to and this is why it is presented in this paper. It conveys valuable insights on the self-organizational aspect of IS networks in contrast to the planning of networks and, moreover, it provides the reader with practical understanding about what symbiotic relationships look like and which forms they can take in a real example. The development of the "National Industrial Symbiosis Programme" (NISP) in the UK constitutes the second model examined in this chapter andthe one that is attributed the highest importance regarding its value in promoting a Pan-European development, which this study aims at.ESIS is supposed to be built on the measures and the experiences of the NISP, analyzing NISP's characteristics hence is very important methodologically. Thirdly, the Iskenderun Bay symbiosis is presented, which is a recent project that resulted from the NISP having been exported to other countries. This project ought to serve as a representative of the success of the NISP's approach towards widespread IS implementation and underline NISP's status as the best practice in this respect.

In a second step,various conditions that, according to the literature, block the emergence of IS networks and that are present in Europe in 2016 are examined so that a clear problem-oriented strategy can be developed and remedies removing these obstacles can be discovered.

The research approach applied in this study is to use relevant literature in order to show how industrial symbiosis networks develop and to illustrate dos and don'ts for regulators that want to accelerate their formation. Afterwards, best practices are included in order to examine concrete steps through which the EU can trulycontribute to IS networking across its Member States.

The inclusion of best practices is a methodological core element of this study. Rather than inventing completely new measures that yet lack extensive scientific exploration and have no empirical groundwork, the idea is to find out what has already been done in other countries (MSs and third states) and which of these successful measures could be implemented in the widerEuropean context, as well.Ultimately, aspects of organization and coordination are discussed in order to provide an answer to the third question posed in this paper and to obtain a complete view of what a European Strategy for Industrial Symbiosis ought to look like.

4. Industrial symbiosis in Europe

The analysis is presented according to the methodological three-step explained in the previous chapter, including the development of industrial symbiosis in Europe, the existing obstacles to its further development and the way towards a European Strategy for Industrial Symbiosis.

4.1 The development of industrial symbiosis in Europe

The development of industrial symbiosis in Europe essentially began in Kalundborg, Denmark. It has been subject to extensive scientific research by scholars of industrial ecology and organizational management. It has, however, long been a unique phenomenon and various attempts to copy it have failed. The "National Industrial Symbiosis Programme" (NISP) can be regarded as the first systematic blueprint approach towards the widespread implementation of IS. It has already been exported into various countries worldwide, including Turkey. The NISP has risen to become the benchmark in the creation of IS networks inasmuch as that countries like France and Finland have already begun to adopt the concept by launching their own national industrial symbiosis programs (Brown, 2015).

4.1.1 Industrial symbiosis in Kalundborg, Denmark

The industrial symbiosis in Kalundborg, Denmark, is the project most referred to in the industrial symbiosis literature. It is the earliest reported case of an inter-firm eco-system and the very term 'industrial symbiosis' actually derives from the Kalundborg case (Ehrenfeld & Gertler, 1997). Located in close proximity to the port, the Kalundborg symbiosis represents a network of currently eight private and public enterprises(*seefigure 2*). Despite its well-developed eco-system, Kalundborg was not a planned project. Instead of having been designed, it rather developed over time in the course of opportunistic business decisions by the companies (Chertow & Ehrenfeld, 2012; Ehrenfeld & Gertler 1997). At this stage, especially the triad of the Statoil oil refinery, Asnaes Power Station[4] as well as pharmaceutical company Novo Nordisk has to be mentioned as the main motor of symbiotic integration (Ehrenfeld & Gertler, 1997). The arrangement at Kalundborg is depicted in *figure 2*, with energy streams, water streams and material streams being colored in red, blue and green, respectively.

[4] The Asnaes Power Station is a 1500 megawatt coal-powered power plant operated by DONG Energy. It is Denmark's largest power plant.

Asnaes provides plasterboard manufacturer Gyproc with gypsum made of scrubber sludge while Statoil and Novo Nordisk receive excess steam from the coal burning. Asnaes also feeds excess heat into the grid, which led to a wave of elimination of oil-fired residential furnaces. Statoil supplies cooling water as well as gas that is burned by the power plant. The gas derives from the refinery's production processes. However, due to its high content of sulfur, it needs to be desulfurized by Statoil prior to transport. The resulting liquid sulfur is trucked to Kemira, which does not belong to the symbiotic arrangement, though. The symbiotic ties can be categorized as energy, water and material flows. The Asnaes Power Station is the main source of energy of the symbiosis. Kalundborg features a vast water exchange network, as nearly all of the participating parties are either receiving or delivering some sort of water supply and hence connected to a common water cycle. While Novo Nordisk shares the energy flow among its subsidiaries, the plant itself also derives its energy from Asnaes. What is striking, however, is that the majority of material streams actually leave the loop arrangement and end up at various third party companies.

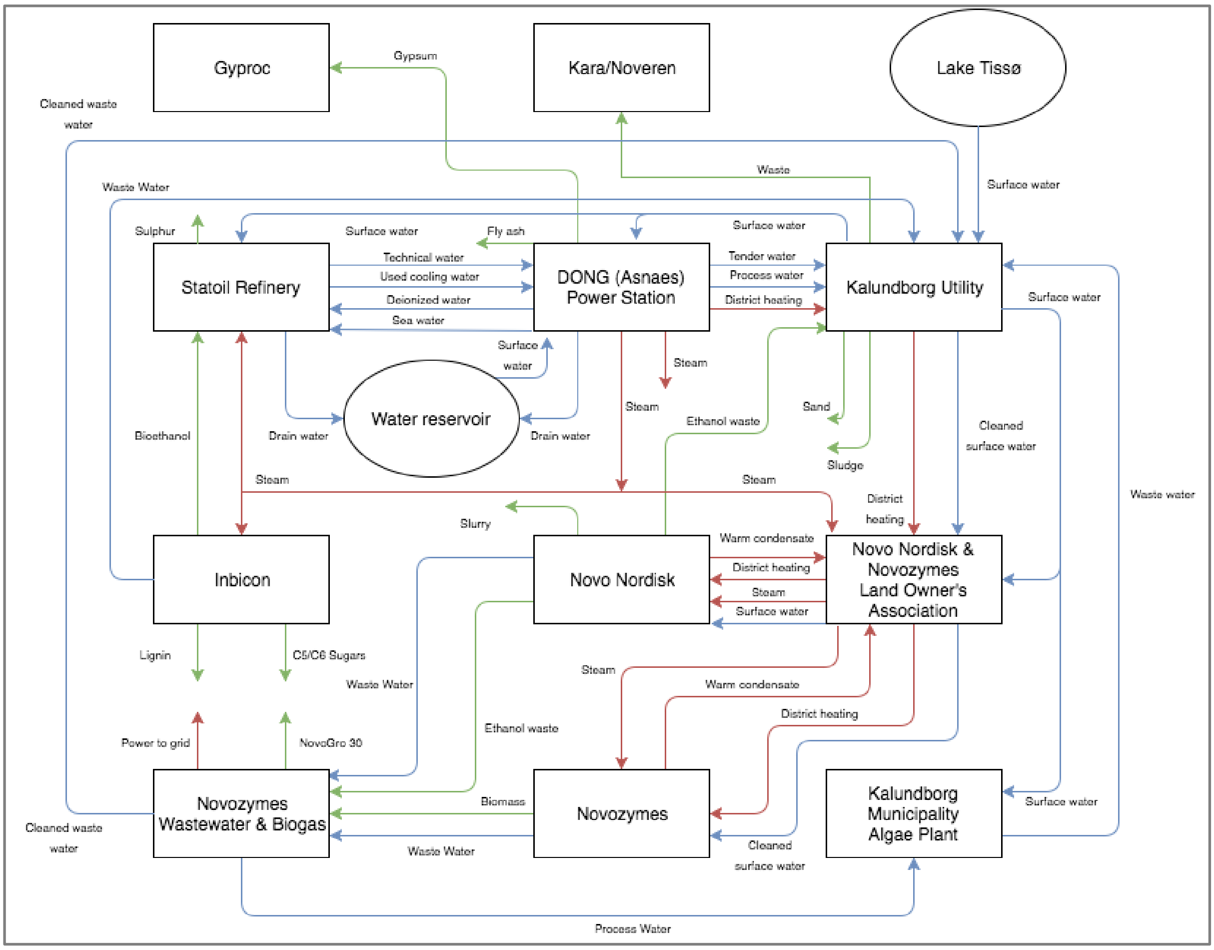

Figure 2: Illustration of the Kalundborg IS network (Data source: Kalundborg Symbiosis, n.d.)

Chertow referred to the Kalundborg case in multiple studies in order to provide further evidence for her claim that successful industrial symbiosis has to evolve rather than be planned

(Chertow 2007; Chertow & Ehrenfeld, 2012). Economic reasoning and opportunistic behavior in the prospect of reduced cost and increased resource security provided the impetus for Statoil, DONG and Novo Nordisk to engage in an ever closer interdependency (Ehrenfeld & Gertler, 1997). Gyproc, Inbicon and Kara/Noveren as well as the city of Kalundborg were added to the system over the course of its development. Yet, new potential members are evaluated strictly in terms of compatibility with the existing arrangement in order to ensure the symbiosis' further survival in the future.

4.1.2 The UK "National Industrial Symbiosis Programme"

The NISP was launched by IS champion Peter Laybourn in 2003 with the objective of implementing examples of industrial symbiosis across the UK. After it had been introduced merely to the West Midlands, Scotland and Yorkshire and the Humber, its immediate positive economic and environmental impact drew the attention of the Department for Environment, Food & Rural Affairs (Defra). In 2005, Defra decided to widen the scale of the program to the national level (Paquin & Howard-Grenville, 2012). NISP led to the development of a nationwide network, in which businesses from all industries could share their knowledge and expertise with regard to enhanced resource efficiency. International Synergies[5] was launched in order to provide the IS projects with expertise for a successful implementation of the concept (Laybourn, 2014). The main goal was a "collective approach to competitive advantage involving physical exchange of materials, energy, water and/or by-products together with the shared use of assets, logistics and expertise (Domenech Aparisi & Davies, 2009). After the successful implementation of the NISP in the UK, International Synergies began exporting the model around the globe in 2007, starting in Brazil, China and Mexico and, by 2016, has supported 30 countries in adopting their own NISP replications (Laybourn, 2016). Between 2005 and 2013, the NISP achieved cost savings of 1,1 billion, 1,4 billion in additional sales, the creation or protection of 10.000 jobs, the recovery and reuse of 45 million tons of materials, the reduction of industrial carbon emissions by 39 million tons (constituting 4% of the UK's industrial CO_2 emissions) plus industrial water savings of 71 million tons. Its network comprisesover 15.000 companies and public investments are rewarded by a rate of return on public funding of 9:1 (Laybourn, 2016).

[5] International Synergies Limited is an organization that provides industrial ecology solutions that aim at the transition towards the circular economy and specializes in the implementation of industrial symbiosis projects.

Benefits	Annual amount	General	5 year span
Cost savings to businesses (€)	243 million		1,21 billion
Increased sales for businesses (€)	234 million		1,17 billion
Jobs saved and created		10.000+	
Private investment (€)	374 million		
Landfill diversion (tons)	9,4 million		47 million
Carbon savings (tons)	8,4 million		42 million
Virgin raw materials savings (tons)	12 million		60 million
Hazardous waste eliminated (tons)	0,4 million		2,1 million
Water conservation (tons)	15 million		72 million
Companies engaged in network		15.000+	
Rate of return on public funding		9:1	

Table 3: Quantified benefits of the NISP (Data source: Laybourn, 2016)

According to International Synergies and their partners in the development of the symbioses, NISP's success derives mostly from its simplicity and its capability to foster trust and a cooperative approach among the project stakeholders (Paquin & Howard-Grenville, 2012). NISP follows a three-step approach of a) creating extensive information channels featuring data about inputs and outputs required by each stakeholder, b) analyzing the data with regard to potential synergies and (material) exchanges and c) promoting pilot projects that illustrate ever new possibilities of reuse, recycling and value addition to waste across different sectors and industrial processes (Domenech Aparisi & Davies, 2009). When it comes to the actual development of industrial synergies, NISP identifies five different phases: 1) identification of opportunities, 2) discussion, 3) negotiation of synergies, 4) implementation and 5) realization (*seetable 4*)(Domenech Aparisi & Davies, 2009). In phase one, NISP takes the role of the facilitator with regard to identifying possibilities for exchange and the role of the broker when identifying potential partners for the respective symbiosis. Matches can be found via the database, site visits to large companies generating extensive waste streams as well as through workshops in which potential can meet. These workshops, or 'quick wins' can be described as "industry speed dating", as each participating business simply writes down their supply and demand and tries to find a potential match among the other participating businesses (Paquin & Howard-Grenville, 2012). In the discussion phase, NISP once again serves purposes of facilitation and brokerage when examining the technical and economic feasibility of the identified exchange opportunities, which is based on analyses of the chemical and physical properties of wastes and the quantity in which the waste could be provided to a potential partner. Upon negotiating an agreement, the conditions of the exchange, such as price, quantity, continuity of waste streams and transport are discussed. However, at this stage NISP does not take the role of a broker, but rather of a facilitator and hence, is not involved in the actual negotiation of a commercial agreement between the stakeholders. Instead, NISP tries to reveal potential obstacles, be they of technological or regulatory nature. It then proposes concrete strategical measures to overcome such obstacles and also identifies partners that are required in order to overcome the problems. During the phase of actual implementation, NISP provides technological and regulatory support to the IS project, which, upon realization, is evaluated and then used as a case study, so that knowledge about the complete development process can be spread and used in order to facilitate the development of future projects.

Phase	NISP main tasks	NISP role
Identification of opportunities	Identify potential IS exchanges Identify potential IS partners	Facilitation Brokerage
Discussion	Analysis of technical and economic feasibility of potential exchanges	Facilitation Brokerage
Negotiation of synergies	Identification of potential obstacles (technological/regulatory) Propose strategies to overcome obstacles Identification of partners/solution providers	Facilitation
Implementation	Support (technological/regulatory)	Facilitation
Realization	Evaluation of project Production of case study, knowledge transfer	Facilitation

Table 4: Tasks and roles of the NISP during the five phases of IS development (Data source: Domenech Aparisi & Davies, 2009)

What makes the NISP distinct from previous attempts to implement industrial symbiosisis the application of a uniform methodology as well as a standardized data collection approach, which both apply in any project in any region whatsoever and hence, constitute a “blueprint” (Paquin & Howard-Grenville, 2012; The Economist, 2015). This makes it fairly simple to export the concept. While slight adjustments can be made according to the feedback from project regions, depending on the size of the network as well as the exchange streams in later stages of development, the general approach remains the same. The actual innovation that was born in the UK was, however, not the idea of industrial symbiosis (which was created in Kalundborg), but rather the system which supports it (European Commission, 2011). NISP applies a holistic systems approach that not only addresses material waste, water and energy, but also logistics, capacity and expertise (Laybourn, 2015).The main focus of the exported NISP model is capacity building, or as Peter Laybourn stated: “we train people in what we do and then we leave” (European Commission, 2011). This also adds a considerable level of comparability to the NISP concept and each new project provides chances for improving the model due to a continuous process offeedback loops, learning and best practices.

The fact that a conceptual design approach towards industrial symbiosis emerged in the UK of all countries is not just purely coincidental. There’s a set of influential economic and political drivers that served well as the fertile soil for widespread implementation of industrial symbiosis and other clean technologies by demanding a high level of resource efficiency (Mirata& Pearce, 2006;

Paquin & Howard-Grenville, 2012). First of all, there was competitive pressure to reduce costs which could be achieved through higher material efficiency during production processes. In addition to that, the International Standard for Environmental Management Systems (ISO 14001)[6] in combination with the European Eco-Management and Audit Scheme (EMAS)[7] drove the UK to adopt more sustainable practices across the whole supply chain. In 1996 and in 2001, the UK adopted the landfill tax and the Climate Change Levy (CCL), respectively. The landfill tax also served as a means to reach the goals of the EU landfill regulation which was ultimately introduced in 1999 and it served as the source of adequate public funding, which contributed to a large share to NISP's success (European Commission, 2011). These pieces of legislation and fiscal instruments drove the incentive towards recycling and reuse of waste materials as well as a more efficient use of energy for production processes. Another aspect is the downsizing of companies which happened especially in the chemical, paper and metal industrial sectors, which tend to fit well into symbiotic systems. The downsizing resulted in an inefficient resource usage, that is, the use of land, infrastructure, utilities and services (Mirata & Pearce, 2006).

What facilitated proper implementation further was the effective way the development was governed regionally via the regional development agencies (RDAs). Following the Regional Development Agencies Act of 1998, eight[8]RDAs were established and assigned the task to:

1. Foster economic development and regeneration
2. Promote competitiveness and supply chain efficiency
3. Promote employment
4. Enhance the development and application of skills relevant to employment
5. Stimulate sustainable development
6. Administer EU regional development funds.

According to Mirata & Pearce (2006), the RDAs showed high expertise and institutional capacity in fostering economic development but yet lacked actual development capacity on environmental functions and hence, working on a regional IS implementation approach was a welcome opportunity for the RDAs (Mirata & Pearce, 2006). The RDAs provided financial support as

[6] ISO 14001 is described as „the principal management system standard which specifies the requirements for the formulation and maintenance of an EMS". Benefits promised are improved environmental management, legal compliance, reduced operating costs, improved stakeholder relationships, proven business credentials as well as the ability to win more business for one's venture (NQA, n.d.).

[7] EMAS is an environmental management system that is built upon its three key elements performance, credibility and transparency and helps organizations strengthening their environmental profile. The European Commission has recognized ISO 14001 as a spring board for its EMAS and integrated the ISO 14001 environmental management system requirements as a crucial component (European Commission, n.d.).

[8] The eight RDAs were assigned to the eight regions of the UK. Being a special region, London received the London Development Agency (LDA), which was subordinate to the London Assembly and the Mayor of London. The eight RDAs were abolished in 2010 following the new conservative government's call for public sector budget cuts and the LDA's abolishment followed in 2012 (The National Archives, n.d.).

well as expertise for the projects initiated via the NISP. As the NISP's facilitation costs of roughly €6 million p.a. are covered by the government, government support in general played a crucial role in the program's success (Mirata & Pearce, 2006). The turn of the millennium hence accounted for a rare combination of very advantageous economic circumstances and well-aimed eco-environmental policies in the UK, which was seized through the collaboration of public and private sector entities and led to a successful methodological approach towards the widespread implementation of industrial symbiosis and still serves as a guiding light for current projects worldwide.

Despite its success and popularity, the UK government withdrew funding for NISP in September 2012 and forced the program to take on a subscription-based model in an attempt to cut public sector expenditure (Brown, 2012). Despite being grateful for having received government funding in the first place, program creator Peter Laybourn also referred to issues associated with relying purely on government funding, saying that the government started making proposals which industries should be worked with (Brown, 2012). Yet, ever since its creation, the NISP has been characterized via the opposite, its "open-house policy" (Brown, 2012), meaning that NISP does not give preference to the industries that promise to be most profitable, but rather pursues an engagement model, providingcross-sectoral support to companies of any size whatsoever.

4.1.3 Industrial symbiosis in Iskenderun Bay, Turkey

Within the framework of the project "Industrial Symbiosis Project in Iskenderun Bay - Implementation Phase", an IS project was launched in Turkey in January 2011 and completed in February 2014. The project was managed by the Technology Development Foundation of Turkey (TTGV) and assisted by stakeholders such as the Middle East Technical University, BTC Crude Oil Pipeline Company and International Synergies (Alkaya, Bögürcü, Ulutas, 2014; International Synergies, 2014). The venture was a direct result of the successful implementation of the NISP in the UK, which served as the blueprint for Iskenderun Bay, the system of which is illustrated in figure 3. In contrast to the Kalundborg case, the IS project in Iskenderun Bay relies heavily on material exchange streams. Another noteworthy aspect is that, while Kalundborg features sort of a give-and-take approach, that is, all but one partner both receive input and provide output to others, the Iskenderun Bay arrangement is less complex. In general, there are less streams connecting each other and, additionally, five out of 16 partners do not employ the give-and-take approach. However, it needs to be mentioned that the Kalundborg symbiosis has a much longer history of development than this young project in Turkey and, consequently, it can be assumed that the symbiosis in Iskenderun Bay will evolve over the course of the years to come (Alkaya, Bögürcü, Ulutas, 2014). The regional development agencies Trakya and BEBKA ("Bursa Eskişehir Bilecik Kalkınma Ajansı") have adopted industrial symbiosis as policy and practice and have been an indispensable factor throughout the development of the symbiosis (International Synergies, 2014).

Although this study covers merely one case of the NISP being exported to other countries, this case reinforces the claim that NISP be general enough to be exportable to other counties (International Synergies, 2014; Laybourn, 2014; 2016). This claim is an important assumption for the success of the European Strategy for Industrial Symbiosis proposed in this study.

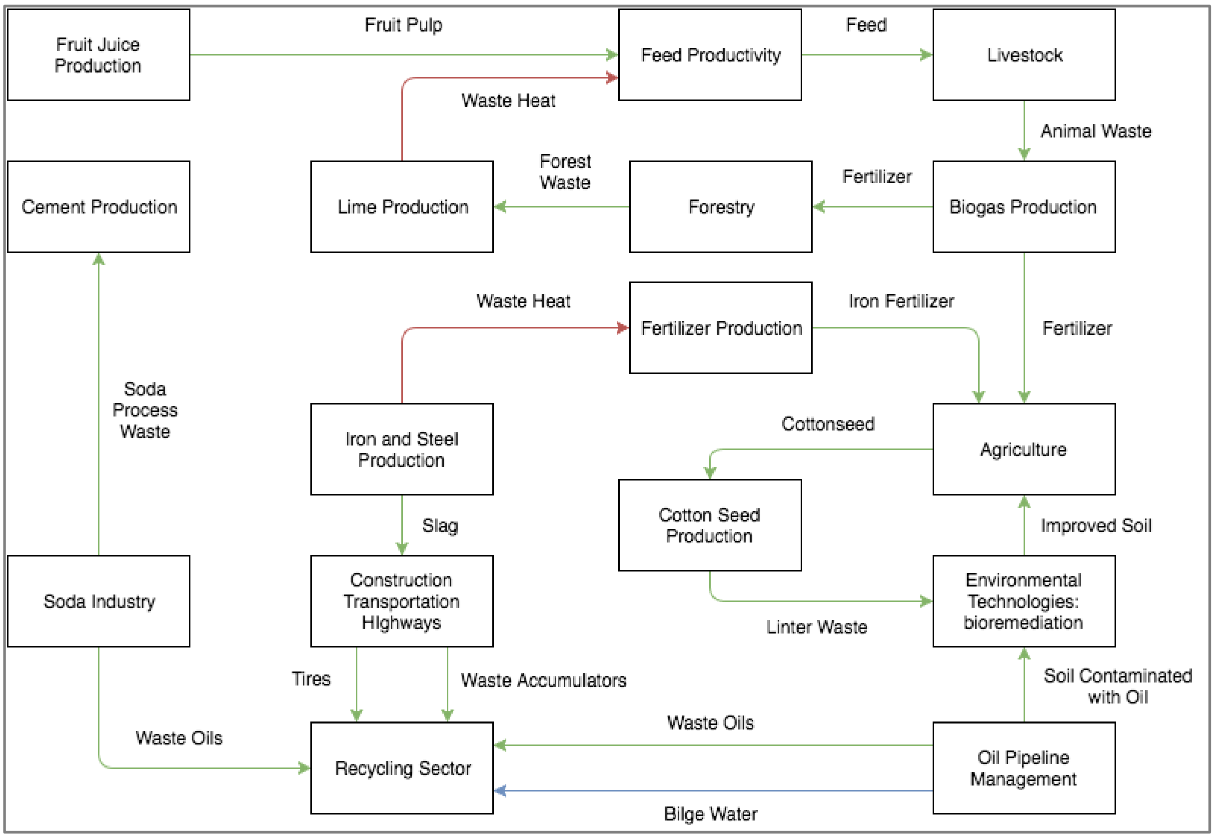

Figure 3: Illustration of the Iskenderun Bay IS network (Data source: Alkaya, Bögürcü, Ulutas, 2014)

This chapter has presented the Kalundborg case, illustrating the developments of symbiotic linkages within industrial networks and serving as a proof for the relevance of self-organization and the local decision-making power of SMEs. The NISP is the current best practice of guided IS development and it incorporates certain characteristics of the middle-out approach (Costa and Ferrão, 2010). The IS project in Iskenderun Bay is one of the well-documented examples where the NISP has been exported to another nation and lead to the successful implementation of an IS network. Jointly with the other examples of exported NISP that have not been covered in this study, the Turkey case shows that the NISP is kept general enough in order to be used as a suitable blueprint in different countries, under different circumstances, so that the concept can be expected to serve well as a guideline for a Pan-European development. This makes the examples an important part of the recommendations presented later in this paper.

4.2 Existing obstacles to industrial symbiosis in Europe

A major problem present in the European context is the lack of public funding for IS projects. In contrast to the Chinese industrial symbiosis development where projects are realized in the form of EIPs while being financed by public budget, the European development relies heavily on investments on the part of the private sector. As Laybourn (2016) put it, the dogma appears to be across the lines of "if the industry benefits, then they should pay". However, as pointed out in the previous chapter, as far as the NISP is concerned, the rate of return on government funding is at 9:1, which actually should serve as an incentive for comprehensive public funding (Laybourn, 2016; Laybourn and Lombardi, 2012). The lack of public funding aggravates another problem pointed out by experts, which is the general perception that industrial symbiosis is "all about waste" (Laybourn, 2016). This creates the impression that the economic benefits, which have been proven empirically have not yet been taken seriously.

Another issue related to funding in a more general sense is the lack of research on regional peculiarities of IS development, which results from a lack of public research funding. Laybourn (2016) calls the EU Horizon 2020[9] program "not really helpful", indicating mistakes in the allocation of research grants. Via an anonymous academic, The Guardian (2014) published even harsher critique on Horizon 2020 by claiming it would be applying a "reversed Robin Hood scheme" in which researchers from institutions located in rich central and northern European countries are much more likely to receive research grants than those from southern or eastern European countries. This situation is not beneficial in the framework of IS development, since it is especially the poorer Member States for which IS constitutes a viable opportunity (Laybourn and Lombardi, 2012).The Guardian (2014) discovered that in 2013, merely 300 researchers received an ERC starting grant, which equals a success rate of roughly 10%. Given the fact that in 2010 about 100.000 PhDs were awarded in EU countries, this number seems even smaller. Additionally, 222 out of these 300 grants were granted to researchers accommodated by institutions located in Germany, France, Israel, the Netherlands, Switzerland and the UK, countries that host well-financed academic institutions anyway. Another aspect being criticized in the article is the imbalanced allocation of grants from a quantitative point of view. While the number of grants provided is considerably small, the amount of money featured by individual grants is very high, with a single one being worth approximately €2 billion (The Guardian, 2014). In order to foster IS development in the poorer regions of the EU, the allocation scheme of the Horizon 2020 funds should consequently be revised.

As was mentioned in the literature review, legal uncertainty with regard to recycling and the reuse of materials is a common barrier to IS efforts. The EU identified a set of barriers restraining the

[9] Horizon 2020 is a €80 billion EU research and innovation program and the biggest of its kind that the EU has ever developed. It comprises, for instance, of research funding in the form of the European Research Council (ERC) starting grants as well as the Marie-Sklodowska-Curie individual fellowships (The Guardian, 2014).

growth of promising waste management practices such as IS in its CE action plan from December 2015 (European Commission, 2015). Firstly, businesses that want to use secondary raw materials face uncertainty with regard to the materials' quality, which leads to a lack of trust and the preference of virgin raw materials. Whether or not secondary raw materials are suitable for "high-grade recycling" (such as for plastics) and whether their quality can compete with virgin raw materials is difficult to assess, since the EU lacks a harmonized legal framework in this respect. The Commission hence calls for harmonized standards, which ought to be developed in accordance with the respective industries that are concerned. Due to coherent 'end-of-waste' criteria that clarify when a secondary raw material should no longer be considered a 'waste' from a legal point of view, the Commission wants to restore trust and certainty (European Commission, 2015). When promoting the reuse of materials, the Commission will also have to address increased security standards on hazardous chemicals. As some products containing such chemicals had been sold before restrictive legislation was introduced, it must be ensured that dangerous chemicals do not stay in the product cycle upon recycling of these products (European Commission, 2015). The Commission also addresses the need for uniform standards regarding recycled nutrients, that is, constituents of organic waste materials that can be reused as fertilizers. Organic fertilizers would reduce the dependence on environmentally harmful mineral-based fertilizers relying on limited phosphate rock (European Commission, 2015). Hence, new measures have to be proposed that enable market access for organic and waste-based fertilizers. Furthermore, the Commission identifies water scarcity as a problem from which the EU is not exempt. Therefore, the industrial use of freshwater should be restricted as much as is feasible in terms of cost and water quality. EU legislation that urges industrial production to rely on a minimum of reused water could be a corrective measure that facilitates risk management and obviates additional cost burden, sinceremoving such substances retroactively may turn out to be very costly, especially for smaller businesses (European Commission, 2015). The same procedure could be applied to raw materials. For certain industries, e.g. the construction sector, an obligation to rely to a specific degree on recycled instead of virgin raw materials could be imposed. However, this policy would have to be implemented stepwise and the feasibility of such a measure would require thorough previous analysis, as smaller and remote businesses may not be able to comply with the conditions.

As was mentioned in the introduction of this paper, facilitating cross-border exchanges is a major challenge on the EU's path towards Europe-wide IS, and certain measures increasing the cross-border exchangeof electronic data on e.g. raw materials yet have to be taken. The JRC Raw Materials Information System launched by the Commission is a step in the right direction, yet it needs to be more comprehensive and could be integrated with other databases, such as the Enterprise Europe Network (EEN), which will be addressed in more detail further below (European Commission, 2015).

Organized IS networks may face yet another issue, at least if the cooperation among the participating firms is perceived as too deep. The EU common market features a set of restrictions on certain types of coordination and cooperation which serve as a means to prevent powerful cartels from coming to existence and distorting the competitive free market. These restrictions are provided for by Article 101(1) TFEU. The concept of industrial symbiosis may challenge provisions (b) and (c) which prohibit the sharing of “markets or sources of supply” and the application of “dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage”, respectively. However, Article 101(3)TFEU features exceptions to the provisions listed above. In case an agreement between undertakings “contributes to improving the production or distribution of goods or to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit”, and while not (a) imposing “on the undertakings concerned restrictions which are not indispensable to the attainment of these objectives” or (b) affording “such undertakings the possibility of eliminating competition in respect of a substantial part of the products in question”. Generally speaking, IS has been identified as a concept which does lead to an improved standard of production as well as technical and economic progress. As the provision, however, includes two necessary conditions to granting an exception to Article 101 TFEU, this matter requires closer scrutiny. Whereas condition (a) should not apply to IS, condition (b) might, in fact, apply. On the one hand, due to the partners of the symbiosis agreeing on buying each other’s by-products in order to insert them in the respective own production chain, the partners essentially cut off free market competition. If the partners, on the other hand, do not agree on this type of mutual trade, they might still prefer buying from each other despite a competitive market, simply because of economic reasons. Whereas they might strike a better deal with other suppliers in the short term, the long term benefits of the symbiotic relationship may still be the decisive factor.

It has become evident that the possible obstruction of competition through certain forms of cooperation is a legitimate concern. Especially the CCC organizations such as the Japanese keiretsu, which have been presented earlier and declared a possible organizational structure for IS networks, might be affected by this issue. Yet, the scope of this paper is too narrow to scrutinize this legal complexity in detail. Legal experts would be required in order to examine the real dimension of the threat EU competition law poses to IS networking.

One last major aspectthat deserves attention and that this paper hopes to address is the current lack of a clear strategy on how to achieve widespread IS. Whereas the Commission, as mentioned earlier, has indeed included IS as an important eco-innovation and best practice in many of its proposals towards sustainable economic growth, it has not yet come up with a clear-cut strategy featuring concrete policy proposals or recommendations to the EU and its MSs. Without a guiding map, that is, a goal-oriented and organized strategy, the path towards industrial symbiosis becomes a much more difficult one.

4.3 The way towards a European strategy for industrial symbiosis (ESIS)

The final chapter of this study provides concrete recommendations for a successful path towards a European industrial symbiosis strategy. It includes a concise summary ofEU policies, issues concerning funding as well as best practices from Hungary and China, which contribute to the importance this study attributes to best practices in enhancing the quality of the policy advice. Furthermore, the organizationalaspects of a potential European industrial symbiosis network are described.

4.3.1 What has been achieved thus far

On December 2nd 2015, the European Commission adopted its "Circular Economy Package" which is to promote the stepwise introduction of circular economy patterns within the economies of the European Union. The package was promoted in particular by Commissioners Jyrki Katainen and Frans Timmermans[10], but also by Members of the European Parliament like, for instance, Ida Auken and Sirpa Pietikäinen[11]. Timmermans called the circular economy a necessity since neither planet nor economy could "survive if we continue with the 'take, make, use, and throw away' approach" (European Commission, 2015). Given his task in the European Commission, Jyrki Katainen promoted the strong improvements the circular economy could bring about with respect to economic growth and increased competitiveness, saying that "the job creation potential of the circular economy is huge, and the demand for better, more efficient products and services is booming" (European Commission, 2015). Next to rather general targets concerning an increase of waste recycling and a reduction of landfilling activities, the Circular Economy Package mentions explicitly its aim to promote industrial symbiosis across the countries of Europe. In response to this European initiative, a group of experts on the field have gathered and associated in the European Industrial Symbiosis Association (EUR-ISA). The aim of this body is to identify obstacles towards the successful implementation of industrial symbiosis projects and to make concrete proposals on how to remove them. Alongside its primary goal, EUR-ISA also seeks cross-border opportunities and serves as a knowledge platform on which knowledge, experience and data can be shared among the participating networks (EUR-ISA, n.d.). According to the IS literature, the exchange of knowledge via a coordination platform is an indispensable factor for the successful development of IS projects (Chertow & Ehrenfeld, 2012; Ehrenfeld & Gertler, 1997; Mirata & Pearce, 2006). EUR-ISA incorporates a number of networks that are either implementing concrete IS projects or supporting the implementation thereof. To date, the

[10] Jyrki Katainen (*1971) is a Finnish politician, former Prime Minister of Finland and current Vice-President of the European Commission while being in charge of Jobs, Growth, Investment and Competitiveness. Frans Timmermans (*1961) is a Dutch politician and diplomat, currently serving as the First Vice-President of the European Commission for Better Regulation, Inter-Institutional Relations, Rule of Law and Charter of Fundamental Rights.
[11] Ida Auken (*1978) is a Danish MEP from the Danish Social Liberal Party and former Minister for the Environment. Sirpa Pietikäinen (*1959) is a Finnish MEP from the Finnish National Party.

organization counts eleven member networks. It features two networks from the United Kingdom, two from Finland, and one from Belgium, Denmark, Hungary, Italy, Romania and Turkey, respectively (EUR-ISA, n.d.).

2009	-	European Waste Framework Directive – Best Practice
2011	-	Roadmap to a Resource Efficient Europe – exemplar
	-	DG Enterprise: Sustainable Industry – Going for Growth – exemplar
	-	Resource Efficiency – exemplar
2012	-	DG Regions: Connecting Smart and Sustainable Growth through Smart Specialisation – exemplar
2013	-	DG Environment: Priority for Industrial Policy – recommendation
	-	DG Enterprise: Communique on Green Entrepreneurship
	-	Commissioner Potočnik launches EUR-ISA
2014	-	Horizon 2020 includes industrial symbiosis to deliver circular economy
	-	European Resource Efficiency Platform key recommendation
	-	Eco-Innovation Library: Innovation Seeds
	-	DG Innovation and Research: Short guide to assessing environmental impacts of research and innovation policy
2015	-	The Commission adopts the Circular Economy Package including revised legislative proposals on waste to speed up Europe's move towards a circular economy

Table 5: Efforts undertaken by the Commission to promote industrial symbiosis and eco-innovation (Data source: Laybourn, 2014)

4.3.2 Funding

As mentioned earlier, the lack of funding is a major threat to IS development. However, the EU does feature various programs, into the funding criteria of which industrial symbiosis appears to fit quite well. The first opportunity is the EU's cohesion policy, including the European Regional Development Fund and the Cohesion Fund (European Commission, 2016). A look at the conditions for ERDF funding reveals four overarching categories, known as the 'thematic concentration', the 'regional concentration' and the low-carbon concentration' of the ERDF. While the first category encompasses the four topics'innovation and research', 'the digital agenda', 'support for SMEs' and 'the low-carbon economy', categories two and three each constitute requirements that are harder to fulfil the higher the applying region is developed economically.Category 2 requires Member States to comply with at least two thematic focuses and category 3 demands the specific project focus on low-carbon economy projects, while the percentage of funding explicitly depending on the fulfillment of these requirements is lower in economically less developed regions, which ought to lead to overall more funding being allocated to applicants from less developed regions. As industrial symbiosis is a concept that contributes to at least two - if not three - out of the four thematic branches (support for

SMEs, low-carbon economy, [innovation and research]), it is eligible for funding not only in poor and remote regions but also in the wealthier regions of the EU. Being a low-carbon venture, IS also falls into the third concentration category, hence showing great potential for receiving ERDF resources (European Commission, 2016).

While ERDF funding basically concerns all European Member States, the Cohesion Fund is merely aimed at those Member States whose Gross National Income per inhabitant is below 90% of the EU average. Thus, for the 2014-2020 period, the Cohesion Fund applies to Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia.One category under which Cohesion Fund money can be granted is environmental projects, such as improving energy efficiency or increasing the use of renewable energy, both representing issues IS can make a real contribution to (European Commission, 2016).

Secondly, there is the EU funded LIFE program, which is divided into two sub-programs specialized on the environment and climate action, respectively. The funding period 2014-2020 stipulates a budget of €3,4 billion (European Commission, 2013). Applying under the LIFE Environment & Resource Efficiency category, IS projects receive the opportunity for further funding.Empirical examples of IS projects receiving LIFE funding include Romania and Hungary, which received funding for projects set to involve 200 companies between 2010 and 2013 (European Commission, 2011). In both countries LIFE funding was required to get the respective programs started in the first place, as it accounted for 42% of the €880.700 budget in Romania and for 50% of the €800.000 budget in Hungary (European Commission, 2011).

According to IS champion Peter Laybourn, the crunch point for any EU funded IS project is reached as soon as the funding comes to an end (Laybourn, 2014). In order for the project to survive, national governments need to step in and compensate at least to a sufficient degree for the expired EU resources (European Commission, 2011). However, this would require the combination of regional approaches paired with clear national strategies, such as happened in the UK where the NISP received government funding in order to get started. The NISP UK inspired 'NISP France' (Programme national de synergies inter-entreprises), which was formally launched in May 2015 and which is funded by the French Provinces and the French Environment & Energy Management Agency (ADEME) (NISP Network, n.d.; Brown, 2015). In September 2014, the Finnish Industrial Symbiosis System (FISS) was introduced after having tested the methodology and concept of the NISP via a one-year pilot (Brown, 2015). The European Union is well-advised to promote the launch of such national IS programs in all Member States. Due to the regional focus of the benchmark programs such as NISP, the EU also promotes its principle of subsidiarity and ensures proper governance of the projects, as it could then allocate its funding directly to the national initiatives rather than individual projects.

4.3.3 *Best practice from Hungary - "Money back through the window"*

In 2002, Hungary launched a program, which annually gathers case studies from companies in order to show that money spent on environmental protection is not 'thrown out the window' but rather comes 'back through the window', indicating that it represents a good investment that pay back in a short period of time, which in turn leads to competitive advantages for companies that demonstrate economic awareness (EEA, 2011). The program is called "Money back through the window" and is coordinated by KÖVET Association for Sustainable Economies, which represents Hungaryin the International Network for Environmental Management, the Global Footprint Network as well as CSR Europe. During the first eight years of its existence, the program collected 370 measures from 78 different organizations, adding up to a total of €80 million in savings (EEA, 2011).

The EU could make use of this example and tackle the problem of information scarcity among businesses with regard to industrial symbiosis, which has become a well-known concept in the realm of industrial ecology but has not received a lot of attention in the common business world. It could publish the extensive scientific research that proves the benefits of engaging in industrial symbiosis networks and thus create a strong incentive for businesses that either are still uncertain whether or not to go this step or have never even heard of the IS concept in the first place. This best practice shows effectively how the sharp presentation of facts relating to economic benefits for companies can create a snowball effect and move other companies towards the adoption of eco-friendly practices by following the good example.This relates well to one specific aspect that was mentioned in the theory section, which is that the prospect of economic profit surpasses environmental benignity when it comes to what steers business action. The capability of industrial symbiosis resulting in economic profit leading to environmental protection, which in turn leads to economic profit due to an upgraded environmental profile of the company is an important lesson from this best practice that the EU should incorporate in ESIS.

4.3.4 *Best practice from China - Circular Economy legislation*

Best practices in terms of policy making can also be found in China. On August 29th, 2008, the 11th National People's Congress of the PRC adopted its Circular Economy Promotion Law. The law is composed of 58 articles and catalogues that issue, for instance, the materials that are subject to compulsory recycle (catalogue of comprehensive utilization) or techniques, materials and products the use of which is either encouraged, restricted or prohibited (catalogue of clean production). While the law does not explicitly mention the term 'industrial symbiosis', its provisionscould be seen as a seedbed[12] for the implementationof IS and Chinese eco-growth in general. This notion can be

[12]Despite not referring to their work, the use of the word "seedbed" in this context is inspired by Arentsen & Bellekom (2014)

perceived in, e.g., Article 55, which states: “Where any power grid enterprise, as in violation of this Law, refuses to purchase the electric power generated by an enterprise with waste heat, waste pressure, coalbed gas, coal slack, slime, refuse or other low-calorie fuels, the power regulatory organ of the state shall order it to correct within a certain time limit and, if any losses are incurred to the enterprise, to make compensation according to law.” (Chinalawinfo Co. Ltd., n.d.).This provision definitely provides a strong incentive for enterprises to engage in symbiotic relationships, in this example with regard to electrical energy input.

However, it follows a clear top-down approach applying ‘the carrot and the stick’, and in its rigidity such a law might conflict with the European idea of a free market, if it were to be reproduced in EU legislation. Nevertheless, according to Mathews & Tan (2016), environmental progress clearly depends on determined government action and their ability to develop and implement industrial policies. If the rewards (be it tax cuts or other economic benefits) offered by the state are rewarding enough in exchange for the firms’ potentially costly restructuring, then the firms are more likely to agree with top-down legislation (Mathews &Tan, 2016). Additionally, the law incorporates multiple provisions regarding the exchange of waste. Article 36 says: “The state upholds producers and operators to set up an industrial waste information exchange system for enterprises to better exchange information about industrial wastes. Enterprises without the conditions for making comprehensive utilization of the wastes generated in the production process shall offer them to those that have the conditions to make comprehensive utilization.” (Chinalawinfo Co. Ltd., n.d.). As the provision does not mention a concrete punishment in case of noncompliance, it is written less strictly as Article 55, but still conveys a clear urge to manufacturers to stay in compliance with the law.

However, while there are statistics that underline the general environmental benefits yielded by China’s Circular Economy Promotion Law (Mathews & Tan, 2016), its practical impact on the Chinese industrial symbiosis development specifically as well as its benchmark potential for EU legislationyet require empirical research. Still, valuable lessons can be drawn from the Chinese example. While the EU - as mentioned earlier in this paper - adopted its Circular Economy Package, it does not yet resemble a directive and rather constitutes a roadmap that does not feature any sort of punishment in cases of noncompliance by Member States. Although China’s approach might be too rigid in the European context, the EU is well-advised to consider amore compulsive character of its circular economy legislation if it wants to ensure its success. This would entail the indication of clear legal consequences that follow the breach of existing rules. Stricter regulation would encourage the creation of IS and eco innovation, since enterprises do not want to face constant legal penalties, which would not only hurt their reputation but also bring along an additional cost burden. Concrete measures could be, for instance, urging all Member States to adopt effective landfill taxes and climate change levies, as has been done in the UK around the turn of the millennium. The EU could move between hard law and soft law and adopt those measures that promise to be the most effective in pushingindustries towards a greener economy. The effectiveness of strong national environmental legislation has been claimed by IE scholars such as Mirata (2005).

4.3.5 Organization and coordination

Another crucial aspect worth discussing is the organization and coordination of a European IS network. In this regard, it is important to include the experience of former researchers and experts on the field, since the organization of IS networks in general has been the subject of various studies already. Perhaps the most valuable benchmark to draw conclusions from is the UK's NISP. As mentioned earlier, NISP drew its success especially from its role as a passive actor, intervening only where intervention from a coordination body was necessary and otherwise letting the businesses organize themselves and build up trust. Social factors and among these especially trust and embeddedness in the community have been identified as the key to successful symbioses, and previous studies have shown that they can only emerge from below and not be imposed top-down upon the potential partners. This is why the European strategy towards IS cannot possibly be one of strict intervention, but rather one of being a *coordinator of coordinators*. The European network should incorporate the many national industrial symbiosis programs, the creation of which the EU has to promote at first,generallyusing the UK NISP as a blueprint.Its organization hence rather resembles an overarching network. The way towards IS requires subsidiarity, and stable networks will emerge where businesses decide freely to commit themselves to a symbiotic relationship because the context for IS is given and provides a strong economic incentive to do so. Hence, the main objective of the EU should be to assist the Member States in creating the right context or seedbed for IS to emerge. This can be realized by funding the MSs' national IS programs and designing a European network in which knowledge, information and data are spread and available to businesses that consider IS as an option. The EU should incorporate the European Industrial Symbiosis Association (EUR-ISA) and provide it with proper funding. Having a sufficient budget, and EU authority, EUR-ISA could become a strong actor and much more effective in fulfilling its mission.In February 2008, the European Commission launched the Enterprise Europe Network (EEN), which is co-financed under the EU funding program COSME (Competitiveness of SME). For the period 2014-2020, a planned budget of €2,3 billion was allocated to EEN (Enterprise Europe Network, 2016). The aim of EEN is to support SMEs with international ambitions and its member organizations include important actors such as chambers of commerce and industry, technology centers as well as research institutes (Enterprise Europe Network, 2016). In order to achieve the best result for the formation of industrial symbiosis networks and to improve the combined effectiveness of both organizations, they should work hand in hand. EEN can enhance its already large online database of companies in such a way that companies willing to participate in such networks can upload the data and information that are of interest to potential partners (e.g. quantity and quality of input and output materials). If funded properly, EUR-

ISA can identify IS network barriers and assist the Member States in removing them. This strategy follows the middle-out approach by Costa and Ferrão (2010), which was presented earlier and which is characterized by targeted interventions that, nevertheless, merely provides incentives and leaves the decision whether or not to engage in symbiotic relationships to the respective enterprises. In its role as a *coordinator of coordinators*, the EU should also promote the utilization of the middle-out approach in the individual national IS programs. An important tool in Costa and Ferrão's (2010) middle-out approach is monitoring, and monitoring progress might be an effective measure employed by the EU, as well. As communicated by the European Commission's (2015) action plan withrespect to monitoring the steps towards a circular economy, the Commission could engage in close cooperation with the European Environment Agency (EEA) and decide on a significant set of indicators that are capable of effectively tracking progress made towards a favorable context in which IS can flourish.A common monitoring framework could be based on relevant sources such as Eurostat and the previously mentioned JRC Raw Materials Information System.

The EU is well-advised to center its approach around champions of IS such as Peter Laybourn and Valdemar Christensen who can guide the project with their invaluable expertise.As both, International Synergies and the Kalundborg Institute have offices in Brussels, they can be consulted easily to provide evidence of and support for the positive economic and environmental impact of industrial symbiosis as well as advanced knowledge on its dynamics and development (Laybourn and Lombardi, 2012). Additional expertise should be drawn from scholars of the field, such as Marian Ruth Chertow, John Ehrenfeld or Murat Mirata who all conducted several pioneering studies on industrial symbiosis. In order to include circular economy dynamics and circular business practices, the Ellen MacArthur Foundation represents another valuable source of expertise. The involvement of IS scholars creates a link to academia, the importance of which has been stressed in the literature (Chertow, 2007; Mirata and Pearce, 2006; Paquin & Howard-Grenville, 2012). By creating this link, the EU also sets a good example for Member State and regional approaches to pursue the same idea.Over the course of time, the growing number ofIS projects will inevitably lead to a higher number of champions, who willin turn provide the European network with expertise and thus guarantee the network's further success.

5. The way ahead for Europe

The European Union has been moving towards the circular economy and especially since the adoption of Horizon 2020 in 2014 and the Circular Economy Package in 2015, it has been showing great interest in the concept of industrial symbiosis as an explicit accelerator towards achieving this goal. This study shows that the European Union,however, has yet been failing to reach its full potential concerning the promotion of IS across its Member States. In the beginning of this paper the question was raised how the EU could *enable the rapid and large scale transition towards IS* and the following paragraphs summarize the necessary steps that were examined in the previous section.

Important lessons that can be drawn from the IS literature, including that planned IS has empirically proven poor sustainability and the more sustainable networks rather grow bottom-up on the basis of economically beneficialopportunitieshaving been seized by individual companies that realized the theoretical benefits of networking mentioned earlier. Yet, pure market development proceeds slowly and lacks valuable guidance of IS experts that could improve the system towards more efficiency and effectiveness. The middle-out approach by Costa and Ferrão (2010) defines the role of the government as one that is characterized by successive interventions at different levels aiming at the creation of a favorable context for IS networks to flourish rather than influencing individual enterprises' decision-making directly or forcing cooperation. This study argues that the EU has to follow the same approach, since, according to the state of research on the field, it promises to be the most effective method to enable a rapid, large scale transition towards IS.In essence, the strategy ought to refrain from rigid top-down planning and rather follow a guided bottom-up approach where companies retain local decision power. Furthermore, it makes sense to make use of best practices from Member States and third countries rather than struggling to find completely new measures.

The EU can also draw inspiration from cooperative organizational cultures such as the Japanese one. As IS networks will have to find the right balance between cooperative and competitive characteristics, valuable lessons could be drawn from organizations that exhibit CCC features, such as the Japanese keiretsu. Certain traits of CPR governance such as the common ownership of machines that serve the maintenance of material streams in symbiotic arrangements or the common responsibility for wastes created might also be interesting options for future IS networks. Such forms of cooperation might, however, be in conflict with EU competition law and therefore, require legal analysis.

EUR-ISA and EEN have the potential to become preciouselements in the European Strategy for Industrial Symbiosis. A properly funded EUR-ISA can act on a Europe-wide scale, identifying barriers to IS development and giving concrete advise to policy-makers on how to get rid of them. Funding and the high profile associated with being an EU funded organization would also help EUR-ISA strengthen its member base, which at this juncture, can be considered rather small.Instead of influencing local and regional IS projects directly, the EU should promote the creation of NISP-resembling national industrial symbiosis programs in all Member States. This can be achieved via the provision of extensive credible information, quantified benefits of currently active IS networks as well as through the inclusion of IS champions and academia. While the EEN is already being granted its budget directly by the EU, it could enhance its database in such a way that it serves the purpose ofconnecting businesses in an effort to makingindustrial symbiosis networks sprout. It should provide space for information and data crucial to IS network formation, such as quality and quantity of in- and output materials and promote companies to actuallydeliver this information to the database.In order to spread information, the EU could adopt a best practice of one of its Member States, Hungary. The "money back through the window" program releases detailed case studies from eco-efficient business practices in order to prove that money invested in environmental friendly practices is - against common industry perception - not money thrown out the window but rather a good investment which pays off in a short amount of time. As has already been shown in the theory section, economic factors rather than environmental goodwill are what drives businesses to adopt eco-friendly measures. Economic profit leading to an improved environmental profile of the company, which in turn leads to economic profit is a very welcome succession of positive aspects. The EU could learn from its Member State by publishing and praising best practices from industrial symbiosis projects and making them freely available.

With regard to funding, the EU already has certain instruments available, yet they need to be channeled correctly. As mentioned previously, funding can be allocated to EUR-ISA and EEN directly, which redirect it to the national IS programs of the Member States. The MSs then use government and EU funding in order to promote the creation of local and regional IS networks. This organized approach is supposed to result in funds being well-allocated, since the national programs arguably have a clearer overview of which project requires how much budget than the EU platform does.IS projects have been identified as viable recipients of grants from the financial instruments of the EU cohesion policy - the ERDF and the Cohesion Fund. As a more general remark, the EU is well-advised to amend the allocation policy of its research and innovation program Horizon 2020. Instead of granting few but overly generous research grants, the goal should be to provide many grants featuring resources that are not significantly larger than sufficient for carrying out the research in a suitable fashion. Creating more equality in the allocation scheme would advance these countries' academic profiles in general and increase the incentive for researchers to conduct research there. The result expected by this study is an even and coherent development of IS networks across the different Member States of the EU.

Although the Circular Economy Package from December 2015 was a big step forward, the EU still lacks a legal framework that encourages environmental friendly industries and punishes wasteful and polluting industries. The Commission could draw its inspiration from China, where a Circular Economy Promotion law was adopted in 2009 and which features concrete hard law measures that encourage CE behavior while punishing those industries that fail to seize the opportunities offered by schools of thought like CE and IE. As outlined earlier, there certainly still has to be found a balance between the rigid Chinese approach to law-making and the European idea of a free common market, which still results in effectively regulated businesses and therefore in strong incentives to engage in symbiotic industrial activities.

These are the steps which should bring the EU closer to ESIS, a clear and goal-oriented strategy enabling the rapid and large scale industrial transition towards the widespread implementation of industrial symbiosis. A successful transition in Europe governed by the European Union would set up a guiding light for other regions of the world to join this new era of industrial development, characterized by economic and environmental prosperity. The table below refers to the key factors influencing the development of IS networks (as presented earlier in *table 1*) by summarizing concrete areas where ESIS could improve the context for industrial symbiosis in Europe.

Category	Key factors addressed by ESIS
Informational	- Availability of timely and reliable information through EEN and EUR-ISA - Information management system monitoring the dynamics of IS development in different countries and regions according to middle-out approach and proposing aimed interventions - Provision of detailed information on quantified benefits of IS and best practices of the field
Organizational & motivational	- Creation of the necessary institutional framework for collaboration in networks - Increase of mental proximity through extensive information flows - Fostering trust - Leaving decision power to local entities
Political	- Adopt effective environmental policies and incentivize environmentally desired practices - Promotion of taxes, fees, fines, levies that do not accord with environmental legislation - Provision of funding to national IS programs - Improve conditions for and allocation policy of Horizon 2020
Technical	- Assist availability of reliable and cost efficient clean technologies through taxation on environmentally harmful technology - Provision of detailed best practices that help individual projects with the technological implementation of synergies
Economic & Financial	- Incentivize private investment through clear information on IS and its benefits - Provision of funding to national IS programs through ERDF, Cohesion Fund, and other instruments - Enable closer scientific examination through Horizon 2020 grants

Table 6: Factors influencing the development of IS networks addressable through ESIS

6. Conclusions

Having provided the recommendations, the primary research question as well as both subsequent questions, which were posed in the beginning of this paper can now be answered concisely.

The European Union can enable a rapid and large scale industrial transition towards IS by developing an organized and goal-oriented European Strategy for Industrial Symbiosis (ESIS). This strategy ought to identify current barriers to IS development and then propose pratical remedies (this study has provided a couple of concrete examples).

Obstacles for the implementation of industrial symbiosis that exist in Europe in 2016 include legal uncertainties, a lack of proper public funding and research gaps, the lack of sufficient knowledge on the part of potential symbiosis partners, trouble with EU competition law and generally weak environmental regulations. Not having any real strategy in the first place is yet another problem.

A Pan-European industrial symbiosis network would constitute a core part of ESIS. It would have to be organized as an overarching platform, encompassing the individual national industrial symbiosis programs, the creation of which the EU needs to promote in the first place and which ought to be oriented strongly towards the development of the NISP.The strategic approach should be characterized by mindful interventions and monitoring, as postulated by the middle-out approach (Costa and Ferrão, 2010) and leave the power with the rather MS programs in order to increase legitimacy and to maintain an effective allocation of resources.Hence, the EU acts as a *coordinator of coordinators*, coordinating the national IS programs and helping in creating a context that works as a seedbed for industrial symbiosis network creation. Such an approach would attribute a significant role to SMEs, which the European Commission perceives as very important (CORDIS, 2015).

As was mentioned when discussing potential barriers to IS development, further research on the conflict between collaboration and competition will be required, which is inherent to IS networks to some extent. It would have to be discussed whether symbiotic relationships really represent a form of collaboration that contradicts the provisions of Art. 101 TFEU and, in case they do, whether or not such relationships can be exempt from this clausedue to their benefits for the environment, research as well as technological and economic development.Further research might also be needed with regard to the NISP's current status as being the best practice in the field, which this study presumed. As IS projects have sproutedin different economies and organizational cultures across the globe, projects from e.g. East Asia, that is China, South Korea and Japan in particular, may challenge the NISP in terms of effectiveness and efficiency. Further research also needs to be conducted on the regional characteristics of IS development. This is important, as ESIS aims at a uniform strategy for Europe. The respective national industrial symbiosis programs require extensive research on regional peculiarities of their economy and organizational culture in order to be effective.

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