Waste management policies for industrial symbiosis development: case studies in European countries

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Industrial symbiosis (IS) emerged as a self-organizing business strategy among firms that are willing to cooperate to improve their economic and environmental performance. The adoption of such cooperative strategies relates to increasing costs of waste management, most of which are driven by policy and legislative requirements.

Development of IS depends on an enabling context of social, informational, technological, economical and political factors. The power to influence this context varies among the agents involved such as the government, businesses or coordinating entities. Governmental intervention, as manifested through policies, could influence a wider range of factors; and we believe this is an area which is under-researched.

This paper aims to critically appraise the waste policy interventions from supra-national to sub-national levels of government. A case study methodology has been applied to four European countries i.e. Denmark, the UK, Portugal and Switzerland, in which IS emerged or is being fostered.

The findings suggest that there are commonalities in policy instruments that may have led to an IS enabling context. The paper concludes with lessons learnt and recommendations on shaping the policy context for IS development.

Key-words: industrial symbiosis; waste management; policy; legislation; Europe

1. Introduction

Human development has been coupled with the evolution of the extraction, use and disposal of natural resources. The altering pattern of human growth improved life style conditions in regions such as Europe, but not without compromising resource availability. This context led to a change in development strategies, towards a vision of sustainability. Stakeholders are called to act responsibly in the equitable sharing of ecological resources, satisfying the needs and aspirations of today and tomorrow's generations [1].

As discussed by Ehrenfeld [1], ecosystems provide the best available example of sustainability: energy and materials are extracted, metabolized and transferred by organisms and across their communities, in a cyclical manner. If anthropogenic systems are driven in a way to emulate ecosystems, it may be possible to learn lessons to progress towards sustainability. This forms the reasoning of Industrial Ecology (IE) [2 - 5], in which industrial systems are described, analyzed and configured as if they were natural, sustainable and mature end of succession (eco)systems.

One important measure relates to the systematic reuse of waste and by-products, which minimizes the need to extract natural resources and the depletion of environmental services [5]. Industrial Symbiosis (IS) can contribute to this objective, since it represents an engagement of traditionally separate industries in a collective approach to competitive advantage, involving the physical exchange of materials, energy, water and/or by-products [6].

A consistent body of IS research suggests how these synergies emerge and can be fostered [e.g. 6 - 14]. Overall, as Mirata [14] observed, IS emerges primarily from the private sector as a self-organising business strategy, driven by economic advantages offered by market dynamics and/or policy requirements. In this context, the authors agree with Boons and Baas [15] that "IS activities are shaped by the *context* in which they occur, described in terms of cognitive, structural, cultural, political, spatial and temporal embeddedness*".*

Although self-organisation is considered a more feasible strategy, some form of coordination can assist further IS development [8, 12, 16, 17]. For example, Gibbs and Deutz [12] mention the catalytic role of the Centre for Alternative Technology in Wales in enabling relationships between businesses, leading to potential eco-industrial developments. However, coordinating

bodies are only able to influence some factors within the context, namely informational, organisational and human related, in a fairly localized manner. As Baas [18] stated, “actors are not equally able to influence each other’s actions and system outcomes, which needs to be taken into account much more fully within IS development”.

Governmental policies are also regarded as being able to influence a wider range of factors [12, 14, 18]. For example, in the Rotterdam region, after a period of strong environmental regulations, the national and sub-national governments facilitated programmes to strengthen economic and environmental performance in industry, including the partial funding of IS projects [18, 19]. However, policies can also pose barriers to IS [e.g. 8, 9, 21]. For example, Desrochers [21] mentioned if Danish regulation were to be similar to U.S. regulation IS development at Kalundborg “would be a very difficult if not impossible task”. In the Rotterdam case, Baas [18] observed that although the regulator engaged with the companies to adjust rules, the policy environment still perceived synergies as handling waste rather than reusing resources.

Since “the role of power is hardly discussed systematically in the IS field” [18], our contribution to this discussion resides on the analysis of governmental influences in the IS development contexts of four European-based case studies. Using a common set of descriptors, cases are analyzed and contrasted in order to identify characteristics of particular governmental jurisdictions that are conducive to IS.

The paper is structured as follows. This section establishes the theoretical reasoning of the paper. Section two outlines the structures that support policy development for the European context, and section three introduces the research framework. The case studies are presented in section four, followed by the discussion of the results (section five). The paper ends with the conclusions, in section six.

2. Policy and legislation in Europe

Policy is the course of action of a governmental body, which translates into strategies, tools, or other public decision [22]. It commonly involves: 1) setting goals, objectives, and; 2) developing instruments of regulatory (e.g. hazardous chemical bans), economic (e.g. landfill taxes) and informational/voluntary (e.g. eco labels) nature.

This paper analyses policy development at three levels: 1)*Supra-national* policies, based on

conventions, protocols or programmes, (e.g. the Basel Convention), laying down a conjunct response to transnational challenges; *2) National* policies, which translate national government objectives, according to its social, economic and environmental context. They can incorporate objectives defined by supra-national policies, or even present more ambitious goals; 3) *Sub-national* policies which are developed at the level of the region, state or municipality. In general, sub-national policies are kept aligned with national objectives; however, they can also be implemented differently in order to address local context factors.

Policy objectives and instruments commonly reflect or are enabled by legislation. Likewise, there may be different levels of legislative authority. In federal and decentralized unitary governments, regions and/or localities may possess some legislative autonomy whereas in unitary systems, this autonomy usually remains with central government (see Figure 1).

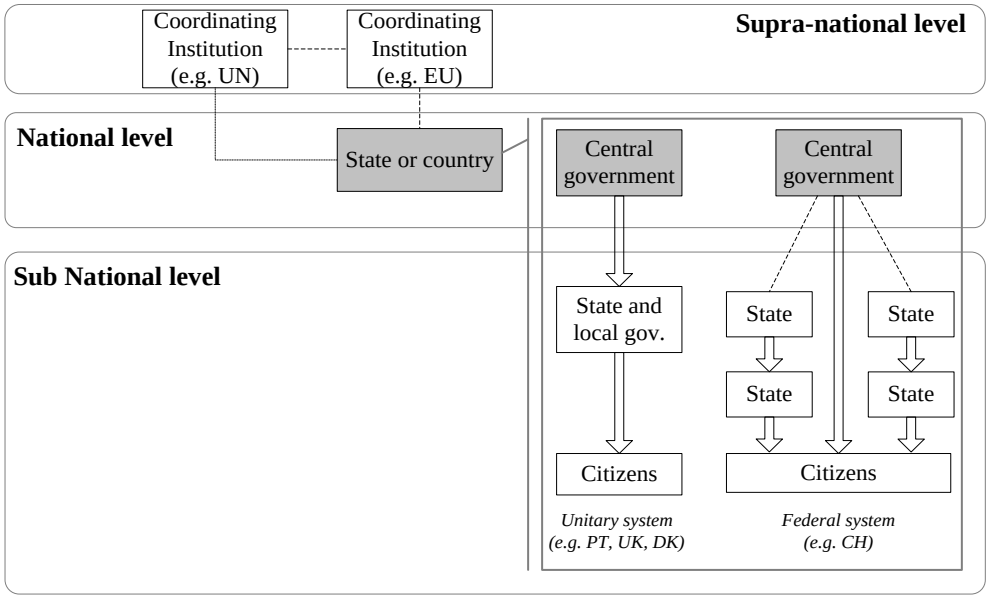


Figure 1 – General schematics of policy and legislative systems

Source: Authors generated

Within the European context, the European Union (EU), as a supra-national institution, has been able to affect policies within the majority of its member countries. In the field of waste management, *The Thematic Strategy on the Prevention and Recycling of Waste* includes the main policies, general objectives and action principles. These principles include firstly the obligation to handle waste without posing a negative impact on the environment or human health and secondly the hierarchy of the best overall environmental options in waste

management, from prevention to disposal [23, 24].

In terms of legislation, the EU influences member countries through *regulations* (laws applied in full throughout the Community), *directives* (binds members to achieve objectives; however, they are free to address their local distinctiveness while incorporating the objectives into their legal system) and *decisions* (binds particular individuals, firms or member states, to perform or refrain from an action, confer rights or impose obligations).

The Waste Directive - part of the waste framework legislation - allows a better uniformity of EU law application, keeping the same objectives throughout its members. It also provides an incentive to develop policies and legislation to achieve more ambitious goals than those already implemented at national level. The latest version of this directive was introduced in November 2008 and member countries are expected to create the laws, regulations and administrative provisions by December 2010 [23].

The Landfill Directive - part of the waste management legislation - is also equally important. It establishes the conditions for the disposal of waste in landfills to minimize negative impacts on the environment and human health. It also introduces bans for certain types of waste (e.g. used tires) and sets targets to progressively reduce the amount of biodegradable waste sent to landfills [24].

In summary, implementation of EU directives is approached differently by the member states to suit their contextual distinctiveness. This explains the reason for different policies and legislations across the EU members and the swift development of IS in some European countries as well.

3. Research framework

The research presented in this paper is mainly of an inductive nature, in which a case study methodology is used. The case study is a research strategy, focusing on understanding the dynamics within single settings [25]. Since the focus is on the policy and legislative contexts, case studies present information mainly of a qualitative nature.

The research is set in the European policy and legislative context, focusing on supra-national, national and sub-national waste policies and legislation influencing the development of IS. The selection of case studies considered the background of the authors, each conducting IS

research in their country – United Kingdom (UK), Portugal (PT) and Switzerland (CH). The case of Denmark (DK) is an exception, justified by its historical relevance to IS research. The selected countries i.e. DK, UK, PT and CH, also provide a heterogeneous sample in terms of 1) governmental structure; 2) supra-national influences (EU members and non EU members), and; 3) type of relationships and coordination between the companies involved in IS (spontaneous or coordinated organisation).

Cases are compared using a range of quantitative and qualitative descriptors, to organize data and identify patterns [25]. The selected descriptors consider IS literature and insights from the research itself. Quantitative descriptors are used to verify the countries' performance in waste management, while qualitative descriptors characterize the governmental structure, legislative influence, and the type of economic, regulatory and voluntary instruments available. Due to the complexities associated with different governmental structures, only a limited number of instruments are selected as descriptors.

Table 1 – Case study descriptors
Source: Authors generated

Descriptor	Characteristics
Quantitative	
Average population Total waste generation	To determine total waste generated per capita
Waste treatment	Status on waste management performance
Qualitative	
Institutional framework	
Type of government Waste legislation level Waste policy level	Characterization of the governmental structure in the country, to understand where the policy and legislative powers are centred.
Economic instruments	
Landfill tax Incineration tax	Taxes help shaping the market in which companies operate, pushing companies to look into waste management strategies which could be more beneficial
Regulatory instruments	
Landfill bans	Regulation that controls the disposal of wastes can lead to its diversion to other alternatives (e.g. recovery).
End of waste/By-product	A by-product classification indicates that there can be materials exempt of being classified as wastes, and therefore can be exchanged as products
Voluntary instruments	
Coordination programmes for collaboration in resource efficiency	Voluntary instruments design to motivate cooperation between companies on resource efficiency issues

Analyzing each case study according to the set of descriptors in table 1, and comparing them, provides an opportunity to identify particularities within, as well as commonalities between the contexts of each case.

4. Case studies

4.1 Denmark

Denmark is known for its progressiveness in waste policy. For example, it was among the first countries to ban organic and combustible wastes from landfill [26]. Still, as a member, Denmark has to implement the European Directives on Waste.

Two main documents set the legislative framework for waste management: 1) Environmental Protection Act, Consolidated Act No. 753 [27]: states that each Danish municipality is responsible for establishing capacity for waste management and provide information on how to dispose all waste produced within its geographical area, independent of origin; 2) Statutory

Order No. 619 [28]: sets the obligations in waste use, transportation, recovery and disposal.

A national waste strategy plan is made every four years, detailing actions to achieve EU targets and setting sub-national targets. In this context, national government makes use of strict economic and regulatory instruments. For example, taxes on landfill and incineration were introduced in 1987 and have been escalating since then. However, currently there are no waste related programmes directed at supporting IS [29].

At sub-national level, municipalities develop waste management plans for short term (4 years) and long term (12 years) periods. Local councils establish schemes to ensure that waste is managed in compliance with the waste hierarchy. For industrial waste, assignment schemes are used: the municipality develops regulations attributing a certain form of treatment to a particular type of waste. The waste producer, which is responsible for its management, must comply accordingly [30]. Furthermore, each municipality can make decisions concerning classification of waste; notification of orders and prohibitions; issue permits for waste management operations and supervise compliance of regulations.

The IS network at Kalundborg emerged from the existing social interactions among local industrialists. Notwithstanding this, Danish policy and legislative context also worked in favouring some of the exchanges [10] by means of stricter regulation and higher taxes while allowing local government to work with the companies and support the exchanges as a waste management option.

4.2 United Kingdom

The EU Waste Framework Directive and associated directives on specific waste streams have become the basis for UK waste management legislation and policy. Key legislative documents include: 1) Environmental Protection Act 1990 [31], which introduces the definition of waste and the duty of care on producers/operators for the collection, treatment and disposal of waste; 2) Environmental Act 1995 [32] which outlines the need for a national waste strategy, the need for enhanced legal and institutional setting for waste management, and sets the producers' responsibility in relation to reuse, recover and recycle of waste.

Waste policy development and enforcement lie with central as well as devolved administrations; but since devolution in the UK is asymmetric, these powers among devolved administrations

differ to some degree. UK's waste policy is reflected in the *Waste Strategy for England 2007* [33]. It proposes instruments and targets for reducing the impact of waste generation and management. Waste policy in devolved administrations is developed along the same lines, albeit adjusted to their own context.

Under this framework, the UK government introduced a mix of economic, regulatory and voluntary instruments which appear to have shaped the policy context for IS development. The Landfill Tax (LT), the Waste Protocols Project (WPP) and the National Industrial Symbiosis Programme (NISP) are among that mix.

The Landfill Tax is implemented throughout the UK and its revenues are partly used to support programmes to improve resource efficiency.

The WPP, a regulatory instrument, aims to deal with uncertainties regarding the EU's waste definition, by which some materials were going to landfill despite their reuse potential [34]. The protocols are quality statements concerning a particular material flow (e.g. flat glass). The information it contains is designed to inform producers, and safeguards consumers, on what technical aspects the material must fulfil in order to be exempt from being considered a waste.

Finally, NISP, a voluntary instrument, assists businesses in redirecting their waste from landfill by helping them to find partners to utilize their wastes as raw material, thereby realizing environmental and economic gains [35]. It evolved from private collaborative efforts, to an England wide programme funded by the Business Resource Efficiency and Waste Programme. It began being funded by devolved administrations in later years, thus expanding to the entire UK territory in the year 2007.

4.3 Portugal

Portugal is among the first European countries to make environmental protection as a fundamental task of Government, under the Constitution. Despite being proactive in certain areas (e.g. used oils), EU directives and regulations make up the base of Portuguese waste legislation.

Portugal centralizes waste legislation development at the national level only. There are two main documents setting this framework: 1) Law 11/87 - National Environmental Act [36]: establishes the overall principles of environmental protection. Article 24 focuses on waste and

its reuse/recycling as raw materials and energy, provided the application of preventive measures, cleaner technologies and economic and regulatory incentives; 2) Law-Decree nº 178/2006 [37]: sets the provisions for all the activities related to waste handling, processing, transport, storage and disposal.

In policy terms, there is one national waste plan and four plans for specific waste flows (e.g. urban, industrial, medical, agricultural), covering targets and instruments. For urban waste, regional plans are also developed. National recycling networks also exist, each dedicated to one of eight types of waste materials. Each system is managed by a not-for-profit entity, formed by representatives of producers and recyclers.

Some policy instruments are already contributing to shape the context for IS development in Portugal. These include the mandatory electronic information reporting on waste, landfill and incineration taxes and the principle of free trade of waste. The later implied the creation of a voluntary instrument named Organized Waste Market (OWM) [38], managed and coordinated by a private entity and backed by public institutions. It is aimed at promoting the offer of and demand for waste materials, facilitate the transactions and promote the use of recycled products in the market.

The use of wastes substitutes for raw materials is considered an option under the Portuguese waste management regulation (e.g. cement producers receive ash from power plants). However, such efforts are scattered, uncoordinated and are somewhat confined to large industries. The reason is partly related to the bureaucracies to obtain the necessary permits.

As a collaborative strategy among different stakeholders for closing material loops, the project of Relvão Eco Industrial Park is currently the only explicit example of IS at national level [39].

4.4 Switzerland

Despite being situated in central continental Europe, Switzerland is not an EU member. However, it keeps bilateral agreements with the EU. As a confederation, the canton (state) level has an increased power of decision.

At supra national level, the Basel Convention [40] is the most influential treaty on Swiss waste policy and legislation. At the national level, the Federal Act on the Protection of the Environment [41] defines the concept of waste and the legal prosecutions in relation to non-compliance. Two

federal ordinances describe the types of waste, the principles for its treatment (Technical Ordinance on Waste (TVA) nº 814.600 [42]) and the control rules for waste movements (Ordinance on the Handling of Wastes (VeVA) nº 814.610 [43]). Several types of waste have dedicated laws and ordinances. In general, reuse and recycling is mandatory, if technically possible, without any specific technological standard.

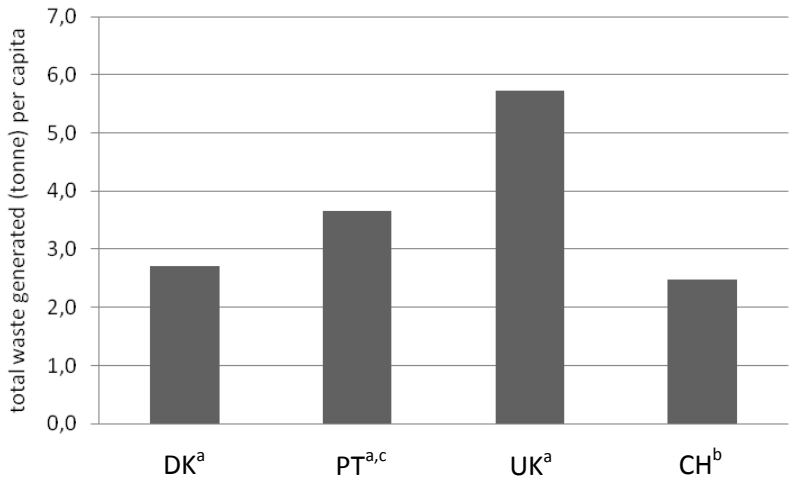
At sub-national level, the 26 cantons develop and apply their own policies and legislation, but keep an alignment with national orientations. For example, the cantons can fix their own landfill price but are responsible for enforcing the national landfill tax. Since there are no special requirements for by-product exchanges, IS could, in principle, be regarded as a potential strategy, provided it does not lead to pollutant diffusion and respects the legislation on hazardous waste handling and movements.

In the particular sub-national case of Geneva, the Geneva Law on waste management L120 [44], defines waste elimination principles, waste handling authorization procedures and recovery incentives. Under the polluter paying principle, businesses are responsible for the management of their urban and special waste. A private recycling market controls waste transfer and recovery. Efficient recycling technologies are favoured through a legal authorisation process as well as dialogue and collaboration with interested parties [45].

Geneva also introduced IE as a legal basis in the Agenda 21 law [46]. Its article 12, called ECOSITE, stipulates "...*the State facilitates possible synergies between economic activities in order to minimize their environmental impacts*". An IE strategy was established in 2002, set up by an Advisory Board for IE and IS Implementation. This programme involved several stakeholders, including government agencies, universities and local industry. Its approach and application includes physical accounting, material flow analysis and an IS coordination and facilitation project [47, 48].

4.5 Cross case comparison

Comparison between case studies uses the collected quantitative and qualitative data to identify patterns across the sample. Figure 3 depicts the quantitative characterization of the cases in terms of waste generation and Figure 4 presents the waste management performance for the years with the latest available data.

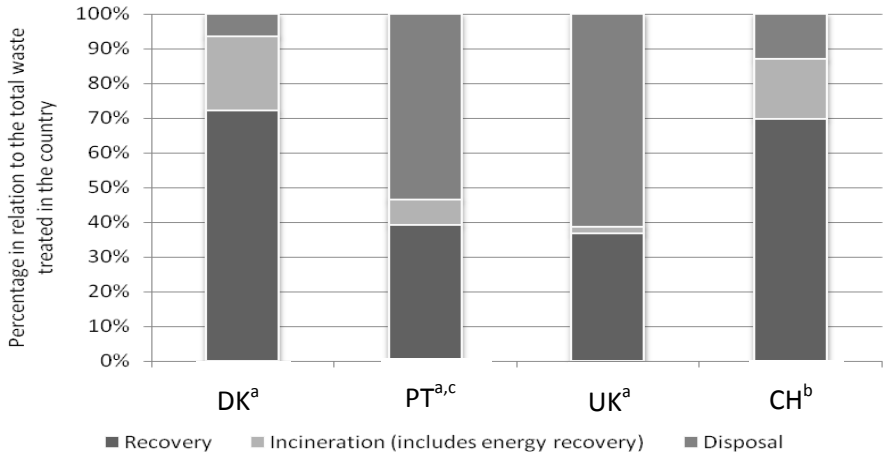


a – DK, UK and PT data for 2006 collected from Eurostat [49]
b – CH data for 2007 collected from Swiss Federal Office for the Environment [50]
c – Calculation made using a estimated value for total waste generated , from Eurostat [49]

Total waste generated calculated using Eurostat data for EWC_Total (total waste generated) for all NACE branches plus households, and for Total Population at January 1st for the corresponding year (including CH).
For a complete list of included waste categories and NACE branches, please consult http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/env_wasr_esms.htm
For CH, data for waste generated includes construction, dangerous and urban waste.

Figure 3 – Total waste generated per capita

Source: Authors generated



a – Data for 2006, collected from Eurostat [49];
b – Data for 2007, collected from Swiss Federal Office for the Environment [50];
c – Estimated provisional values for PT;

Figure 4 – Waste treatment

Source: Authors generated

As noted, the sample is divided into two groups: DK/CH present higher recovery rates combined

with the lowest generation of wastes per capita. In contrast, PT/UK present higher landfill rates and waste generation per capita. By looking at the qualitative descriptors (Table 2), it is possible to suggest that these performances are a result of a different evolution within each context, particularly with respect to economic and regulatory instruments.

Denmark has been shaping its context since 1987, with an increasing incineration and landfill tax coupled with a strong landfill ban in 1997. Switzerland introduced taxes and a ban on all combustible wastes in 2001 and 2002 but, by this time, waste incineration with energy recovery and a solid recycling network were already rooted in the country. Although the UK introduced a landfill tax in 1996, this only became effective in 1999, after the introduction of an increasing yearly rate (tax escalator). Further landfill restrictions were introduced in 2006 for liquid wastes and tires. Finally, Portugal also has landfill bans for certain waste flows, albeit introduced earlier than in the UK. However, landfill and incineration taxes only came into effect in 2006, and therefore their impact on waste management is still to be felt.

Table 2 – By-product and end-of-waste conditions
Source: Authors generated

			DK		UK		PT		CH	
Political framework	Type of government		Unitary system						Federation	
	Waste legislation level		National + Sub-national		National + Sub-national		National		Sub-national	
	Waste policy level		National + Sub-national		Sub-national		National		National + Sub-national	
Economic instruments	Year of introduction	Landfill tax [1](2009) [€/tonne]	1987	50.7 + 25%VAT	1996	46.23	2006	5	2001	11.21[2]
				20.8[3]+ 25%VAT		2.89[4]				9.89[5]
		Incineration tax (2009) [€/tonne]	1987	44.4 + 25%VAT	-		2006	1	-	
Regulatory instruments	Year of introduction	Landfill bans	1997	Combustible waste	2006	Used tires Liquid waste	2002	Used tires Liquid waste	2002	Combustible waste
	End of waste / By-product use		Municipal protocols that favour discussing waste management options with industry (sub-national)		*Waste protocols*: technical parameters establishing when a treated material is no longer considered a waste (sub-national, England only)		Companies need to be registered as waste management operators – comply with Best Available Techniques for waste treatment (national)		Waste and by-product exchanges are allowed between companies, provided they are licensed for handling waste (sub-national, Geneva canton)	
Voluntary instruments	Coordination programmes for collaboration in resource efficiency		-		NISP (sub-national to national)		Organized Waste Market (national)		ECOSITE (sub-national)	

[1] For non-hazardous industrial wastes disposal in landfill
[2] For stabilized residues
[3] For landfill of residual waste – slag and fly ash
[4] For inert wastes
[5] For reactor landfills (e.g. slag)

Table 2 demonstrates that in terms of political framework, with the exception of PT, some decentralization in waste management policy and legislation exists.

Regarding economic instruments, current landfill taxes are above 10€/tonne for the majority of the cases. DK stands out with the heaviest taxes for both landfill and incineration, although the UK is expected to increase up to 83€/tonne in 2013.

In terms of regulation, DK and CH impose landfill bans on all combustible wastes, while UK and PT only ban singular flows and adopted phasing out targets instead (e.g. organics). However, when it comes to declassification of materials from waste regulations, the UK is the only country in the sample currently developing regulations for that purpose.

DK and CH are able to use its sub-national legislative influence to work closely with economic actors (e.g. manufacturers, recyclers) interested in using wastes or by-products as raw materials. Therefore, they are able to evaluate each case and establish the necessary rules to be applied.

Voluntary instruments based on collaborative efforts for resource efficiency are also common in the sample. In UK and CH, government funded programmes are implemented to identify and support the emergence of collaborative business networks. In UK, programmes are directed at improving the waste management profile of the country, while CH aims at optimizing an already implemented recycling network. PT is also seeking to optimize its recycling networks, by requesting companies to set up a management entity for the OWM. This programme aims to support the reuse of waste materials among companies, and to improve market acceptance of the manufactured products.

5. Discussion

5.1 Policy and legislative levels of influence

The cases provide some evidence of decentralization regarding industrial waste management policy and legislation. This evidence is aligned with the views of researchers who support the involvement of local government in driving and assisting collaboration between companies and providing “tailored” instruments to support synergies [e.g. 17, 51]. Even in PT, local government is motivating collaboration between public institutions, university, industry and the community for IS development [39]. Still, it is important to guarantee national objectives and targets, and avoid

dissension with local businesses' interests. For example, Flynn [52] states that in DK control and inspection duties were given back to counties for fear that some municipalities might be influenced by specific industries and conflict with national interests. Therefore, it is important that sub-national governments have the capabilities to develop, regulate and monitor options made under the "umbrella" of concepts such as IS.

Local government can act as a bridge between national government and local companies, but its influence is limited. Higher levels of influence (e.g. supra-national, national) can set the objectives and targets to which sub-national level agents (e.g. local government, companies, universities) are left to respond with solutions. Christensen confirmed this position in Gertler [54]: "Economics alone will bring you a certain amount of symbiosis. To go further, you need political impetus to require pollution control technologies and/or to adjust prices to make symbiotic arrangements economically viable".

5.2 Policy instruments

The second point is related to how countries cope with potential barriers to waste/by-product reuse as raw materials. Researchers [e.g. 55, 56] consider the EU waste definition as one of such barriers. Although considered a relevant issue, the cases analyzed show that the exchange of wastes for substitution purposes is possible, even with such a debatable definition.

The analysis demonstrates that technical barriers emerge in relation to 1) market incentives to reuse waste, 2) technological standards for waste management 3) expectations concerning material quality and 4) information about alternative waste management options.

The cases could provide insights on how government influence helps mitigate these barriers. Strong economic and regulatory instruments (e.g. landfill taxes and bans) can contribute to make options such as reuse or recycling economically viable. However, this can be insufficient in adding value to the material itself. In such cases, government involvement with the industry in assessing alternative waste management options or in developing regulated quality standards for recovered materials would be a way forward.

Another challenge relates to the requirement of technological treatment standards for companies who wish to use wastes as raw materials. These standards aim to maximize efficiency with the least environmental impact. Companies need to secure them in order to

receive the necessary permits. However, the potential recycling role of manufacturing technologies already in place is seldom evaluated. This means that, in order to reuse a waste, companies need to invest in additional equipment, which could reduce the economic benefit of using a raw material substitute.

In some of the cases, government adopted a more flexible approach to these issues. Waste regulations in CH and DK focus more on guaranteeing environmental standards, instead of focusing on the means to achieve them. This could provide a niche to test alternative technological and collaborative solutions. As for UK and PT, by involving recyclers, which already have technological standards in place due to their primary activities, this barrier is somehow mitigated.

As observed, government programmes directed at improving resource efficiency among companies help fostering IS development. These voluntary instruments contribute to increase information availability, facilitation and assistance. This can help businesses to perceive economic advantages in environmental outperformance even in cases where the social and economical context does not favour going beyond compliance.

Government provides the objectives as well as economic and regulatory support, while the programme is developed and managed by private agents such as business associations and universities together with industry. However, it is important to prevent potential withdraw of governmental funding, the risk being that companies will no longer participate once the service ceases to be supplied at zero cost. To prevent this situation, 1) the programmes should be implemented and managed in collaboration with the companies, including the development of alternative financing strategies and 2) the programmes should rely on strong social networking to stimulate trust and interaction to a point where the governmental scaffolding is no longer required.

In summary, a government contribution to shaping the context for IS development could take the form of an integrated set of policy instruments that influence markets towards reuse and recycling, in which collaboration between companies is fostered. While policies at the supra-national level set strong objectives, those at national level could work towards strong economic and regulatory instruments to secure those objectives (e.g. taxes and bans), leaving enough

flexibility at sub-national level to find the best economic and environmental responses with stakeholders such as companies and research institutions. Moreover, voluntary instruments developed in partnership with the industry could help direct companies towards collaborative strategies in waste management and control fly-tipping.

5.3 Future opportunities

In October 2008, the EU Parliament approved a new Waste Framework Directive [23]. It introduced new approaches to dealing with the increasing generation of waste. One of these approaches is the definition of by-product and end-of-waste.

By-product is considered a substance or object, resulting from a production process, the primary aim of which is not the production of that item, may be regarded as not being waste, if the conditions set in article 5 of the Directive are met. The End of Waste status applies to materials that have undergone a recovery operation, including recycling, and that comply with specific criteria to be developed in accordance to the conditions also set by the Directive, in article 6.

Besides the definition and main principles, the EU also directs member countries to develop their own End of Waste criteria and implementation mechanisms to motivate market demand. The cases presented demonstrate that some countries are already developing pro-active responses to such supra-national challenges, either by developing new regulatory instruments (e.g. waste protocols in UK) or voluntary ones (e.g. Organized Waste Market in PT). Such instruments can be used to identify, test and validate markets, economically and environmentally, for a diverse range of by-products and residuals, with the additional benefit of this improvement being based on the performance of networks rather than individual companies.

In this context, it is possible to suggest that shaping a policy and legislative context to support IS can be seen as a strategy aligned with the objectives of the EU. The new provisions set by the Directive can also, in turn, help shape the context to overcome some of the barriers associated with IS.

This process can be greatly improved if all participating agents (e.g. government, universities and companies) align their actions to common objectives, at all levels. As current policy theory suggests [52, 57], inter level collaboration should be motivated, with mutually reinforced

responsibilities. Furthermore, and most importantly, scientific evidences should be integrated early in the policy development process.

6. Conclusions

This research sought to better understand legislative and policy contexts in cases where IS networks are developing and the potential contribution that IS can make to the implementation of the EU Waste Directive.

As a general conclusion, it appears evident that governmental institutions could greatly contribute to shape the context underlying IS development. The case studies analysed provide some insights on potentially influential factors: flexible regulation in waste management (mainly associated to sub-national levels) together with strong economic/regulatory instruments, deployed nationally, that penalizes lower hierarchy waste management options. Voluntary instruments, in the form of coordination programmes, could provide information and facilitation assistance for companies to identify economically viable alternatives for their wastes.

In this context, policy and legislation can positively influence IS development by setting clear objectives and supporting business eco efficiency activities. This sends important signals to the market that guides businesses to IS related actions, without direct governmental intervention in that process.

However, some difficulty persists in coordinating policies and actions across the supra-national, national and sub-national levels of government. If there is enough flexibility to implement innovative, locally adaptable solutions and transfer their associated knowledge across levels, it is possible to contribute to more effective waste policies and shape the context for industrial symbiosis.

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References

[1] Ehrenfeld J. Industrial ecology: paradigm shift or normal science? American Behavioral Scientist 2000; 44(2): 229-244.

[2] Frosch R, Gallopoulos N. Strategies for Manufacturing. Scientific American 1989; 189(3): 144-152.

[3] Graedel T. On the concept of industrial ecology. Annual Reviews in Energy and the Environment 1996; 21:69-98.

[4] Ehrenfeld J. Would Industrial Ecology Exist without Sustainability in the Background? Journal of Industrial Ecology 2007; 11(1): 73-84.

[5] Erkman S. Industrial ecology: an historical review. Journal of Cleaner Production 1997; 5(1-2):1-10.

[6] Chertow M. Industrial Symbiosis: Literature and Taxonomy. Annual Review of Energy and Environment 2000; 35:313-337.

[7] Lowe, E. Creating by-product resource exchanges: Strategies for eco-industrial parks. Journal of Cleaner Production 1997; 5 (1/2): 57-65.

[8] Chertow M. “Uncovering” Industrial Symbiosis. Journal of Industrial Ecology 2007; 11(1): 11-30.

[9] Desrochers, P. Industrial symbiosis: the case for market coordination. Journal of Cleaner Production 2004; 12(8-10):1099-1110.

[10] Jacobsen N, Anderberg S. Understanding the Evolution of industrial symbiotic networks: the case of Kalundborg. In van den Bergh J, Janssen M, editors. Economics of Industrial Ecology. Cambridge: MIT Press, 2004; pp. 313-336.

[11] Mirata M, Emtairah T. Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme. Journal of Cleaner Production 2005; 13(10-11): 993-1002.

[12] Gibbs D, Deutz P. Reflections on implementing industrial ecology through eco-industrial park development. Journal of Cleaner Production 2007; 15(17):1683-1695.

[13] Hewes A, Lyons D. The Humanistic Side of Eco-Industrial Parks: Champions and the Role of Trust. Regional Studies 2008; 42(10):1329-1342.

[14] Mirata M. Industrial symbiosis: a tool for more sustainable regions? Lund, Sweden: IIIEEE Lund University, 2005.

[15] Boons F, Baas L. Industrial symbiosis in a social science perspective. Discussion proposal for the Third Industrial Symbiosis Research Symposium, Birmingham, UK, 2006.

[16] Schwarz E, Steininger K. Implementing Nature´s Lesson: The Industrial Recycling Network Enhancing Regional Development. Journal of Cleaner Production 1997; 5(1-2): 47-56.

[17] Mirata M. Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges. Journal of Cleaner Production 2004; 12(8-10): 967-983.

[18] Baas L. Industrial Symbiosis in the Rotterdam Harbour and Industry Complex: Reflections on the Interconnection of the Techno-Sphere with the Social System. Business Strategy and the Environment 2008; 17: 330-340.

[19] Baas L, Boons F. An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems. Journal of Cleaner Production 2004; 12(8-10): 1073-1085.

[20] Ehrenfeld J, Gertler N. Industrial ecology in practice: The evolution of interdependence at Kalundborg. Journal of Industrial Ecology 1997; 1(1):67-79.

[21] Desrochers P. Market processes and the closing of industrial loops. Journal of Industrial Ecology 2000; 4(1): 29-43.

[22] Helfand G, Loomis J. Environmental Policy Analysis for Decision Making (The Economics of Non-Market Goods and Resources). New York: Springer, 2001.

[23] EC - European Commission. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste. Official Journal of the European Union L 312/13, 22.11.2008.

[24] EC - European Commission. Directive 1999/31/EC of the European Parliament and of the Council of 26 April 1999 on the landfill of waste. Official Journal of the European Union L 182, 16.7.1999.

[25] Eisenhardt K. Building theories from case study research. The Academy of Management Review 1989; 14 (4): 532-550.

[26] EEA - European Environment Agency. The road from landfilling to recycling: common destination, different routes. Luxembourg: Office for Official Publications of the European Communities, 2007.

[27] Consolidation Act No 753 of August 25, 2001 Law on Environmental Protection. Available

from (in Danish): https://www.retsinformation.dk/Forms/R0710.aspx?id=12503 [Accessed on 28 October 2009].

[28] Statutory Order No 619 of 27 June 2000 on Waste. Unofficial translation supplied by the Waste Centre Denmark [By electronic request, July 2008].

[29] Brackhahn B. Personal communication. Waste Information Centre Denmark, July 2008.

[30] Danish Government. Waste Strategy 2005-2008. Copenhagen: Danish Ministry of the Environment, 2004.

[31] Environmental Protection Act 1990 (c. 43), Available from: http://www.opsi.gov.uk/acts/acts1990/Ukpga_19900043_en_1.htm [Accessed on 18 October 2009]

[32] Environment Act 1995 (c. 25). Available from: http://www.opsi.gov.uk/acts/acts1995/Ukpga_19950025_en_1 [Accessed on 18 October 2009]

[33] Department for Environment Food and Rural Affairs. Waste Strategy for England 2007. London, UK: The Stationery Office, 2007. Available from: http://www.defra.gov.uk/environment/waste/strategy/index.htm [Accessed on 28 October 2009]

[34] Environment Agency UK. Waste Protocols Project. Available at: http://www.environment-agency.gov.uk/business/topics/waste/32154.aspx. [Accessed on 15 January 2009]

[35] Agarwal A, Strachan P. NISP: Towards developing a new and integrative methodology to evaluate industrial symbiosis networks. Industrial Symbiosis in Action: Report on the Third International Industrial Symbiosis Research Symposium. New Haven: Yale F&ES Publication Series, 2007; pp.21-24.

[36] The Environmental Framework Act no. 11/87 of April 7, 1987. Available from (in Portuguese): http://dre.pt/pdf1sdip/1987/04/08100/13861397.pdf [Accessed on 29 October 2009].

[37] Law Decree No 178/2006 of 5 September 2006 on the General regime for waste management. Available from (in Portuguese): http://dre.pt/pdf1sdip/2006/09/17100/65266545.pdf [Accessed on 29 October 2009].

[38] MAOTDR - Ministério do Ambiente, do Ordenamento do Território e Desenvolvimento Regional (Ministry for the Environment, Territory Ordenance and Regional Development). Mercado Organizado de Resíduos, Apelo à demonstração de interesse (Organized Waste Market: call for interest). Lisbon: MAOTDR, 2008.

[39] Costa I, Ferrão P. Developing a local approach to eco industrial parks: the case of Chamusca EIP. Paper presented at the 14th Annual Sustainable Development Research Conference, New Delhi: India; 21-23 September 2008.

[40] UNEP – United Nations Environment Programme. Website for the Basel Convention. Available at: http://www.basel.int/text/documents.html. Last access: July 2009.

[41] Swiss Confederation. 1983. Environmental Protection Act (EPA). Status August 2008, n°814.01.

[42] Swiss Confederation. 1990. Technical Ordinance on Waste (TVA). Status January 2009, n°814.600.

[43] Swiss Confederation. 2005. Ordinance on the Handling of Wastes (VeVA). Status August 2005, n°814.610.

[44] State of Geneva. 1999. Law on waste management, n ° L 1 20.

[45] State of Geneva. Plan de gestion des déchets du canton de Genève 2009-2012 (Waste Management Plan for the Geneva Canton 2009-2012). Available at: http://etat.geneve.ch/dt/SilverpeasWebFileServer/PGD-09-basse-def.pdf?ComponentId=kmelia104&SourceFile=1236171797567.pdf&MimeType=application/pdf&Directory=Attachment/Images/. [Accessed on 29 July 2009]

[46] State of Geneva. 2001. Law on public action toward sustainable development. n° A 2 60.

[47] GEDEC - Service Cantonal de Gestion de Déchets (Canton Service for Waste Management). Ecologie industrielle à Genève: Premiers résultats et perspectives (Industrial Ecology in Geneva : Principal results and perspectives). Genève : Département of the Territoire - République et canton de Genève, 2005.

[48] Massard G, Erkman S. A regional Industrial Symbiosis methodology and its implementation in Geneva, Switzerland. Paper presented at the 3rd International Conference on Life Cycle Management. Irchel: University of Zurich; August 27 to 29, 2007.

[49] Eurostat – European Statistical Office. Waste Statistics Regulation database. Available at: http://epp.eurostat.ec.europa.eu/extraction/evalight/EVAlight.jsp?A=1&language=en&root=/theme8/env/env_wasgen . [Accessed on 13 November 2008]

[50] OFEV - Office Fédéral de l'Environnement (Federal Office for the Environment). Statistiques des déchets (Waste statistics). Available at : http://www.bafu.admin.ch/abfall/01517/01519/index.html?lang=fr. [Accessed on 11 December 2008]

[51] Korhonen J, von Malmborg F, Strachan P, Ehrenfeld J. Management and policy aspects of Industrial Ecology: an emerging research agenda. Business Strategy and the Environment 2004; 13: 289-305.

[52] Flynn B. Is local truly better? Some reflections on sharing environmental policy between local governments and the EU. European Environment 2000; 10: 75-84.

[53] EC - European Commission. The story behind the strategy: the EU Waste Policy. Brussels: European Commission, 2005.

[54] Gertler N. Industrial Ecosystems: Developing Sustainable Industrial Structures. Unpublished M.S. Thesis, Boston: Massachusetts Institute of Technology, 1995.

[55] Malcolm R, Clift R. Barriers to industrial ecology: The strange case of the "Tombesi Bypass". Journal of Industrial Ecology 2002; 6 (1): 4-7.

[56] Pongrácz E, Pohjola V. Re-defining waste, the concept of ownership and the role of waste management. Resources, conservation and Recycling 2004; 40: 141-153.

[57] Holmes J, Clark R. Enhancing the use of science in environmental policy-making and regulation. Environmental Science and Policy 2008; 11: 702-711.