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Abstract

A set of factors facilitate the role of Eco-Industrial Parks in addressing the many environmental challenges arising with economic development: among such factors the local context in which the EIP is embedded, i.e. the cohesion of the community, the cooperation among actors, the proximity and the adaptability, as well as the global context and economic phase play a major role. EIPs' evolution process is path-dependent, hence also history and choices made in the past as well as the context of the industrial sector are very important in determining their success. We study the industrial area of Venice, namely Porto Marghera, as a showcase, in order to understand how history can twist the evolution of an industrial area and determine its destiny. The analysis covers Industrial Symbiosis leverage factors, as well as the local, national and international context drivers that, over time, promoted or hindered the development and evolution of the area. We show how, due to the action of such multiple factors, such large and major Italian industrial area presenting just few years ago characteristics that could have favoured its development as an EIP, resulted eventually in a failure and the closing down of the most relevant economic activities supporting the functioning of the EIP itself. Context factors and single specific shocks, related to local issues as well as to the global, regional, and national scale, shifted the evolutionary path of a well-integrated EIP, even though the technical and internal characteristics of the industrial area were in place.

Keywords: Industrial Symbiosis, Eco-industrial Park, Chemistry sector, Italy

1. Introduction

"Industrial Symbiosis engages traditionally separate industries in a ***collective approach*** to competitive advantage involving physical ***sharing*** of materials, energy, water, and/or by products" (Chertow 2000).

According to this definition, Industrial Symbiosis (IS) allows to look at industrial production from three different perspectives: the physical aspects of production, the organizational aspects, and the economic ones. These perspectives correspond to three different interacting processes, giving rise to economic value, meaning that the results of the Industrial Symbiosis are economically sustainable through time, contributing to societal balance between environmental and economic goals. The collective perspective proposes a vision in which the competitive advantage for each separate industry is achieved, beyond the strategic positioning of one business entity, over its rivals within the industry. The notions of competitive advantage and Industrial Symbiosis, as well, are taken from biology and its evolutionary framework: achieving a competitive advantage means to strengthen one's own position within the (business) environment. Yet, Industrial Symbiosis does not assume the evolutionary selection mechanism, i.e. survival of the fittest, as it is typically the case in Economics. As in the ecological approach, where the system is at the centre of the stage, Industrial Symbiosis looks at mutualistic and symbiotic relationships, where different entities benefit from the exchange of materials, energy or information, achieving a collective benefit greater than the sum of individual benefits that could be achieved by acting alone. When the industrial systems follow these principles, adopting the natural ecosystem evolution as a metaphorical model for their development, they are referred to as industrial ecosystems (Korhonen et al. 2004, Espinosa 2005) or Eco-Industrial Parks (EIP). The EIPs represent the concrete realization of the concept of Industrial Symbiosis at inter-firm level.

In principle, industrial parks, in the form of an EIP, offer a way to combine economic development and good environmental conditions, standing as a real answer to the environmental challenges. They can be an important strategy, not only for emerging countries (that are investing in greenfield projects), but also for the industrialized ones, where environmental regulations, risk management and public acceptance often represent strict requirements that may hinder the survival of existing industrial areas. By closing the loop within industrial parks, that is directing used materials and by-products back to production processes within the area, EIPs are minimizing the use of resources coming from outside and the production of waste, representing an effective way to reducing costs

for firms and to improving environmental performance of industrial areas, thus promoting their sustainability.

The positive experiences made in different parts of the world, in addition to numerous failed efforts to develop EIPs according to the closing loop approach (Lowe and Evans 1995) underlay that the latter is an important tool for the realisation of eco-industrial parks. Yet, it represents only one out of a list of factors that create the premises for a successful eco-industrial park design. Optimizations of energy and material consumption, minimization of waste generation, and the exchange of by-products are all necessary, but not sufficient, conditions for the survival and the development of EIPs. The context in which they are embedded is of the utmost importance: the presence of a community, the cooperation, the proximity and the adaptability play a major role for an effective, sustainable and functional EIP.

EIPs functioning refers to the "3-2 heuristic" principle, defined as the minimum criterion to identify symbiosis. According to it, at least three different entities have to be involved in the exchanges of at least two different resources in order to distinguish a basic industrial ecosystem, even if still immature, from other types of industrial arrangements and cooperation (Chertow 2005).

The relevant literature highlights a set of further technical and context related factors that favour the development of IS. Among those, we may cite the existence of *synergies* among the firms, the availability of *infrastructures*, the presence of a *flexible regulatory framework* and *favourable policies*, the existence of some *information management systems,* of *facilitators* and the presence of a *coordination unit.*

In the real world, most of the industrial parks need to face other local, national, regional and global constraints such as the evolution of the international division of labour, the globalization processes, and the financial crisis. All of them affect the possibility of a successful development of eco-industrial parks.

This paper aims at studying the industrial park of Venice, namely Porto Marghera, and its development over time, focusing on the Industrial Symbiosis leverage factors, as well as the local, national and international context drivers that, over time, promoted or hindered its development and evolution. The paper is structured as follows: in section 2, on the basis of a literature review, we discuss the major factors favouring the development of an EIP; a brief history of Porto Marghera and its evolution over time is presented in Section 3; in Section 4 we discuss whether Porto Marghera ever showed the relevant characteristics of an EIP; the recent evolution and the causes of Porto Marghera's decline are discussed in Section 5, while Section 6 concludes.

2. *Structure and Context : Enhancing the Development of an Eco-Industrial Park*

The variety of structural and context factors supporting the development of an industrial park as an EIP is stressed in the relevant literature. Some, like the existence of *synergies* among firms, are a necessary condition; in Chertow (2000) three possible mechanisms that foster the Industrial Symbiosis are described, namely the green twinning, the pre-existing organizational relationships, and the anchor tenant model. All of them rely on pre-existing synergies among firms and productions to "propel Industrial Symbiosis". Industrial Symbiosis can evolve from green twinning, that is "a single material or energy exchange" (Chertow 2003), showing a clear, relevant and identifiable environmental and economic benefit which may be the stimulus for the development of further exchanges (Ehrenfeld and Chertow 2002). Exchanges of this kind include, for example in the case of a power plant, the co-generation of steam and electricity, the use of recirculated water or the conversion of ash into building materials (Ehrenfeld and Chertow 2002).

Industrial symbiosis can also evolve from existing organizational relationships or networks; these organizational relationships are the result of a common need to solve common necessities, such as accessing natural resources, dealing with natural disasters or hazards, or to jointly address new environmental regulations. For instance, in Kalundborg, the pioneer and the most famous case of Industrial Symbiosis, the partnership among the firms was stimulated by the need to solve the common need for a surface water resource (Chertow 2000, Ehrenfeld and Chertow 2002). A third enabling mechanism for EIPs is offered by the anchor tenant model, where the large scale throughput of the anchor may attract the co-location of other industries and businesses, according to the model of up-stream or down- stream vertical integration, supplying raw materials or using by-products (Lowe 1997).

The exchange of by-products can be a solid base for the development of an EIP among firms, but it requires dedicated *infrastructure*, calling for large investments, and, therefore, introducing a relevant constraint to the economic viability of specific symbiosis initiatives (Chertow 2000). For this reason, the existence of appropriate infrastructure is recognised as a fundamental element of Industrial Symbiosis (Coˆte´ and Hall 1995, Frosch and Gallopoulos 1989).

The role of environmental regulation in supporting Industrial Ecology is ambiguous; the notion of waste is crucial, since IE considers all materials either as resources or by-products that can be exchanged through Industrial Symbiosis mechanisms, while environmental regulations, in most of the countries, considers by-products as waste originated within the single production process, and as such, their transport and storage is strictly ruled within the waste management policy. These limitations are even more restrictive when dealing with hazardous substances, and regulations may

result in a barrier to the development of Industrial Symbiosis. Accordingly, a *flexible regulatory framework* and *favourable policies* are supportive of IS development (Chertow 2000, Coˆte´ and Hall 1995, Lowe and Warren 1996, Cote' and Smolenares 1997, Gertler 1995, Desrochers 2002). This is one of the lessons learnt from Kalundborg, where the flexibility of the Danish regulatory framework, that asks firms to submit detailed plans of their efforts for a continuous environmental performance improvement, instead of imposing technology standards, has encouraged the evolution of industrial symbioses (Ehrenfield and Chertow 2002).

Chertow (2000) underlines the matching of inputs and outputs in order to create links across industries as a further key element that promotes symbiosis. To support and enhance these links, the development of an *information management system*, fed by a systematic collection of information about inputs and outputs of the different entities, is an enabling condition, facilitating the flow of materials and energy within the system (Coˆ te´ and Hall 1995, Lowe and Warren 1996, Chertow 1999, Coˆte´ and Cohen-Rosenthal 1998).

Organizational factors, such as the presence of *facilitators* and of a *coordination unit,* support the establishment and maintenance of the momentum of a symbioses (Coˆte´ and Hall 1995, Coˆte´ and Cohen-Rosenthal 1998, Mirata 2004, Chertow 2004), also by facilitating the involvement of different stakeholders, the exchange of information, the opening of new and larger flows.

Summing up, twenty years of practice and reflection around the model of Industrial Symbioses have identified the favourable prerequisites for the development of an EIP and these elements can be gathered in a check list and used to evaluate specific instances and cases of industrial parks. This analysis will be carried out on Porto Marghera in paragraph 4.

3. Porto Marghera's Historical Development

The industrial park of Porto Marghera is located 5 km NW of the historical centre of Venice, between the urban areas of Marghera and Mestre on the mainland and the coastal lagoon. It spans on an area of 2000 hectares representing, in terms of extension and importance, one of the main Italian industrial sites, centrally located within the Venetian Lagoon, one of the UNESCO's world heritage sites.

Figure 1 Porto Marghera industrial area.

The location of a large industrial pole in an extremely fragile environmental context, given by the nearby presence of the city of Venice and the lagoon ecosystem, can only be explained going through the area's history. At the beginning of the XX century the port of Venice, which at the time was located in the insular area, had reached the maximum level of traffic, showing its structural limitations, such as the absence of rail and road connections to the mainland and the lack of land which turned into a severe physical constraint to any possible expansion. Therefore, the development of a commercial port and an adjacent industrial area on the mainland, exploiting the physical characteristics deriving by its favourable geographical position – located in proximity of the core of the Italian manufacturing industry in the Po valley, and on the Adriatic route – appeared to be a profitable opportunity. In addition to this, it was also considered the availability of labour force at low cost, as at that time the area was mostly rural and economically depressed.

In 1917 the Municipality of Venice and the Italian government signed an agreement in order to build the new port; the construction started in 1919 and in 1928 fifty-eight firms were already settled in the first industrial zone of Porto Marghera (Piva and Tattara 1983, pp. 139-140). The possibility for those plants to receive the necessary raw material directly on their quay was a strategic factor that favoured the settlement of basic industry, explaining the successful and rapid

development of Porto Marghera and in 1940 almost all the industrial sites in the area were occupied by firms (Nappi 1994, p. 95). In this period, the increasing needs of the war boosted industrial orders, but the war brought also bombings and plunders and an adjustment period followed the end of the conflict and in the early '50s the necessity of an expansion was manifest. Year 1955 marked the beginning of the second phase of Porto Marghera's development: the new city plan established the expansion of the port and the construction of the second industrial zone. The chemical sector played a dominant role in this second phase, occupying 84% of the total area: several chemical and petrochemical firms were attracted by the opportunity to settle down in an area developed as an integrated pole, with the aim to favour exchanges among activities. Porto Marghera became the core of the Italian chemistry and petrol-chemistry: in particular, the main activities in Porto Marghera were linked to the Chlorine cycle that includes dangerous and potentially polluting activities and substances.

In 1965 there were 229 firms located in Porto Marghera, employing nearly 33.000 people, the highest number of people ever employed in this industrial area (Table 1). In that period, the second zone was already saturated and plans for a further expansion of Porto Marghera into a third industrial zone were already being considered. The new project included the excavation of a new channel in the lagoon (in order to allow bigger and heavier ships to enter in the lagoon and reach the port in Porto Marghera) and the creation of new landfill areas in the lagoon to host further development. The project would have had heavy consequences on the extremely fragile hydrological equilibrium between the lagoon and the sea, already under substantial pressure from the anthropic activity. These drawbacks were not considered until then and the damage was already done. However, in 1966 Venice experienced a terrible flood: water reached 194 cm over the average sea level, flooding over 80% of the city, causing extensive damages. This disaster sparked off a movement of the public opinion for the safeguard of Venice. The local population blamed the short-sighted approach that had characterised most transformations which occurred in the lagoon during the century; in particular, the construction of the two industrial zones and the excavation of the navigation channels and inlets, the consequent pollution of the air, water and soil, were seen as main factors that lowered the resilience of the lagoon system and its capability to mitigate the impact of natural, though extraordinary, events like the 1966 flood.

The flood, and the subsequent pressure of the public opinion, posed the basis of a special law on the safeguard of Venice which entered into force in 1973. The development of the third zone was then definitively abandoned. However, until the '70s the growth of industries in the area continued, with a specialization in oil refining, metallurgy and steel, phosphates and fertilizers industries. In the '60s-'70s Porto Marghera represented, and not only in Italy, a model of concentration of industrial

activities, that worked as pivot of the entire Italy's North-Eastern economy. The crisis of this model started in the late 70s. The causes of the crisis were not local, but national and even international. The main determinants were the raw materials' price increase (oil first of all), a lower commitment of the government in terms of investments (less public money), and the rising environmental concern among the population. Moreover, a general restructuring process of the industrial sectors took place in that period in all the Western countries: many plants closed down causing a sharp decrease of the industrial occupational rates.

Table 1. Firms and employees in Porto Marghera

	1965		1999		2004		2007		2009	
	Firms	Empl	Firms	Empl	Firms	Empl	Firms	Empl	Firms	Empl
Food	9	419	5	148	4	147	5	154	6	141
Water, Gas, Energy	14	1.088	7	750	8	552	9	674	9	558
Ceramic, Glass, Construction material.	16	2.595	8	571	9	521	13	537	12	365
Chemistry	23	14.233	16	3.364	13	2.525	10	1.842	8	977
Mechanics	57	4.645	49	2.425	50	2.119	42	2.384	30	1.913
Metallurgy, iron and steel industry	15	6.487	11	1.237	12	1.053	7	836	6	517
Oil	23	1.460	15	528	13	530	12	583	11	529
Other Sectors	72	1.963	185	3.875	197	4.430	597	7.698	676	8.750
Total	229	32.890	296	12.898	306	11.877	695	14.708	758	13.750

Source: own elaboration on data from Ente Zona Industriale[1]

In 1991 Porto Marghera had already lost nearly 13.000 employees with respect to 1965. In the following decade other 7.000 employees were lost, with a loss of almost 20.000 units, equivalent to the 60% of the workforce. In the same period, the number of firms grew by nearly a hundred units as a result of two parallel processes: firstly, the shift from the Fordist model characterized by few, big and vertically integrated firms towards a model characterised by small and medium horizontally integrated enterprises that resulted in the fragmentation of the productive cycles in the chemical sector; secondly, the shift towards new specializations of the industrial sector and the growing importance of the non-industrial sectors. Moreover, in the 90s the main national actors of the chemical sector, EDISON and ENI, restructured their business strategies deciding to abandon the chemical sector. Following that, ENI progressively ceded all the activities carried out in Porto Marghera downstream of the ethylene production to multinational firms, i.e. Dow, Solvay, Ineos Vinyls, Ineos EVC present in the area. In 2001 the industrial pole of Porto Marghera counted

[1] Ente Zona Industriale (EZI) is an industrial association of Porto Marghera which involves 43 firms. It plays an important role on the prevention of industrial accidents and pollution control. Another important association in the area is the Provincial Industrial Association (Unindustria). Both these associations are signatories of the Chemistry Agreement

13.200 employees and 322 firms. In the period 2001-2009 the number of employees grew by a meagre 4.5% while the number of firms by 135%.

3.1 Recent Evolution in Porto Marghera

Currently, there are nearly 750 firms in Porto Marghera (Table 1). Among them we still find some belonging to traditional sectors: chemistry, oil refining, shipbuilding, metallurgy, iron and steel industry, and power/electricity generation. Big multinational players are represented by firms like Pilkington (float glass), Alcoa (aluminium), ENI R&M (oil refining), Polimeri Europa (polymers) ENEL and Edison (power generation) which are still significant in terms of production and employment (Table 2).

These figures show that, despite the general turn-over toward logistics and commercial sectors, the traditional activities still represented an important presence in Porto Marghera in the early 2000, with over the 60% of the employees.

Table 2. Main activities and firms in Porto Marghera in early 2000.

Sector	**Main Products/Activities and firms**
Chemistry	Acetone cyanohydrin (Arkema), Toluene diisocyanate (Dow), VCM, PVC and raw plastic production (Ineos Italia and Ineos Compounds, former EVC), Polymers (Polimeri Europa), Fluoridric acid and hydro fluorocarbon (Solvay Fluor Italia), chloride salts (Syndial)
Oil	Refinery (ENI Refinery), Cracking (Polimeri Europa), Coastal depots (Petroven, Decal)
Other industries	Float glass (Pilkington Italia), Air fractioning and industrial gas production (Sapio), Copper and zinc products (Simar), Shipyard (*Fincantieri - Cantieri Navali Italiani)*
Energy	Power Plants (ENEL Fusina, ENEL Porto Marghera, EDISON Levante, EDISON Azotati)
Waste and Water	SPM, MASI

Source: own elaboration

Another important factor influenced the area's evolution over the last 15 years: the recognition by law (in 1998) of Porto Marghera as one of the first 14 Italian industrial areas with the highest environmental risk, because of the contamination of the soil and water, legacy of past activities. The law planned the financing mechanisms for the decontamination of these areas, in order to safeguard the health and the environment, and at the same time, to allow the redevelopment of the territory (Co.S.E.S. 2004), even if the availability of the funds were not certain.

In 1998 different authorities, private companies and industrial associations signed the "*Accordo di Programma per la Chimica a Porto Marghera*" - Agreement for Chemistry Programming in Porto Marghera. Its main aim was to create and maintain over time ideal conditions for the coexistence of

environmental protection and the development of the chemistry sector in Porto Marghera. Consequently, its specific goals were the reduction and the management of the environmental risk and the redevelopment of Porto Marghera.

One of the reasons that pushed these actors to sign the agreement was the common need to comply with important new directives of the European Union on risk management, i.e. the directive 96/82/EEC (known as Seveso 2) on the control of major-accident hazards involving dangerous substances; the directive 96/61/EEC concerning integrated pollution prevention and control; the directive 94/63/EEC on the control of Volatile Organic Compound (VOC) emissions resulting from the storage of oil derivatives and their distribution from terminals to service stations; the 96/62/EEC Air Quality framework Directive for urban conglomerates. All of them put severe requirements for industries (Da Ronch et al. 2009).

The commitments within the agreement that seem of major interest from the point of view of this study deal with environmental monitoring and risk management. In particular, the signatories were committed to develop *environmental management systems* within the firms, to present an annual *environmental accounting*, to improve some *processes* and to develop research to support these improvements, to reduce and rationalize the movements (of raw materials and products), to substitute specific processes and substances with less polluting and hazardous ones and to promote industrial and scientific research.

As mentioned above, one of the "by-products" of the Agreement was the collection of series of a wide spectrum of data on the environmental accounting. The collected data consisted in the main outputs and transport modalities of each firm; the consumption (and in specific cases the production) of electricity (in kWh), thermal energy (in kJ) and total energy (in TEP); the quality and quantity of air emissions in terms of distinct pollutants; water withdrawal quantity differentiated according to usage; waste water quantity and modality of treatment, and pollutants discharged into lagoon; the quantity and treatment typology of solid waste, and environmental performance indicators. ARPAV, the Regional Agency for the Protection of the Environment, has been charged with collecting and elaborating these data.

On the basis of this green accounting, for each firm it is possible to track down the flows of materials and energy and the exchanges among them in the period 1998-2007. In particular, there is evidence of several exchanges going on in the petrochemical area in the late '90s - early 2000 years, even though just a limited number of them regarded by-products (Figure 2). They were mainly exchanges of products, energy and waste directed to the treatment plant within the area. Syndial, which included a chemical plant, a power plant and an incinerator, represented one of the main actors involved in the exchange, since it sold chemical products, steam and electricity to many of

the other firms in the petrochemical area. Another important actor was MASI which managed an incinerator and other treatment facilities receiving the solid waste and the wastewater of many firms in the area.

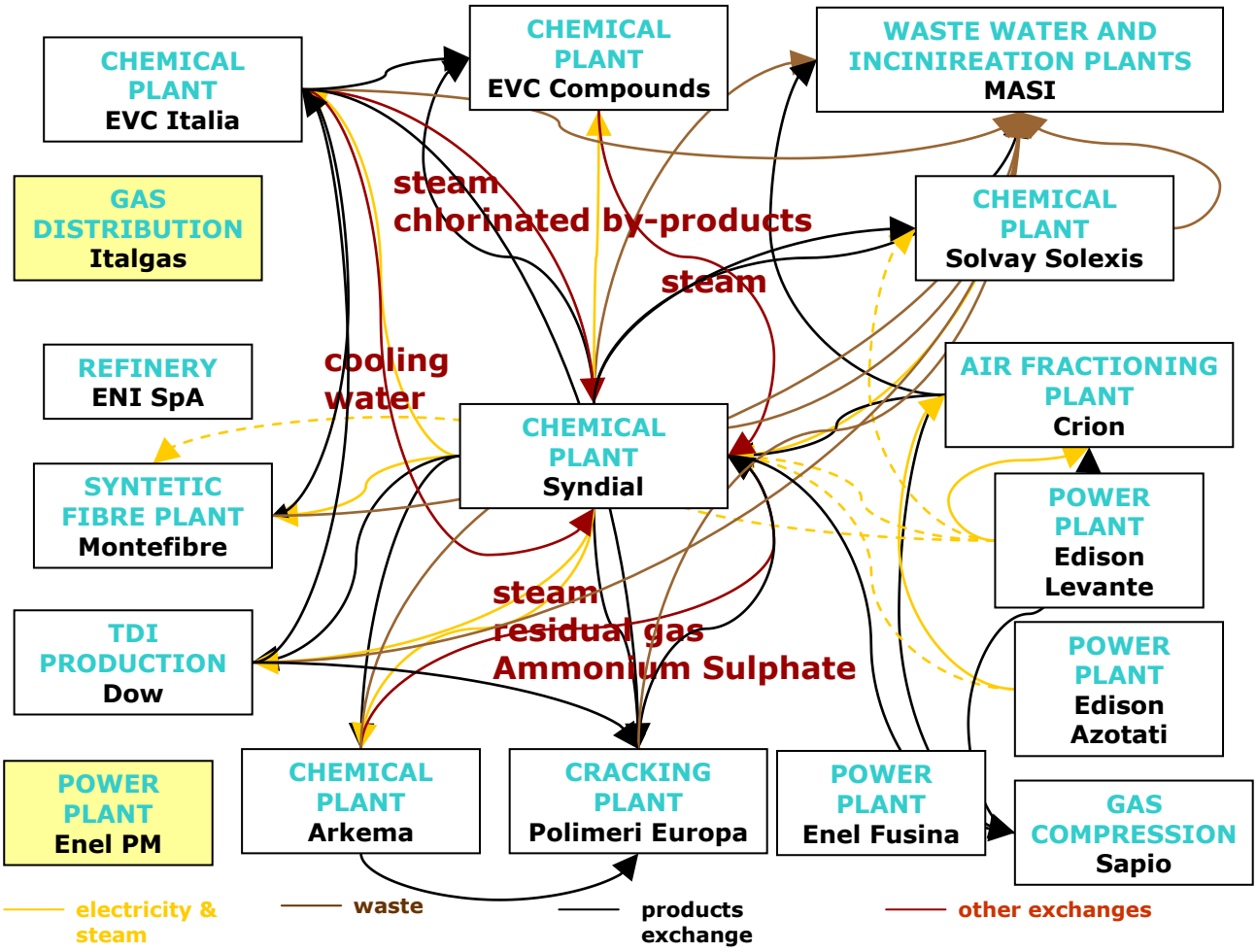

Figure 2 Exchanges among the firms involved in the environmental accounting in 2004

4. *Porto Marghera as Eco-Industrial Park*

The long and articulated history of Porto Marghera industrial area, its important economic role at the national and European level, the complexity of the industries involved, the heavy environmental burden, and the high social conflict in the area motivates our interest in studying the Porto Marghera industrial park. By using the language, principles, and tools of Industrial Ecology we can evaluate if it ever had the characteristics that would enhance its transformation into an Eco-industrial park and to develop in Industrial Symbiosis. The reference year we chose is 2004, a period when institutional and productive conditions were apparently supporting such possibility; we take as reference the favourable factors identified in section 2 to discuss our hypothesis.

With reference to year 2004, the application of the "3-2 heuristic" highlights the existence of a basic industrial ecosystem, though still immature. In particular, within the high number of finite product exchanges, there were by-products exchanges of steam, cooling water, hydrogen and chlorinated substances[2]. The latter were moved from the EVC Italia chemical plant to Syndial chemical plant. Steam had a more complicated network of exchanges: it was a by-product of many chemical processes (EVC, Arkema) and of electricity generation and was used to satisfy internal needs in a first order. The surplus was normally ceded to a network of pipelines managed by Syndial that acted as a compensation room. Moreover, Arkema and Syndial exchanged residual gas (Ammonium Sulphate) while Syndial (in a first moment) and Polimeri Europa and EVC Italia supplied hydrogen (a by-product of the ethylene cracking) to Sapio (an industrial gases producer) and to ENEL Fusina (power plant). Within this framework, Syndial could be considered the anchor tenant of the area, attracting satellite firms (Figure 2).

It is important to notice that since long most of the exchanges within Porto Marghera occurred by pipelines, representing an infrastructural network which constitutes an important asset for further developing by-products exchanges.

From the institutional point of view, the Chemistry Agreement offered, at that time, the voluntary base to enhance further opportunities of cooperation and networking.

Pre-existent synergies were operating in the area since long time: exchanges of steam and cooling water were active and the signatory parties of the Agreement offered a wider organizational partnership stimulated by the need to comply with the new environmental legislation, the possibility and need to jointly work to prevent and manage the risk, and lastly, the tempt to lobby for the redevelopment of the industrial zone, thanks also to public money.

With regard to the context conditions, the role of the regulatory framework is twofold: on one side it played a positive role, stimulating the Agreement for the Chemistry and the commitments within it; on the other side, the restrictive legislation concerning waste transportation and storage, and the special laws for the safeguard of Venice were posing significant obstacles to the development of further symbiosis, tightening up the transportation rules and increasing the costs. The Agreement itself required a rationalisation in the transport of hazardous materials.

[2] It is worth to mention that since Syndial, the biggest chemical actor in Porto Marghera, consisted of many integrated plants, most of the material flows and by-product exchanges were intramural. Therefore the "3-2 criterion" could not be applied to them. This was true up to the point that parts of Syndial were ceded to new actors in the area (for example Dow Chemical Italia). As a consequence, after that exchanges of by-products between what turned to be two different entities were subject to the application of the "3-2 heuristic".

Exogenous elements, related to the context variables, were driving the game; the possible future scenarios of the area development were strictly linked to the political choices, regarding some key industrial sectors and firms, in particular, the chemical sector, the future of which was determined at a national and even European level.

However, the presence of facilitators and a coordination unit created a favourable context to set in motion the symbiosis development. Among the signatories of the Agreement for the Chemistry, some entities could cover the function of coordination, such as ARPAV, and the industrial associations (Ente Zona Industriale, Unindustria). These entities have been well established in the area in the last decades, and they were already been acting as facilitators, in the field of risk management and monitoring.

Finally, the Agreement posed the base for the development of an advanced information system, giving rise to a database, developed by ARPAV, collecting the environmental accounting of all the firms involved in the project, producing a systematic collection of the relative data, thus offering an important starting basis to facilitate the exchange of information and materials.

Table 3 Industrial Symbiosis favourable factors for Porto Marghera industrial park in 2004.

Favourable Factors	Presence in Porto Marghera
Existing Synergies	Yes
Infrastructures	Yes
Flexible regulatory framework	No
Favourable policies	Maybe
Facilitators and coordination unit	Yes
Systematic collection and management of information	Yes

Source: own elaboration

Table 3 shows that most of the structure and context factors favouring the development of EIPs were present in the last decade; basing our expectation on this analysis, we could have foresee a further development and strengthening of the symbiosis in the industrial area of Porto Marghera, but the situation in the last decade, as represented in the Figure 1, evolved differently and the recent situation, with reference to year 2012, did not support these expectations.

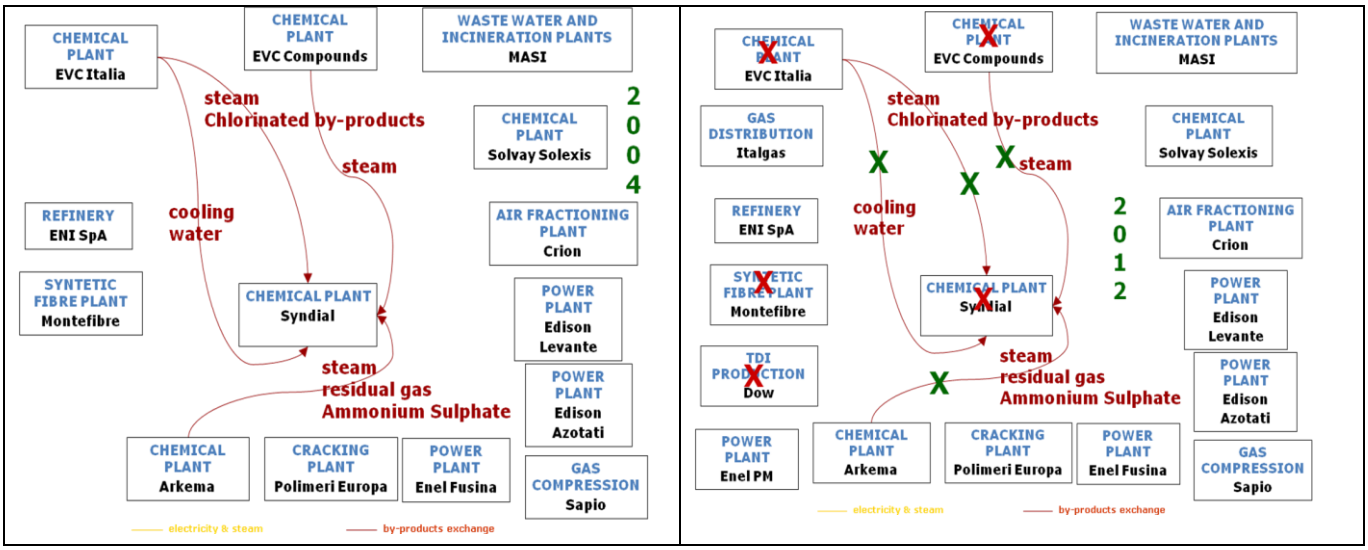

Figure 3 Comparison between by-products exchanges in Porto Marghera in 2004 and in 2012.

5. *Structure and context: the Drivers of the recent decline*

In order to understand the reasons of the unexpected evolution of Porto Marghera in the last ten years, despite the favourable factors present in the park in 2004, we need to look beyond the borders of the Porto Marghera industrial area. The recent evolution of Porto Marghera shows that many of the plants and firms in the area have been temporary or definitively shut down in the last years, as summarised in Table 4.

The disappointing situation depicted in Table 4 is the result of various factors, some of which depending on the local context, others influenced by national, regional and even global scenarios.

Starting from the highest scale, the evolution of the situation of the chemical firms acting in Porto Marghera reflects major changes at global level; these firms gave up diversification in production, becoming very specialized, given the global concentration and a fierce competition context where only leaders survive. Survival, in Europe, requires new investments for improving the quality and decreasing production costs, and reaching scale economies, concentrating the activity in big plants. Plant size is critical all around Europe, traditionally characterized by small industrial areas, while competitors worldwide show a much higher concentration. The scale factor is even more critical in Italy. For example, the cracking plant in Marghera, with a production of 370 thousand tons of ethylene, is the second in the country (Becchi 2009), whereas competitors in Europe have sites where the ethylene production exceeds the million tons.

Table 4. Situation in 2012 of the main plants in Porto Marghera. In grey there are highlighted those shut down in the recent years or currently in crisis.

Name	**Activity**	**Situation in 2012**
Alcoa	Aluminium	Active, but reduced capacity of production
Arkema Srl	Production of Acetone cyanohydrin a – an intermediate product neccessary to the synthessis of Polymethyl methacrylate (PMMA)	Active
Dow Poliuretani Italia	Toluene diisocyanate (TDI) production	Closed since August 2006
ENI S.p.A. Raffineria di Venezia	Processing of crude oil for light distillates (LPG and gasoline), middle distillates (petrol and diesel) and heavy distillates (fuel oil, bitumen). In addition to crude oil, rework or mixing of other raw materials and finished products to be commercialized	Active
Fincantieri	Cruise ships and ferries production	Active, but production affected by the economic crisis
EVC/INEOS Compounds S.p.A	Processing of Poly vinyl chloride (PVC) for the production of plastic and rigid grains	Production halted in 2009
Montefibre S.p.A.	Acrylic fibres production	Production halted in 2009
Pilkington Italia S.p.A.	Float glass production	Active
Solvay Fluor Italia S.p.A.	Hydrofluorcarbons (HFC), hydrochlorofluorocarbons (HCFC), aluminium polychloride production	HCFC production still active, but highly affected by the economic crisis
Syndial S.p.A.	Chloride salts production	Production halted in 2009
EVC/Vinyls Italia	Vinyl Chloride Monomer cycle	Production halted in 2009

Source: own elaboration

Up against this necessity to concentrate the production in a certain site, it is clear that the chemical firms, mainly represented nowadays by multinationals, are not choosing Italy for their plants. As reported by Trifirò (2009b), an example is represented by Dow Chemical, that just after shutting down the plant in Porto Marghera, announced the realization of a three times bigger one in another country in Europe. Similarly, Ineos Vinyls, while leaving Italy, where it controlled the majority of the Polyvinyl chloride (PVC) market, was buying an entire PVC production line in another EU country that covered also raw materials (Trifirò 2009a).

Italy seems not to be very attractive for investments in the chemical sector, not only for the small size of the existing plants, but also, and mainly, for the high costs of production. This aspect affects all of the industrial sectors and, in particular, the highly energy demanding ones, such as the chemical and non-ferrous metal sectors, as the recent Alcoa event witnesses. The company has in recent years threatened to abandon its two Italian plants if the Italian government did not take adequate measures to mitigate the energy costs which, on the other hand, the European Commission

would (probably) consider as illegal governmental contributions. Still with reference to production costs, those related to transport are also relatively high in Italy. Last, but not least, Italy is characterized by slow bureaucracy. Therefore, transaction costs are very high. The case of INEOS is striking. The firm had to wait for about three years for the approval of plans to increase the production capacity and in contemporary introduce environmental improvements for the entire production process. The approval of the same authorization would have taken about three months in the United Kingdom and only two months in Germany (Trifirò 2008).

All these aspects are really relevant, if we also consider that most of the industrial sectors which are present in the area of Porto Marghera are global and characterized by the presence of multinational firms, typically acting at the world scale when considering competitive aspects and taking investment decisions.

Even ENI, the Italian energy giant, once leading the fortune of the Porto Marghera industrial area and the evolution of the chemical sector in Italy, decided to abandon the chemistry and concentrate in the more promising energy sector. Commentators saw this decision as a result of the high instability and social turmoil in the area, thus also influencing the behaviour of other foreign firms, which through time left the area, searching for new sites in Europe. There is no doubt that, after many years of day by day living, the future of the chemical sector in Italy seems quite negative, as it would require high investments, alliances among firms, and industrial areas restructuring all over Italy, with a high price to be paid in terms of job losses and social unrest. Such evolution seems quite unlikely now, under the on-going economic crisis, and in the future.

Other context factors to be mentioned have a local scale: in 2005 an environmentalist political movement in Venice promoted a referendum among the local population in order to decide on the future of the chemical sector in Porto Marghera. People were asked by mail whether they wanted or not the closure of the activities involving Chlorine. The referendum, concluded in 2006, resulted in 80% of the responding population in favour of the closure of Chlorine production, witnessing that a great part of the local population were not supporting the existence of Porto Marghera.

The referendum constituted a divide, together with a trial that involved civil parties seeking damages over Montedison and EniChem former executives for exposure to vinyl chloride monomer (VCM) which caused pollution leading to the death of 140 workers before 1995. The Porto Marghera trial, after many years and contradictory judicial sentences, has come to an end in 2006 finding guilty all the accused.

The highly critical public opinion since then was a major obstacle also to some new investments and new product lines; an example is the shutting down by Dow of its Toluene diisocyanate plant, few months after the referendum, claiming the existence of an European overproduction, on the one

side, while opening a new and bigger plant in Europe, only few months later. The choice of Dow resulted in a loss not only of jobs, but also in possible improvements in the environmental condition in the area (Trifirò 2006).

Eventually, the macro economic factors, and the influence of the long lasting economic crisis, have recently affected other firms and others sectors, even those more promising and active with investment plans in the area, as in the case of Pilkington glass plant and Fincantieri ship constructor, that were compelled to revise their perspectives in the area, but did not proceed due to economic constraints.

6. Conclusions

Typically, heavy industrial productions are concentrated in large industrial areas, offering the opportunity of synergies among firms but also frequently resulting in a heavy burden for the local environment. This is the case of the industrial park of Porto Marghera, located close to the historical centre of Venice, in the coastal area and spanning 2000 hectares. Its history and evolution are useful to understand the complexity of every attempt to decouple economic growth and environmental damages as influenced by different factors at diverse scales. Industrial Symbiosis offers a reference model to achieve a collective competitive advantage, resulting in positive and sustainable economic results on the one side, while approaching conflicting goals of the society, i.e., economic growth and environmental safeguard, on the other one. EIPs are diffused in several countries and have exhibited different fortunes and opportunities to develop more sustainable industrial production. The analysis of many experiences worldwide has highlighted that a variety of factors are at work in determining a positive path of evolution for EIPs. Some of these factors pertains the internal functioning of the EIPs, typically technical, infrastructural and economic ones; other elements for success are found in the context, typically the cohesion of the community, the regulatory framework and arrangements, and local and national political positions. Also the macro context is of course extremely relevant, and it may work as a trigger or as an obstacle, for the flourishing of Industrial Symbiosis.

We studied the industrial area of Porto Marghera, as a showcase, to understand how history and choices can twist the evolution of an industrial toward the favorable situation of becoming an EIP and what other factors can influence it. This important and major Italian industrial area, that just few years ago presented characteristics that could have favored its development as an EIP, is nowadays very far away from this scenario and it is almost imploded as an active economic site.

The shutting down of the main productions and the uncertain future of many of the remaining ones strongly reduced the diversity that would give to this industrial area more survival possibilities and the capacity to adapt to changes.

Moreover, the uncertainty of the future of the area makes particularly risky investing in initiatives aiming at a circular use of the resources and promoting exchange of by-products, considering that the collaborators could suddenly disappear and the area is not able to attract substitutes.

External macro and micro factors highly influenced this unexpected evolution. The global and European restructuring of the chemical sector, focusing on the concentration of the production in few big plants, the high costs of the Italian bureaucracy and services in the country, the public opinion opposition to whatever hazardous activities in the lagoon of Venice, and the lack of a clear and stable political strategy for the area, making it very risky to invest, played a key role in determining the recent situation.

Summing up, this analysis highlights how context factors and single shocks, not only related to the local scale, but also to global, regional and national level and, therefore, more difficult to control and manage, are truly determining the evolutionary path of possible EIPs, even when the technical and internal characteristics of an industrial area would be favourable.

This makes more difficult, especially in mature economies, to plan EIP, as the factors to consider are too many and some of them not easy to control.

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