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CIRCULAR ECONOMY AND INDUSTRIAL SYMBIOSIS

Possible Pathways in the Industrial Area of Rieti-Cittaducale

SECS-P/06

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To a South young female

“You never change things by fighting the existing reality.

To change something, build a new model that makes the existing model obsolete"

Richard Buckminster Fuller

INTRODUCTION

In the last few decades, thanks to the publication of several international scientific researches and essays, the awareness of the close link among economic activities, the environment and the human well-being has largely increased (Boulding, 1966, Commoner, 1971; Georgescu-Roegen, 1971; Meadows et al., 1972; Daly, 1973; Bundtland, 1987; Millennium Ecosystem Assessment, 2005b; Stern, 2006; IPCC, 2007; TEEB, 2010).

Currently, manufacturing "is responsible for around 35 per cent of global electricity use, over 20 per cent of CO_2 emissions and over a quarter of primary resource extraction; it accounts for 23 per cent of global employment as well as for 17 per cent of air pollution-related health damage. Estimates of gross air pollution damage range from 1 to 5 per cent of global Gross Domestic Product" (UNEP 2011b, p. 244).

"At the global level, the consumption of natural resources and production of waste have increased to a greater scale than ever before. Data indicate that global raw material use rose during the 20th century at about twice the rate of population growth. For every 1% increase in GDP, raw material use has risen by 0,4%. Furthermore, much of the raw material input in industrial economies is returned to the environment as waste within one year. Although there has been some relative decoupling of economic growth and natural resource use, it is insufficient to cope with the even higher demands from a projected world population of more than 9 billion people by 2050 and from the rapid economic growth in newly industrializing countries. Unsustainable consumption of natural resources and concomitant environmental degradation translates into increasing business risks through higher material costs, as well as supply uncertainties and disruptions" (G7 Germany, 2015a, p.6).

In Europe it is estimated that resource efficiency could result in overall benefits of €1.8 trillion by 2030 (twice the benefits seen on the current development path); an 11% GDP increase by 2030 versus today (4% in the current development path); an increase average disposable income for EU households by €3.000 (11% higher than the current development path); a 32% drop of primary material consumption; a 48% reduction of carbon dioxide emissions by 2030 (Ellen MacArthur Foundation et al., 2015).

In order to meet this goals many international organizations and governments are placing greater emphasis on the implementation of a green economy and its ability to reorient the current production system towards sustainable processes and products. The greening of the production system can lead, in fact, to a more efficient use of resources, thus avoiding excessive human pressures on biodiversity, ecosystems and their services, i.e. on the natural capital, that has become a key strategic asset for sustainable economic development of countries (OECD, 2011; TEEB, 2010; UNEP, 2011b; United Nation, 2015).

In this context, an increasing effort has been devoted to the research on the numerous implications between environmental and regional economic development. Many studies have focused on the concept of *regional sustainability* and the local environmental impact of industrial production, highlighting, in particular, their impact on the well-being of local communities (Batabyal and Nijkamp, 2010; Giaoutzi and Nijkamp, 1994; Gutman, 2007; Wallis et al., 2007).

It’s interesting to highlight that, at the international level, many countries are trying to green their production systems by adopting initiatives seeking the development of a circular economy through resource efficiency (European Commission, 2014c; 2015b; G7 Germany, 2015a; 2015b; People's Republic of China, 2008).

Indeed, reshaping the current linear model of production in a circular way can be an effective policy to promote a new model of development which improves local production system competitiveness, while preserving biodiversity and ecosystem services and so improving local communities’ well-being. In this direction the key case is certainly the model of industrial symbiosis realized in the eco-industrial park at Kalundborg in Denmark that is the first concrete realization of an industrial ecosystems at local level (Chertow, 2000, 2007). Thus, improving a circular economy through industrial symbiosis may lead to a virtuous interaction between companies and territory. If the companies’ production were turned out by minimizing the waste of resources and/or reusing in their process the waste generated by nearby companies, this could enable collaboration between companies, which can lead to win-win opportunities both economic and environmental levels (La Monica e al., 2014).

These considerations are particularly in line with the current topics of 2014-20 EU programming period where the circular economy and the industrial symbiosis are considered strategic factors to improve resource efficiency in business–to-business relations, to promote a smart, sustainable and inclusive growth. and to foster a greater territorial cohesion (European Commission, 2010; 2011a; 2014a; 2014b; 2015b; 2015h; 2015i).

It’s important to note that until a short time ago despite relevance of this topic eco-industrial development have generated, with a few exceptions, little interest in the regional science (Desrochers and Leppälä, 2010).

In this context, my PhD thesis aims to verify whether industrial symbiosis pathways can be implemented in an industrial area, in order to analyze and evaluate ex-ante the possible effects on the local resources management. The main objective of this research in fact is to verify whether some industrial symbiosis pathways can be implemented in the industrial area of Rieti-Cittaducale managed by Consorzio di Sviluppo Industriale della Provincia di Rieti. In order to achieve this objective the thesis aims to answer the following research questions:

(I) Why is it important to move from a linear economy to a circular economy through industrial symbiosis?

(II) What economic concepts can be used to explain the industrial symbiosis at the regional level?

(III) What are the most interesting initiatives of circular economy and industrial symbiosis in different territorial scale?

(IV) How can we verify opportunities of industrial symbiosis in the industrial area of Rieti-Cittaducale?

(V) Are there some possible pathways of industrial symbiosis that can be implemented in the industrial area of Rieti-Cittaducale?

With the aim to answer these research questions the thesis is organized into six chapters.

In the first chapter, I will show why the industrial symbiosis can be considered an effective industrial policy tool for the transition towards a circular economy. For this purpose, I will first focus on the main reasons of the decoupling between economic growth and human pressure on biodiversity and ecosystem services. Then, I will focus on the importance of the transition from an open and linear economy to a closed and circular one in order to overcome such decoupling. Finally, a description the most relevant issues concerning the industrial symbiosis will take place, by discussing the extent to which it may be an effective tool to convert in a circular way the current linear model of production.

In the second chapter, I will describe the main theories and models of regional economics, explaining more effectively the industrial symbiosis. To do so, I will tackle the different concepts of space in the economic theories and their most important features, by focusing, in particular, on two groups of economic theories, the *industrial location theories* and the *local development theories*. The role played by industrial symbiosis in the regional economics will be then discussed at the end of the chapter.

In the third chapter, after describing the main policies on circular economy at the international level, I will present some successful cases of industrial symbiosis at different spatial scales. Namely, two experiences of industrial symbiosis at the local level (Kalundborg in Denmark and Guigang Group in China), and two experiences at the regional level (National

Industrial Symbiosis Programme, NISP in UK. and ENEA experiences of industrial symbiosis in Italy) will be discussed.

In the fourth chapter I will explain the methodology used to verify whether some industrial symbiosis pathways can be implemented in the industrial area of Rieti-Cittaducale. At first I will describe the research methodology used; after I will focus on methodology applied to the industrial area of Rieti-Cittaducale.

In the fifth chapter I will introduce the case study of industrial symbiosis in the industrial area of Rieti-Cittaducale, in the implementation of which I was directly involved. At first, I will describe the industrial cluster and its territorial context; then, I will show the input/output matching of companies and the scenario analysis of the matches identified.

In the last chapter I will display the possible pathways of industrial symbiosis in the industrial area of Rieti-Cittaducale. At first I will focus on the main industrial symbiosis pathways identified; then I will discuss the main economic and environment results that can be achieved through their implementation.

The evidences emerged from the analysis developed in these six chapters will be the basis to draw some conclusions and answer to the research questions that inspired this thesis.

Chapter 1

Circular Economy and Industrial Symbiosis

The first chapter discusses why the industrial symbiosis can be considered an effective industrial policy tool for the transition towards a circular economy. To this purpose, it first tackles the main reasons of a decoupling between economic growth and human pressure on biodiversity and ecosystem services. Then, it focuses on the importance of the transition from an open and linear economy to a closed and circular one in order to reach a decoupling. Finally, it describes the most relevant issues concerning the industrial symbiosis, highlighting how this field of industrial ecology can be an effective industrial tool in order to convert in a circular way the current linear model of production.

1.1 The main reasons for a decoupling between economic growth and human pressure on biodiversity and ecosystem services

In the last few decades much literature has been published on *green economy*[1] (see Table 1.1) and the related concepts of *green growth* (see Table 1.2). These concepts are used interchangeably by now. They are based on an integrated and holistic approach in order to incorporate environment and development in economic decision-making, policy and planning (United Nations, 2012).

A green economy (or green growth) mainly wants to dispel a myth on the greening of the economy, that there is an inescapable trade-off between environmental sustainability and economic progress and that is, instead, green and growth can go hand-in-hand together (UNEP 2011b; OECD 2011).

[1] "The term green economy was first coined in 1989 in a report written by a group of leading environmental economists for the Government of the United Kingdom, entitled Blueprint for a Green Economy (Pearce, Markandya and Barbier, 1989) The concept of green growth has its origins instead in the Asia and Pacific Region in 2005 at the Fifth Ministerial Conference on Environment and Development (MCED) (UN 2012)-

Table 1.1. Definition of Green Economy

"A Green Economy can be defined as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2010b, p.5).
A system of economic activities related to the production, distribution and consumption of goods and services that result in improved human well-being over the long term, while not exposing future generations to significant environmental risks or ecological scarcities (UNEP, 2010c, p.5)
An economy that results in improved human well-being and reduced inequalities, while not exposing future generations to significant environmental risks and ecological scarcities. It seeks to bring long-term societal benefits to short-term activities aimed at mitigating environmental risks. A green economy is an enabling component of the overarching goal of sustain-able development (UNCTAD, 2011, p.vi)
Green economy is "a resilient economy that provides a better quality of life for all within the ecological limits of the planet" **(**Green Economy Coalition 2015)
"The "Green Economy" is described as an economy in which economic growth and environmental responsibility work together in a mutually reinforcing fashion while supporting progress on social development" (International Chamber of Commerce, 2011, p.2)
"The Green Economy is not a state but a process of Transformation and a constant dynamic progression. The Green Economy does away with the systemic distortions and dis-functionalities of the current mainstream economy and results in human well-being and equitable access to opportunity for all people, while safeguarding environmental and economic integrity in order to remain within the planet's finite carrying capacity. The Economy cannot be Green without being Equitable (The Danish 92 Group forum for sustainable development, 2012, p.1)
"The green economy involves largely new economic activities and must provide an important entry-point for broad-based black economic empowerment, addressing the needs of women and youth entrepreneurs and offering opportunities for enterprises in the social economy "(Economic Development Department, Republic of South Africa, 2011, p.8).
"It can be seen as a lens for focusing on and seizing opportunities to advance economic and environmental goals simultaneously" (UNCSD, 2011, p.4)

Source: Own compilation and United Nations, 2012

The main concept of green economy is that of *natural capital*, "an economic metaphor for the limited stocks of physical and biological resources found on earth, and of the limited capacity of ecosystems to provide ecosystem services" (TEEB 2010, p.33)

The economic concept of natural capital matches essentially with the ecological concepts of biodiversity[2] and ecosystem[3] (TEEB 2010; UNEP 2011b).

Table 1.2. Definition of Green Growth

"Fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD, 2011)
"aims to foster economic growth and development while ensuring that natural assets and environmental services are protected and maintained. The approach places a premium on technology and innovation — from smart grid systems and high-efficiency lighting systems to renewable energies including solar and geothermal power — as well as on improving incentives for technology development and innovation" (United Nations Secretary-General's High-level Panel on Global Sustainability, 2012, p.24).
"growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural-hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive. […] Inclusive green growth aims to operationalise sustainable development by reconciling developing countries' urgent need for rapid growth and poverty alleviation with the need to avoid irreversible and costly environmental damage" (World Bank, 2012, p.2)
"Green growth can be defined as economic progress that fosters environmentally sustainable, lowcarbon and socially inclusive development. Pursuing green growth involves outlining a path to achieving economic growth and well-being while using fewer resources and generating fewer emissions in meeting demands for food production, transport, construction and housing, and energy" (UNESCAP et al, 2012, p.17)
"Green growth is the new revolutionary development paradigm that sustains economic growth while at the same time ensuring climatic and environmental sustainability. It focuses on addressing the root causes of these challenges while ensuring the creation of the necessary channels for resource distribution and access to basic commodities for the impoverished" (Global Green Growth Institute, 2015)

Source: Own compilation and United Nations, 2012

There are strong linkages between ecosystems and human well-being and, in particular, on ecosystem services (see Figure 1.1) (Millennium Ecosystem Assessment, 2005b).

[2] *Biodiversity* means "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (United Nations 1992, p.3*)*.

[3] *Ecosystem* means "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (United Nations 1992, p.3), i.e. as a single system of interdependent elements. "Ecosystems can be relatively undisturbed by people, such as virgin rainforests, or can be modified by human activity" (TEEB 2008, p.12).

Figure 1.1. Linkages between Ecosystem Services and Human Well-being

Source: Millennium Ecosystem Assessment 2005b, p. vi.

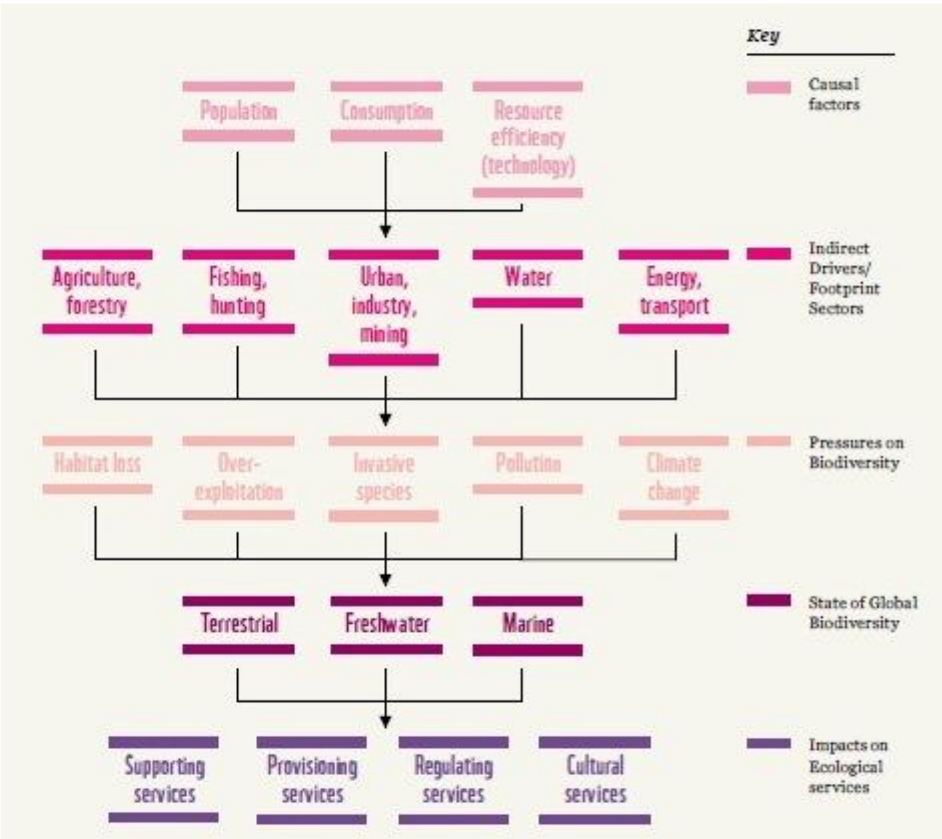
Human well-being is assumed to have multiple constituents, including: *basic material for a good life*; *health; good social relations*; *security*; *freedom of choice and action* (Millennium Ecosystem Assessment, 2005b).

Both quantity and quality attributes of biodiversity are important when considering the links between nature, economic activity and human well-being. In recent literature, these links are often described using the concept of ecosystem services, that is the direct and indirect, material and non-material human benefits obtained from ecosystems as a result of the state and quantity of natural capital. According to the Millennium Ecosystem Assessment there are four categories of ecosystem services that contribute to human well-being, all underpinned by biodiversity (Millennium Ecosystem Assessment, 2005b; TEEB, 2010):

- *Provisioning services:* they are ecosystem services that describe the material outputs from ecosystems. They include: *food*; *raw materials*; *fresh water*; *medicinal resources.*

- *Regulating services:* they are the services that ecosystems provide by acting as regulators, e.g. regulating the quality of air and soil or by providing flood and disease control. They include: *local climate and air quality regulation*; *carbon sequestration and storage*; *moderation of extreme events*; *waste-water treatment*; *erosion prevention and maintenance of soil fertility*; *pollination*; *biological control*.
- *Cultural services:* they are the non-material benefits people obtain from contact with ecosystems. They include: *recreation and mental and physical health*; *tourism*; *aesthetic appreciation and inspiration for culture, art and design*; *spiritual experience and sense of place*.
- *Supporting services*: They underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals. They include: *habitats for species*; *maintenance of genetic diversity*.

Figure 1.2. Interconnections between people, biodiversity, ecosystem health and provision of ecosystem services



Source: WWF 2010, p.11.

The concepts of ecosystem services and natural capital can help us recognize the many benefits that nature provides, but also how it can be continuously damaged by man, considering that all human activities make use of ecosystem services can also put pressure on the biodiversity that supports these services (see Figure 1.2) (TEEB 2010, WWF 2010). The extent of human impact on biodiversity depends on three factors:

- the total number of consumers, or population;
- the amount each person is consuming (i.e. lifestyles);
- the efficiency with which natural resources are converted into goods and services (depending mainly on the technology used).

Human demands for food, drink, energy and materials, as well as the need for space for towns, cities and infrastructure depends, in large part, on these three factors. These demands are largely met by a few key sectors: agriculture, forestry, fisheries, mining, industry, water and energy, which form the indirect drivers of biodiversity loss. The humanity puts direct pressures on the biodiversity and on ecosystem service, mainly through five ways: *habitat loss, alteration, and fragmentation; over-exploitation of wild species populations: pollution*: *climate change*: *invasive species*.

Biodiversity loss can cause ecosystems to become stressed or degraded, and even eventually to collapse. Indeed, it is increasingly clear that many ecosystems have been degraded to such an extent that they are nearing critical thresholds or tipping points, beyond which their capacity to provide useful services can be drastically reduced (TEEB, 2010; WWF 2010). According to the Millennium Ecosystem Assessment in the last 50 years, about 60% of the Earth's ecosystem services examined have been degraded or used unsustainably from human activities, including capture fisheries, water supply, waste treatment and detoxification, water purification, natural hazard protection, regulation of air quality, regulation of regional and local climate, regulation of erosion, spiritual fulfillment, and aesthetic enjoyment (Millennium Ecosystem Assessment, 2005b).

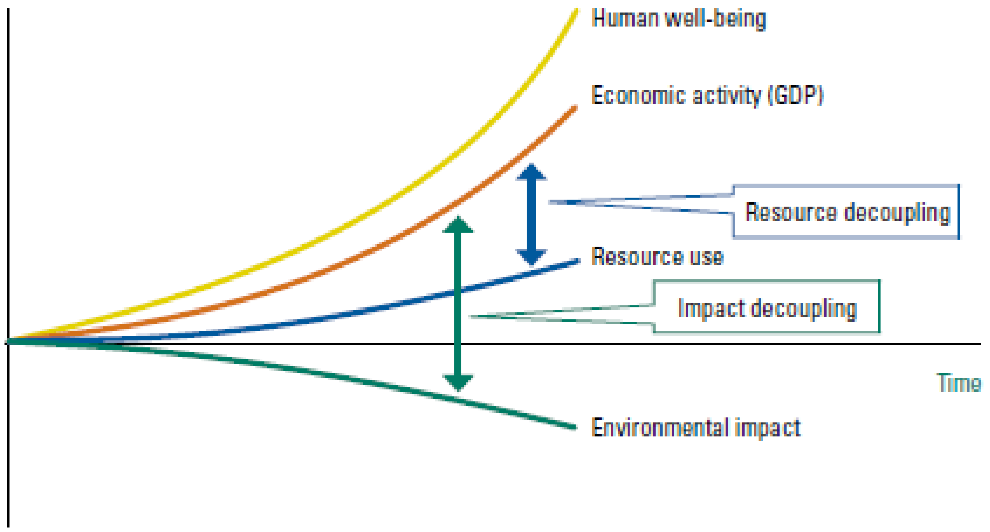
The strength of the linkages between ecosystem services and human well-being and the potential for mediation by socioeconomic factors differ in different ecosystems and regions. Local communities are influenced in fact by: *global factors* including commodity prices (e.g. global trade asymmetries that influence local production patterns) and global climate change (such as sea level rise); *regional factors* including water supply regimes (safe piped water in rural areas), regional climate (desertification), and geomorphological processes (soil erosion and degradation); *local factors* including market access (distance to market), disease prevalence (malaria, for example), or localized climate variability (patchy thunderstorms). Different strategies and interventions can be applied to enhance human well-being and conserve ecosystems (Millennium Ecosystem Assessment, 2005b).

According to UNEP in order to transition toward a green economy we need public and private initiatives that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services so to maintain, enhance and, where necessary, rebuild natural capital (UNEP, 2011b; 2016)

"In order to achieve these goals, natural resource[4] use and associated negative environmental impacts, on a global and long term level, must as far as possible be decoupled from the economic activity required to support a growing population" (UNEP, 2011a, p.1)

A decoupling[5] among economic activity, environmental impacts and natural resource use (see Figure 1.3), through the development and the application of green technologies or eco-innovation, can be a strategic option both at the country and the industrial sector level, in order to get a higher competitiveness and a lower pressure on environment (European Commission 2005a, OECD, 2011; UNEP 2011a; 2011b; 2014b; United Nations, 2015).

Figure 1.3 Decoupling among economic activity, environmental impacts and natural resource use.



Source: UNEP 2011a, p.5.

[4] "*Natural resources* can be given a broad definition that includes anything that occurs in nature that can be used for producing something else" (UNEP, 2011a, p.1).

[5] The concept of decoupling resource seems to have been adopted for the first time at the international level in policy paper 'Environmental Strategy for the First Decade of the 21st Century by OECD Environment Ministers in 2001 (OECD, 2001).

According to OECD “the term *decoupling* refers to breaking the link between *environmental bads* and *economic goods* (OECD, 2002, p.1). Continuing OECD explains that “decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force (e.g. GDP) over a given period. Decoupling can be either *absolute* or *relative*. Absolute decoupling is said to occur when the environmentally relevant variable is stable or decreasing while the economic driving force is growing. Decoupling is said to be relative when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the economic variable” (OECD, 2002, p.1). It’s important to note that a few years before, the World Business Council for Sustainable Development (WBCSD) coined the concept of *eco-efficiency*, which is achieved through the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life cycle (Schmidheiny, 1992). Although term *decoupling* was not mentioned, the substance was already being used, including the life cycle approach” (UNEP, 2011a). According to UNEP “decoupling means using less resources per unit of economic output and reducing the environmental impact of any resources that are used or economic activities that are undertaken” (UNEP, 2011a, p. xiii).

Two key aspects of decoupling are resource decoupling (achieving the same or greater output with fewer inputs) and impact decoupling (doing less environmental harm per unit of output)[6]: resource decoupling could be referred to as increasing resource productivity, and impact decoupling as increasing eco-efficiency.

“Resource decoupling means reducing the rate of use of (primary) resources per unit of economic activity. This dematerialization is based on using less material, energy, water and land resources for the same economic output. Resource decoupling leads to an increase in the efficiency with which resources are used. Such enhanced resource productivity can usually be measured unequivocally: it can be expressed for a national

[6] Even in this case we can be made a distinction between ‘relative’ and ‘absolute’ decoupling. “Relative decoupling of resources or impacts means that the growth rate of the environmentally relevant parameter (resources used or some measure of environmental impact) is lower than the growth rate of a relevant economic indicator (for example GDP). The association is still positive, but the elasticity of this relation is below 1 (Mudgal et al., 2010). Such relative decoupling seems to be fairly common. With absolute decoupling, in contrast, resource use declines, irrespective of the growth rate of the economic driver. This latter relation is shown by the Environmental Kuznets Curve that claims that if prosperity rises beyond a certain point, the environmental impact of production and consumption decreases. Absolute reductions in resource use are rare (De Bruyn, 2002; Steger and Bleischwitz, 2009); they can occur only when the growth rate of resource productivity exceeds the growth rate of the economy” (UNEP, 2011a, p.5).

economy, an economic sector or a certain economic process or production chain, by dividing added value by resource use (e.g. GDP/Domestic Material Consumption). If this quotient increases with time, resource productivity is rising. Another way to demonstrate resource decoupling is comparing the gradient of economic output over time with the gradient of resource input; when the latter is smaller, resource decoupling is occurring.

Impact decoupling, by contrast, requires increasing economic output while reducing negative environmental impacts. Such impacts arise from the extraction of required resources (such as groundwater pollution due to mining or agriculture), leading all of them to adopt policies that commit both governments and industries to reduce the amount of resources used for each unit of production (or increase resource decoupling) and reduce negative impacts on the environment (or implement impact decoupling) production (such as land degradation, wastes and emissions), the use phase of commodities (for example transport resulting in CO2 emissions), and in the post-consumption phase (again wastes and emissions). Methodologically, these impacts can be estimated by life cycle analysis (LCA) in combination with various input-output techniques [UNEP, 2010a]. Impact decoupling means that negative environmental impacts decline while value is added in economic terms. On aggregate system levels such as a national economy or an economic sector, it is methodologically very demanding to measure impact decoupling, because many environmental impacts need to be considered, their trends may be quite different or not even monitored across time, and system boundaries as well as weighting procedures are often contested" (UNEP, 2011a, pp.4-5).

In order to support a more rapid decoupling of growth rates from rates of resource use and negative environmental impacts[7], the transition from a linear economy toward a circular economy can be an effective strategy (Ellen Macarthur Foundation 2012, 2013, 2014; European Commission, 2014a; 2015b; G7 Germany, 2015a; 2015b; People's Republic of China, 2008).

[7] It's important to note that "decoupling may also experience a 'rebound effect', which requires addressing the concern that efficiency gains in resource use may paradoxically lead to greater resource use" (UNEP, 2011a, p xvi). "The *rebound effect* [otherwise known as Jevon's Paradox] is the quantitative difference between the projected savings of resources that should have been derived from a given set of technological changes and the actual savings derived in practice, measured in percentage terms. It determines the actual level of decoupling that can be achieved by a given set of sustainability innovations" (UNEP, 2011a, p.68).

1.2 The transition from a linear economy to a circular economy

Economic development so far has been based on a rapid rise in the use of natural resources such as energy, materials, water and land (UNEP, 2011a).

The global economy's evolution has been dominated by a linear model of production and consumption, that is a *take-make-dispose* model where companies extract materials, apply energy to them to manufacture a product, and sell the product to an end consumer, who then discards it when it no longer works or no longer serves the user's purpose. The low level of resource prices during most of the past century has supported economic growth in advanced economies but also created the current wasteful system of resource use. Reusing materials has not been a major economic priority, given the ease of obtaining new input materials and cheaply disposing of refuse. In fact whilst major strides have been made in improving resource efficiency and exploring new forms of energy, less thought has been given to systematically designing out material leakage and disposal, entailing significant losses of value and negative effects all along the material chain (Ellen MacArthur Foundation, 2012; McKinsey Global Institute, 2011).

According to Ellen MacArthur Foundation[8] the linear production model incurs unnecessary resource losses in several ways: w*aste in the production chain; end-of-life waste*; e*nergy use; erosion of ecosystem services.*

The current model creates imbalances on economic growth. The troubles inherent in a system that does not maximise the benefits of energy and natural resource usage have become evident both in the high level of real commodity prices, and in their volatility. Several factors indicate that resource scarcity, price squeezes, and volatility will continue or increase in particular because of demographic trends. It is estimated in fact that the world population is projected to grow to 9 billion by 2050, triggering a surge of demand both larger and in a shorter time period than the world has ever experienced. If in the last century the decline of resource prices has fuelled much of the economic growth, higher price levels could make it harder to further growth in the coming. Against this backdrop, a change of the

[8] The Ellen MacArthur Foundation is a registered charity founded on 23 June 2009 by Dame Ellen MacArthur It works with business, government and academia to build a framework for an economy that is restorative and regenerative by design. Its mission is to accelerate the transition to a circular economy. (Charity Commission, 2016; Ellen MacArthur Foundation, 2016a). Since 2012 the Foundation has published numerous works on this topic (Ellen Macarthur Foundation, 2012; 2013; 2014; 2015a; 2015b; 2016b; Ellen Macarthur Foundation et al., 2015; Lovins and Braungart, 2014; Webster, 2015; World Economic Forum et al., 2016).

entire operating system toward a circular economy seems necessary (Ellen MacArthur Foundation, 2012).

"In contrast to the take-use-dispose paradigm in a traditional linear economy, in a circular economy, resources are kept in use for as long as possible, extracting their maximum value. Products and materials are recovered and renewed, leveraging business models designed to support this regenerative activity. In closing materials loops or cycling resources, the circular economy looks to natural systems—or more precisely, nature as represented in ecosystem ecology—as an inspiration for resource efficiency in anthropogenic systems" (Journal of Industrial Ecology, 2016).

The origin of the term *Circular Economy* is uncertain. This concept has deep-rooted origins and cannot be traced back to one single date or author. However, its practical applications to modern economic systems and industrial processes have gained momentum since the late 1970s as a result of the efforts of a small number of academics, thought-leaders, and businesses (Ellen MacArthur Foundation, 2012, Murray et al., 2015). These include Boulding's essay on *The Economics of the coming spaceship earth* (Boulding, 1966), Commoner's *Four Laws of Ecology* (Commoner, 1971), notions of closing and slowing loops (Stahel and Reday-Mulvey, 1981), analogy between industrial ecosystems and biological ecosystems (Frosch and Gallopolous, 1989); industrial and socio-economic metabolism (Ayres 1994; Fischer-Kowalski and Hüttler 1998), biomimicry (Benyus 1997) and biomimetics (Bhushan 2009), and cradle to cradle (McDonough and Braungart 2002).

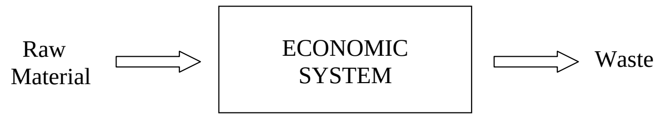
In 1966 Kenneth Boulding in *The Economics of the Coming Spaceship Earth* used two metaphors to explain why the Earth has necessarily to move from an open (and linear) to a closed (and circular) economy: the metaphor of the *cowboy* and the metaphor of *astronaut.* For the sake of picturesqueness, Boulding chooses the expression *the cowboy economy* to define an open economy because the cowboy is the symbol of the illimitable plains and is also associated to reckless, exploitative, romantic, and violent behavior which is characteristic of open societies. On the contrary he calls the closed economy *the spaceman economy*, in which the Earth is imagined as a single spaceship without unlimited reservoirs of anything, either for extraction or for pollution, and where, therefore, man must find his place in a cyclical ecological system capable of continuous reproduction of material form even though it cannot escape from having inputs of energy. In this work the author thinks that we are in the middle of a long process of transition in the nature of the image man has of himself and his environment. In particular we are hard moving from an open vision to a closed one of the earth system. According to Boulding an open system implies that some kind of a structure is maintained in the midst of a throughput from inputs to outputs. In a closed system, instead, the outputs of all parts of the system are linked to the inputs of other parts. There are no inputs from outside and no outputs to the outside. Systems may be open or closed in respect to a number of classes of inputs and outputs. Three important classes are matter, energy, and information (Boulding, 1966).

Through the use of the metaphor of the cowboy and of astronaut author argued that we must cease to behave as if we lived in a *cowboy economy*, with unlimited new territory to be conquered and learn to treat planet earth as a *spaceship*. The spaceship is a circular system in which every effort has to be made to recycle materials, reduce wastes, conserve exhaustible energy sources and tap into potentially limitless energy sources such as solar power. In the Boulding's essay the spaceship is therefore an effective metaphor of the earth with which the author wants to emphasize the need to contemplate Earth as a closed economic system, where the economy and environment are not characterized by linear interlinks, but by a circular relationship in the sense that everything is an input into everything else (Pearce and Turner 1990; Turner et al, 1994)

Economists have to come to grips with the consequences of the transition from the open to the closed. The vision of a closed earth system requires economic principles which are somewhat different from those of an open one such as the laws of thermodynamics. The laws of thermodynamics are some of the most fundamental and powerful of all the laws of physics and they can help clarify the finite nature of the biophysical world in which our economy works. In according to Isaac Asimov the two laws of thermodynamics can be summarized as "the total energy content of the universe is constant, and the total entropy is continually increasing" (Asimov 1970, p.9). "The first law states that all matter and energy in the universe is constant, that it cannot be created or destroyed. Only its form can change but never its essence. The second law, the Entropy Law, states that matter and energy can only be changed in one direction, that is, from usable to unusable, or from available to unavailable, or from ordered to disordered. In essence, the second law says that everything in the entire universe began with structure and value and is irrevocably moving in the direction of random chaos and waste" (Rifkin 1980, p.6).

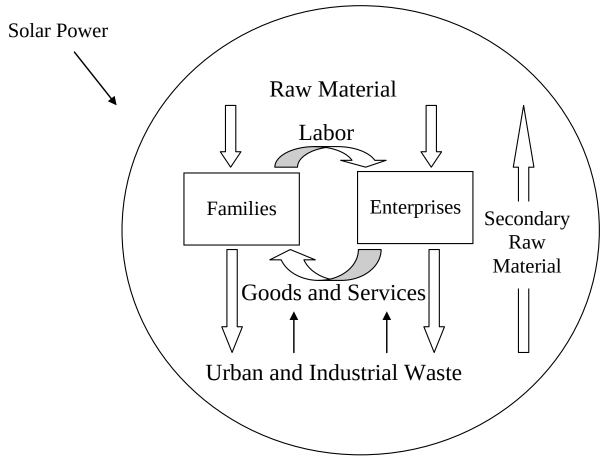
From a thermodynamic point of view there are three kinds of systems: opened, closed, and isolated. *Open systems* exchange both energy and matter. *Closed systems* exchange energy but do not exchange any appreciable matter. *Isolated systems* exchange neither energy nor matter. *The Earth is a closed system*, that is it exchanges energy with the solar system but except for an occasional meteorite or some cosmic dust it does not exchange matter with the outside universe (Rifkin, 2003). The Earth has a limited amount of concentrated energy resources (fossil fuels) and of useful raw materials. Recycling increases the duration of the resources, allowing more re-use, but it is not possible forever, because there is always a share of raw materials dispersed or degraded qualitatively. It is also not possible for the energy, that degrades irreversibly. Every replacing a fossil fuel with a renewable source of energy or recycling fights the tendency to entropy of the human economy (Bresso 1997).

Figure 1.4. An open and linear economy.



Due to the laws of thermodynamics there is thus the necessity of changing the traditional view of the economy: from an open and linear economy (see Figure 1.4) to a closed and circular one (see Figure 1.5).

Figure 1.5. A closed and circular economy.

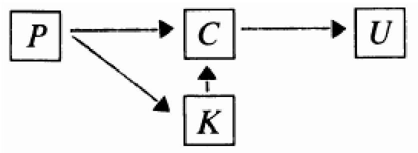


Source: La Monica et al, 2014.

In a linear economy natural resources are taken from the environment to be transformed by the economic system (production and consumption) to be then put back into the environment as waste. This vision of the economy is typically associated with the begining of industrial society, where one gets the impression of an unlimited availability of resources. (Bresso 1997). On the contrary the processes of production and consumption must be circular (at a low entropy), that is they must be able to reduce the use of limited natural resources and recycle waste for the sustainability of life on the planet Earth (spaceship of the humanity).

In the light of Boulding's contribution, the two laws of thermodynamic and important implications of the environment-economy interaction, in the *Economics of natural resources and the environment*, David W. Pearce and R. Kerry Turner explain how we can change our conception of how economic system works. According to the authors if we ignore the environment the economy appears to be a linear system (see Figure 1.6), where *Production* (P) is aimed at producing *consumer goods* (C) and *capital goods* (K). In turn, capital goods produce consumption in the future. The purpose of consumption is to create *utility* (U) or *welfare*.

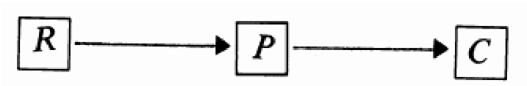
Figure 1.6. A linear economy



Source: Pearce and Turner, 1990, p.35

Leaving out U and K for convenience we can add in the flow of *natural resources* R to give a more complete picture. Resources are an input to the economic system. Adding resource still produces a linear system (see Figure 1.7):

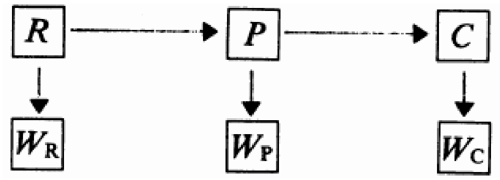
Figure 1.7. A linear economy adding natural resources



Source: Pearce and Turner, 1990, p.36

This system however system takes into account the first function of natural environments, that is, to provide resource inputs to the reproductive system. This picture is still incomplete because it says nothing about *waste products* (W). The natural environments are in fact the ultimate repositories of waste products: carbon dioxide and sulphur dioxide go into the atmosphere, industrial and municipal sewage goes into rivers and the sea, solid waste goes to landfill, chlorofluorocarbons go to the stratosphere and so on. it is important to emphasize that the waste is produced also in the natural systems (for instance trees dispose of their leaves) but key difference between natural and economic systems is that natural systems tend to recycle their waste (the leaves decompose and are converted into an organic fertilizer for plants and for the tree itself creating the waste in the first place). On the contrary, economies have no such in-built tendency to recycle. That's why it seems fair to concentrate on wastes from the economy in extending our picture of economy-environment interaction.

Figure 1.8. A linear economy adding waste products



Source: Pearce and Turner, 1990, p.36

Waste arises at each stage of the production process: the processing of resources creates waste (WR), as with overburden tips at coal mines; production creates waste (WP) in the form of industrial effluent, air pollution and solid waste; final consumers create waste (WC) by generating sewage, litter, and municipal refuse. So we might take the linear system and expand it a little further (see Figure 1.8): There is an interesting relationship between R and the sum of the waste flows generated in any period of time ($W= W_R+ W_r+ W_e$). If we forget for the moment about production going to create capital stock, then *the amount of waste in any period is equal to the amount of natural resources used up*. That is:

$$R= W= W_R+ W_r+ W_e$$

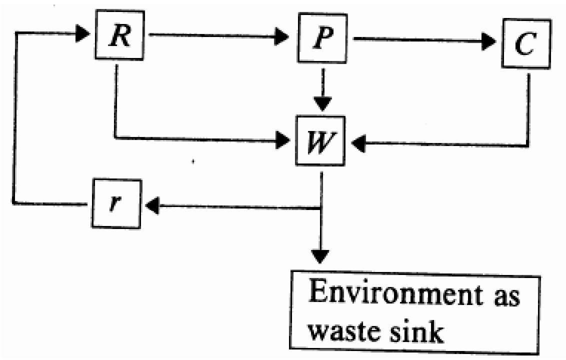
This equivalence[9] is thanks to the *First Law of Thermodynamics*: we cannot create or destroy energy and matter. Whatever we use up by way of resources must end up somewhere in the environmental system, it cannot be destroyed but can be converted and dissipated. For example coal consumption in any year must be equal to the amount of waste gases and solids produced by coal combustion. Some of it will appear as slag, some as carbon dioxide and so on.

Now we can think of be converting the linear economic system into a circular system (see Figure 1.9). The box (r) is recycling, that is we can take some of the waste (W) and convert it back to resources: for example the bottle banks for recycling glass bottles; the

[9] This equivalence is not a hard and fast one if we consider the capital formation, since some of the resource flows become embodied in the capital equipment. But at the same time capital equipment constructed in past periods will be wearing out, so it will appear as a waste flow. Then in any given period we shall have a more complicated relationship between R and W.

lead in junked car batteries is generally recycled; some waste paper returns to be pulped for making further paper and so on. But a great deal of waste - indeed the majority of it - is not recycled. As the diagram shows it goes into the environment.

Figure 1.9. Converting of a linear economic system in a circular economic system



Source: Pearce and Turner, 1990, p.38

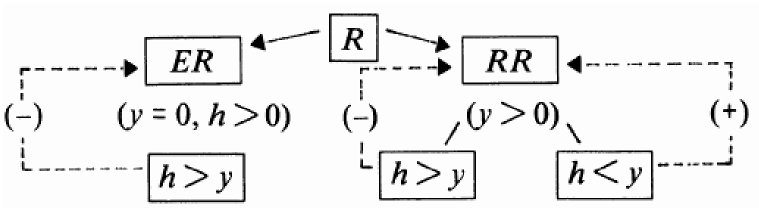
The box (r) is *recycling*, that is we can take some of the waste (W) and convert it back to resources: for example the bottle banks for recycling glass bottles; the lead in junked car batteries is generally recycled; some waste paper returns to be pulped for making further paper and so on. But a great deal of waste - indeed the majority of it - is not recycled. As the diagram shows it goes into the environment.

Not all waste is recycled because of the Second Law of Thermodynamics. In terms of the circular flow diagram above there is a basic reason for the lack of recycling that is apart from missing opportunities. The materials used in the economy tend to be used *entropically*, i.e. they get dissipated within the economic system: for example of the many hundreds of components in a car it is possible to recycle only a few of them (maybe aluminum in some parts, steel in the car body, lead from the batteries), while wood and plastic are generally impossible to extract without the expenditure of such large sums of money, what would not make any sense. In other cases it is not technically feasible to recycle: for example let's think of lead in leaded gasoline that cannot be captured from the car exhaust and returned to the economic system. Moreover there is a whole category of resources that cannot be recycled such as energy resources: even if we captured the carbon dioxide from burning fossil fuels, we would not be able to produce other fuel; if we captured some of the sulphur oxides, we could well recycle sulphur, but for sure we could not recycle energy. Therefore, entropy places a physical obstacle, another boundary, in the way of redesigning the economy as a closed and sustainable system.

The unrecyclable waste flow goes into the environment. The environment has a capability to take waste and to convert it back into harmless or ecologically useful products: this is the environment's assimilative capacity and it represents the second major economic function of natural environments. As long as we dispose of waste in quantities and qualities that are commensurate with the environment's assimilative capacity, the circular economic system will function just like a natural system, although of course it will still draw down the stocks of any natural resources that do not renew themselves (*exhaustible resources*). As a consequence the system will still have a finite life determined by the availability of the exhaustible natural resources. But if we dispose of waste in such a way that we exceed and damage the capability of the natural environment to absorb it, then the economic function of the environment as waste sink will be impaired. Essentially we will have converted what could have been a renewable resource into an exhaustible one[10].

The resources box (R) in the diagram can be expanded to account for two types of natural resource: *exhaustible resources* (ER) cannot renew themselves and include such resources as coal, oil and minerals; *renewable resources* (RR) have the capacity to renew themselves. Some resources are mixes of renewable and exhaustible (e.g. soil). Some renewable resources are very slow-growing, some are fast-growing. Clearly, if we harvest a renewable resource at a faster rate than the rate at which it grows, the stock will be reduced. In this way a renewable resource can be *mined*, treated like an exhaustible resource. If we wish to sustain renewable resources we must be careful to harvest them at a rate which should not be greater than their natural regenerative capacity. The resource subsector appears as Figure 1.10 where y refers to the yield of the resource, and h to the rate at which it is harvested (extracted, exploited). The *plus* sign tells us that if $h < y$ the resource stock grows, and if $h > y$ the stock falls (the minus sign).

Figure 1.10. Natural resources: exhaustible and renewable

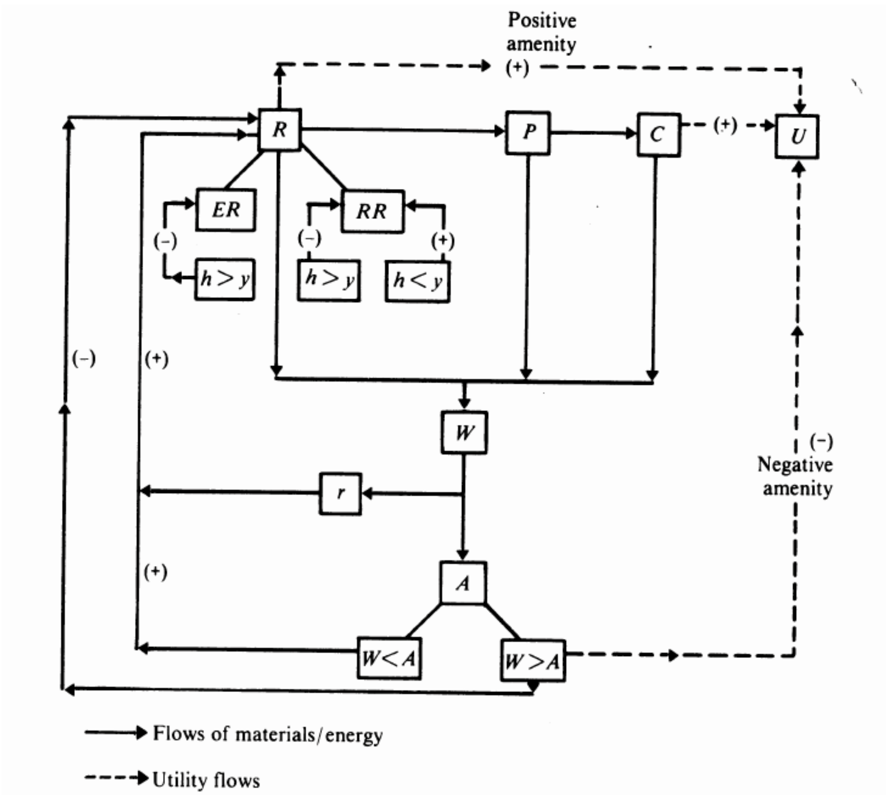


Source: Pearce and Turner, 1990, p.39

[10] It is important to emphasize that the assimilative capacity of the environment is thus a resource which is finite and that is so long as we keep within its bounds, the environment will assimilate waste and essentially return the waste to the economic system.

Now we can complete the picture of the circular economy (see Figure 1.11): instead of being an open and linear system because of the laws of thermodynamics it is a closed and circular economy. If we add back in the flow of consumption to utility we can highlight the third function of the environment, i.e. to supply utility directly in the form of aesthetic enjoyment and spiritual comfort, whether it is the pleasure of a fine view or the deeper feelings about nature. It's interesting to note that if we dispose of wastes (W) in excess of the assimilative capacity (A) of the environment, we shall damage this third function: e.g., polluted rivers detract from this economic function.

Figure 1.11. The circular economy



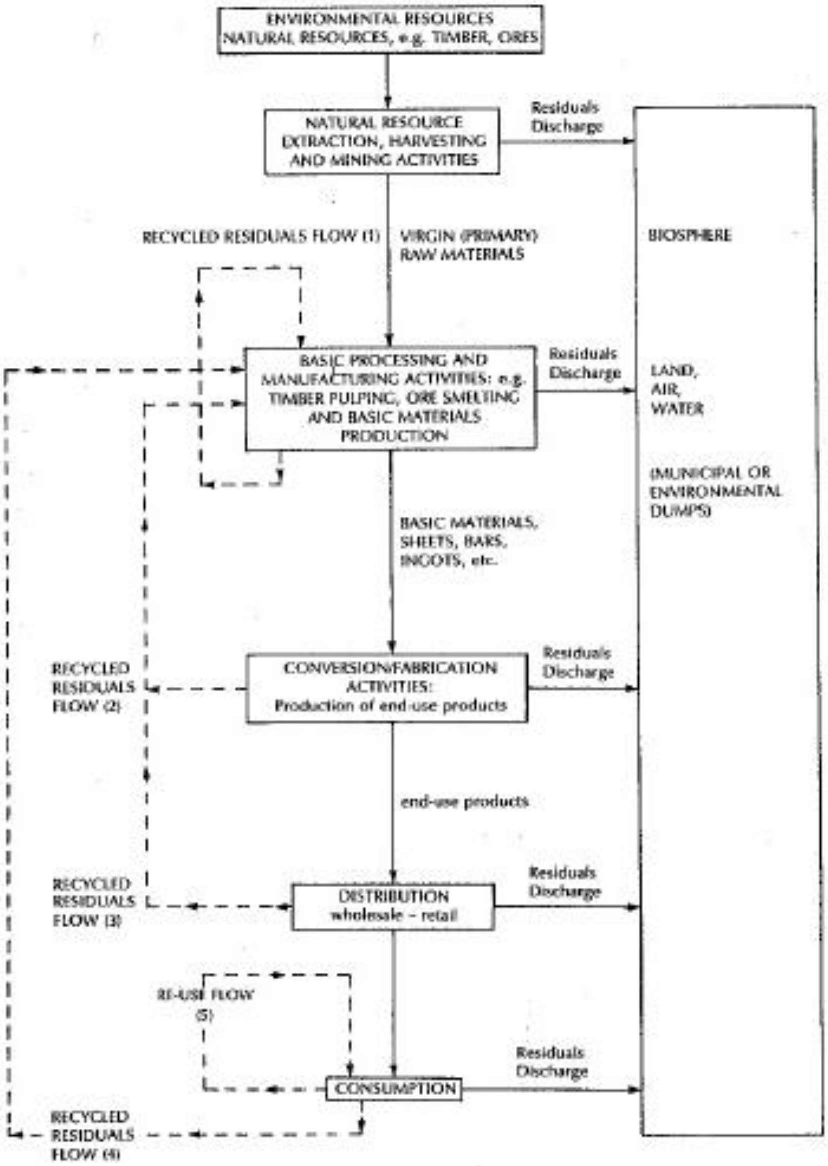
Source: Pearce and Turner, 1990, p.40

In a circular economy we identify three economic functions of the environment as resource supply, waste assimilation and aesthetic commodity. They can be regarded as components of one general function of natural environments: the function of life support (Turner et al. 1994).

The circular flow on the figure 1.12 is sometimes called a *materials balance model* (Ayres and Kneese 1969; Kneese et al. 1970). In the *Environmental economics: an elementary introduction* R. Kerry Turner, David W Pearce and Ian Bateman effectively describe this model. Materials balance model portrays the economy-environment interactions, representing the economic system as a materials processing and products transformation system (see Figure 1.12). This model is always based on two laws of thermodynamics:

1) All resource extraction, production and consumption eventually result in waste products (residuals) equal in matter/energy terms to the resources flowing into these sectors.
2) There is no possibility of the 100% return (recycling) of these waste products to enter the resource flow again because of the entropy (Ayres e Kneese 1989).

Figure 1.12. Simplified material flow chart



Source: Turner et al 1994, p.19

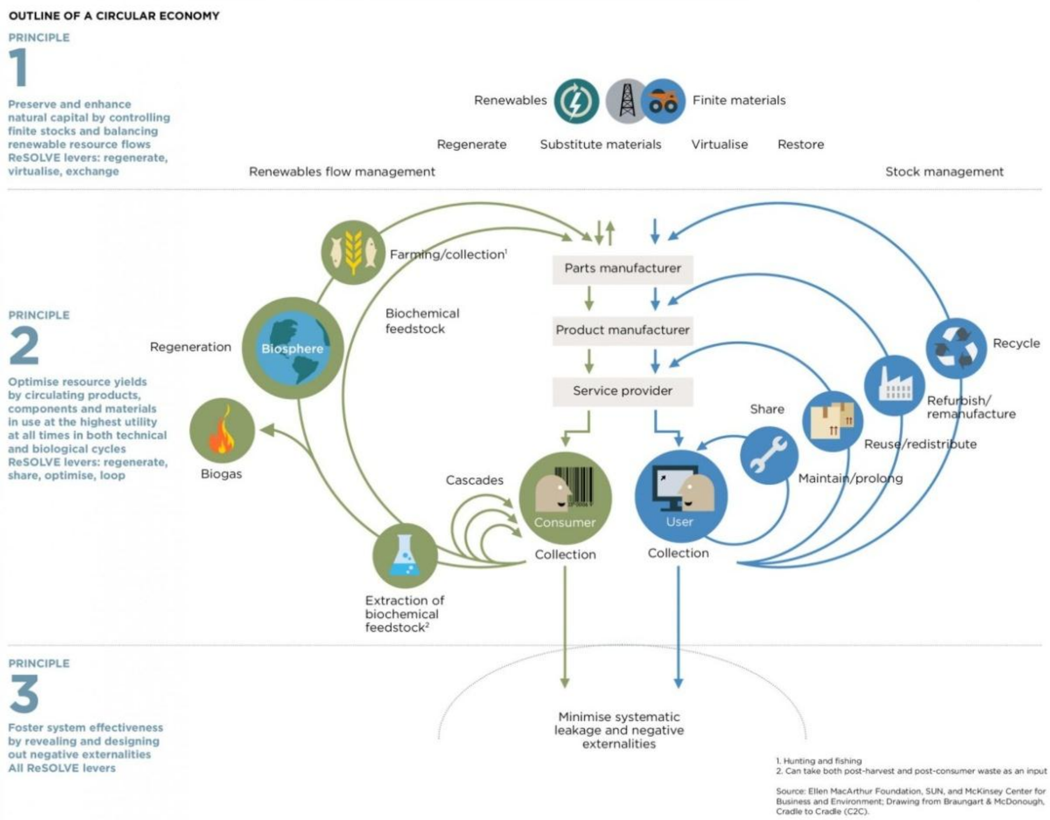
All economic systems contain a number of recycling flows, although the level of recycling effort and activity varies between national economies. *Recycling flow* (1) is known as the *home scrap* flow because the recycled *secondary* material never leaves the processing plant. Home scrap recycling rates are very high. *Recycling flow* (2) *prompt scrap* flow it also has a high activity rate, but does require the intervention of a secondary material merchant firm to facilitate the collection of scrap and its redirection back into basic processing. *Recycling flow* (3), *commercial scrap* is composed of packaging waste and is the staple business of the recycling merchant firms. *Recyc1ing flow* (4), *post-consumer scrap* is the potentially recyclable components of the household and small commercial premises waste stream (municipal solid waste, MSW). Activity rates associated with this type of recycling have historically been low in all industrialized economies. *Recycling flow* (5), *re-use* is a practice that has almost but disappeared in modern economies such as returnable bottles and a limited number of other examples. Type 1, 2 and to a lesser extent 3, recycling generally operates at a high activity rate, while types 4 and 5 remain at relatively low levels of activity. It is due to four physical factors (characteristics) and the influence of thermodynamics: *mass,* that *is the volume* of recyclable materials; *homogeneity,* that is the level and consistency in quality terms (known as grade) of the recyclable materials; *contamination,* that is the degree to which different materials and other substances are mixed together; *location,* that is the number of points at which the materials are first discarded as waste). If we compare home scrap (flow 1) and post-consumer scrap (flow 4): the former is characterized by large mass, high homogeneity, low contamination and single location; the latter is characterized by small mass, low homogeneity, high contamination and multiple locations. In financial (private cost) terms the profitability of recycling flows 1, 2 and 3 will be much higher than flow 4; indeed the latter will often incur net financial costs[11].

The extent of recycling in a national economy will also be determined by other factors, such as the *relative prices* of secondary (recycled) and primary raw materials as inputs into production processes; the *end-use structure* (number of uses and the grade of material required) for any given secondary material: typically lower grade secondary materials, e.g. mixed waste papers and mixed colour glass, and the small number of uses that are available; *technical progress* in both secondary and primary materials industries; historical and cultural factors which condition the degree of *environmental awareness* in society (Turner et al. 1994).

[11] It's important to stress This does not mean that recycling of MSW may not yield net social benefits sufficient to outweigh the private costs and therefore represent an economically efficient activity.

It's important to note that in recent years the circular economy has been increasingly discussed in the political and economic field, but this concept is also eclectic and there is no scientifically endorsed definition. According to Ellen MacArthur Foundation "the concept is characterised, more than defined, as an economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles [see Figure 1.13]. It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimizes system risks by managing finite stocks and renewable flows. It works effectively at every scale. This economic model seeks to ultimately decouple global economic development from finite resource consumption" (Ellen MacArthur Foundation, 2015b, p.5).

Figure. 1.13. Circular Economy System Diagram



Source: Ellen MacArthur Foundation, 2015c, p.6

It's important to note that a circular economy distinguishes between technical and biological cycles. The technical cycle involves the management of stocks of finite materials. Use replaces consumption. Technical materials are recovered and mostly restored in the technical cycle. The biological cycle encompasses the flows of renewable materials.

Consumption only occurs in the biological cycle. Renewable (biological) nutrients are mostly regenerated in the biological cycle

The circular economy rests on three principles: 1) Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows (e.g replacing fossil fuels with renewable energy or return nutrients; 2) Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles (e.g. sharing or looping products and extending product lifetimes); 3) Foster system effectiveness by revealing and designing out negative externalities (such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use).

It's important to underline that while this principles are principles for action, key characteristics in a circular economy are synthesized in this way: *Waste is "designed out",* that is in a circular economy, waste does not exist and is designed out by intention; *Diversity builds strength*, that is in a circular economy diversity is valued as a means of building strength. Across many types of systems, diversity is a key driver of versatility and resilience; *Renewable energy sources power the economy*, that is the energy required to fuel the circular economy should be renewable by nature, in order to decrease resource dependence and increase systems resilience (e.g. to oil shocks); *Think in systems*, that is in a circular economy systems-thinking is applied broadly; *Prices or other feedback mechanisms should reflect real costs*, that is in a circular economy, prices act as messages, and therefore need to reflect full costs in order to be effective.

Figure. 1.14. Measuring the circular economy

		PRIMARY METRIC	SECONDARY METRICS
PRINCIPLE 1	Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows	Degradation-adjusted net value add (NVA)[1]	• Annual monetary benefit of ecosystem services, e.g. from biodiversity and soils • Annual degradation • Overall remaining stock
PRINCIPLE 2	Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles	GDP generated per unit of net virgin finite material input[2]	• Product utilisation • Product depreciation/lifetime • Material value retention ratio (energy recovery, recycling and reman industry) / value of virgin materials (rolling net average last five years)
PRINCIPLE 3	Foster system effectiveness by revealing and designing out negative externalities	Total cost of externalities and opportunity cost	• Cost of land, air, water, and noise pollution • Toxic substances in food systems • Climate change, congestion, and health impacts

1 The System of Environmental-Economic Accounting, 2012.
2 Adapted based on the EU's Resource Efficiency Scoreboard (Eurostat, 2014). The adaptation is to deduct recovered materials and only include finite materials.

Source: Ellen MacArthur Foundation et al. 2015b, p.25

In a circular economy some metrics can monitor the application of three principles (See Figure 1.14); these principles can translate into six business actions, called ReSOLVE framework: 1) *Regenerate*: shifting to renewable energy and materials; reclaim, retain, and regenerate health of ecosystems; and return recovered biological resources to the biosphere; 2) *Share*: sharing assets (peer-to-peer sharing of privately owned products or public sharing of a pool of products), reusing them throughout their technical lifetime (second-hand), and prolonging their life through maintenance, repair, and design for durability; 3) *Optimise*: increasing performance/efficiency of a product; remove waste in production and the supply chain (from sourcing and logistics to production, use, and end-of-use collection); leverage big data, automation, remote sensing, and steering; 4) *Loop*: keeping components and materials in closed loops and prioritise inner loops. For finite materials, this means remanufacturing products or components and as a last resort recycling materials. For renewable materials, this means anaerobic digestion and extracting bio-chemicals from organic waste; 5) *Virtualise*: delivering utility virtually: dematerialise directly (e.g. books, CDs, DVDs, travel); dematerialise indirectly (e.g. online shopping); 6) *Exchange*: replacing old materials with advanced non-renewable materials; apply new technologies (e.g. 3D printing and electric engines); choose new products and services (e.g. multi-modal transport) (Ellen MacArthur Foundation, 2015b; 2015c).

At the end it's interesting to highlights that we can identify seven main schools of thought related to the circular economy (Ellen MacArthur Foundation, 2016a): *Biomimicry (*Benyus, 1997); *Blue Economy (*Pauli, 2010); *Cradle to Cradle (*McDonough and Braungart, 2002); *Industrial Ecology* (Frosh and Gallopoulos, 1989)*; Natural Capitalism* (Hawken P., et al., 1999); *Performance Economy* (Stahel and Reday-Mulvey, 1981); *Regenerative Design* (Lyle, 1996).

1.3 The industrial symbiosis as a tool for realizing a circular economy

Industrial symbiosis is a field of industrial ecology[12]. In industrial ecology a central concept is the transition of industrial system from a linear pathway, where resources are consumed and harmful waste is dissipated into the environment, to a more closed system,

[12] Industrial ecology is based on systems analysis and higher level systems approach in order to framing the interaction between industrial systems and natural systems. This systems approach methodology was born by work of Jay Forrester at MIT in the early 1960s and 70s (Forrester, 1968; 1971). In *Limits to Growth* (Meadows et al., 1972) this work is furthered (Garner and Keoleian, 1995).

like ecological systems (Garner and Keoleian, 1995). To achieve this, industrial ecologists simultaneously promote economic development and the reduction of environmental impacts through more efficient use of energy inputs and materials such as the waste reduction at source and the implementation of *closing the loop*, i.e. linkages where the waste products of one line of work become the valuable input of another. This approach contrasts with the *linear model*, where the flow of material from one stage to the next is independent of all other flows thus creating useful products and waste/ polluting emissions in all production phases (Ayres and Ayres 2002; Jelinski et al., 1992; Desrochers, and Leppälä, 2010).

Considered by some academic researchers as the *science of sustainability* (Frosch and Gallapoulos 1989; President's Council On Sustainable Development 1996, Allenby et al. 1999; Cohen-Rosenthal 2003; Ehrenfeld, 2004; Gibbs, 2008), the concept of *industrial ecology* [13] dates back to 1989 when Robert A. Frosch and Nicholas E. Gallopoulos published *Strategies for Manufacturing*. In this paper the authors state that "the traditional model of industrial activity - in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of-should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process - whether they are spent catalysts from petroleum refining, fly and bottom ash from electric-power generation or discarded plastic containers from consumer products – serve as the raw material for another process" (Frosh and Gallopoulos, 1989, p.144).

The concept of industrial ecology comes from a simile between industrial systems and ecological systems. According to the authors, in fact, "the industrial ecosystem would function as an analogue of biological ecosystems. (Plants synthesize nutrients that feed herbivores, which in turn feed a chain of carnivores whose wastes and bodies eventually feed further generations of plants.)" (Frosh and Gallopoulos, 1989, p.144). Frosh explains better this conception in a subsequent paper: "the idea of an industrial ecology is based upon a straightforward analogy with natural ecological systems. In nature an ecological system operates through a web of connections in which organisms live and consume each other and each other's waste. The system has evolved so that the characteristic of communities of living organisms seems to be that nothing that contains available energy or useful material will be lost. There will evolve some organism that will manage to make its living by dealing

[13] It's important to note that the concept of industrial ecology existed well before the expression, which began to appear sporadically in the literature of the 1970s (Erkman, 1997).

with any waste product that provides available energy or usable material. Ecologists talk of a food web: an interconnection of uses of both organisms and their wastes. In the industrial context we may think of this as being use of products and waste products. The system structure of a natural ecology and the structure of an industrial system, or an economic system, are extremely similar" (Frosh, 1992, p. 800). In this way, mimicking nature, industrial systems can transit from the current wasteful linear models of production to a circular economy in which the inputs of natural resources are reduced and waste become output and energy cascaded for other firms through an industrial ecosystem (Gibbs, 2008).

It's important to note that according to Frosch and Gallopoulos an ideal industrial ecosystem may never be attained in practice. Both manufacturers and consumers must change however their habits to approach it more closely (Frosh and Gallopoulos, 1989).

Table 1.3. Similarity among the biosphere and the industrial system or technosphere

Biosphere	Technosphere
Environment	Market
Organism	Company
Natural Product	Industrial Product
Natural Selection	Competition
Ecosystem	Eco-Industrial Park
Ecological Niche	Market Niche
Anabolism / Catabolism	Manufacturing / Waste Management
Mutation and Selection	Design for Environment
Succession	Economic Growth
Adaptation	Innovation
Food Web	Product Life Cycle

Source: Cutaia L. et al., 2012 p.91 (processing by Ayres, 1989)

It is important to emphasize that in 1989 before the publication of Frosh and Gallopoulos, Robert U. Ayres proposes a similarity among the biosphere and the industrial system or technosphere (see Table 1.3). According to the author if in the biosphere evolution has led to an efficient use of materials and energy, that doesn't happen in the technosphere, where we see the exploitation of resources and where unused by-products (emissions into air, water, soil) are released into the environment. Learning by the biosphere, the technosphere can design and manage their own processes, improving efficiency and limiting as much as possible the release of unused products in the environment (Ayres, 1989).

Ayres also introduces the concept of *industrial metabolism* that "is the whole integrated collection of physical processes that convert raw materials and energy, plus labor, into finished products and wastes…" (Ayres, 1994, p.3). "The aim of industrial metabolism studies is to gain improved knowledge and understanding of the societal uses of natural resources and their total impact on the environment. The basic idea is to analyze the entire flow of materials and identify and assess all possible emission sources and other effects in connection to these flows" (Anderberg, 1998, p.312).

Based always on ecological metaphor in 2009 Weslynne S. Ashton proposed a description of ecological attributes and their industrial parallels (see Table 1.4) (Ashton, 2009).

Table 1.4. Ecosystem attributes and their industrial parallels

Ecosystem attribute	*Description*	*Industrial parallel*
Organism body size	Range of physical sizes of organisms within the same species	Company size (sales, employees, physical footprint)
Niche size and specialization	Range of foods consumed and habitats occupied by organisms of the same species	Business scope (range of inputs needed and output products or services)
Food web	Consumption of organisms of different species—connections show flows of energy and matter between species	Supply chain (sale of products and services)
Species life cycles and reproductive strategies	Life span of organisms and reproduction strategies	Company strategy: size, location of markets, cost of production, level of research and development
Intraspecies and interspecies competition	Competition for food resources and habitats among organisms in same and different species	Competition within and across industrial sectors
Species diversity and dominance	Number of different species; dominance of certain species due to body sizes, population, role in ecosystem	Industry diversity and dominance
Species migration, turnover, extinction	Migration to newly opened areas, competition for resources and habitat may lead to some species dying off locally	Industry turnover—change of dominant industrial sectors
Energy flows	Generation of energy by primary producers (autotrophs) in the system, consumption by various species (heterotrophs)	Energy generation, consumption, efficiency, and losses
Mineral and nutrient cycles	Minerals and nutrients flow through the system, with uptake by organisms for their survival and conservation, especially through cycling	Flow, storage, and cycling of different types of materials
Role of external inputs	Importance of inputs (nutrients, minerals, organisms) to a system from outside its boundaries	Role of imported materials, knowledge, capital
Role of detritus	Importance of dead, organic matter in supplying nutrients to the system	Role of waste and recycled materials
Role of symbiosis (mutualism)	Importance of mutually beneficial relationships among organisms (especially of different species) to access resources	Presence of by-product exchanges, utility- or service-sharing agreements
Feedback loops	Positive and negative feedbacks that reinforce or control system growth	Market demand, agglomeration effects

Source: Ashton, 2009, p.230

Since 1989 a lot of definitions of industrial ecology have been proposed (see Table 1.5).

Table 1.5. Definition of Industrial Ecology

"Somewhat teleologically, "industrial ecology" may be defined as the means by which a state of sustainable development is approached and maintained. It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical, and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely, given continued economic, cultural, and technological evolution" (Allenby, 1992, p.57).
"Industrial ecology provides for the first time a large-scale, integrated management tool that designs industrial infrastructures "as if they were a series of interlocking, artificial ecosystems interfacing with the natural global ecosystem." For the first time, industry is going beyond life-cycle analysis methodology and applying the concept of an ecosystem to the whole of an industrial operation, linking the "metabolism" of one company with that of others" (Hawkins, 1993, p.62)
"Industrial ecology is the study of the flows of material[s] and energy in industrial and consumer activities, of the effects of these flows on the environment, of the influences of economic, political, regulatory, and social factors on the flow, use and transformation of resources. The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities" (White, 1994, p.v).
"Industrial Ecology is a new ensemble concept in which the interactions between human activities and the environment are systematically analysed. As applied to industry, IE seeks to optimize the total industrial material cycle from virgin material, to finished product, to ultimate disposal of waste" (Graedel, 1994, p. 23).
"Industrial ecology is the study of the physical, chemical, and biological interactions and interrelationships both within and between industrial and ecological systems" (Garner and Keoleian, 1995, p.2)
"It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital." (Graedel and Allenby, 1995, p.9).
"Industrial ecology takes a systems view of the use and environmental impacts of materials and energy in industrial societies. It employs the ecological analogy in several ways, including analysis of materials flows" (Andrews, 1999, p. 366).
"Industrial ecology is an evolving framework for the analysis and design of public policy, corporate strategy, and technological systems and products" (Ehrenfeld, 2000, p.229).
…"use nature's model of material recycling, energy cascading and solar energy-based sustainable ecosystems in transforming unsustainable, fossil fuel-based and wasteful industrial systems into more ecosystem-like systems" (Korhonen et al., 2004, p.803)

Source: Own compilation

According to Andy Garner and Gregoiy A. Keoleian, in 1995, there was still no single definition of industrial ecology that is generally accepted (and probably it is still missing today). However these authors have noted that most definitions comprise similar attributes with different emphasis. These attributes include: a systems view of the interactions between industrial and ecological systems; the study of material and energy flows and transformations; a multidisciplinary approach; an orientation towards the future; working to change linear (open) processes to cyclical (closed) processes so that the waste from one industry is used as an input for another; seeking to reduce the industrial systems' environmental impacts on ecological systems; working towards the harmonious integration of industrial activity into ecological systems; industrial systems being changed to emulate more efficient and sustainable natural systems; the identification and comparison of industrial and natural systems hierarchies, which indicate areas of potential study and action (see Table 1.6) (Garner and Keoleian, 1995).

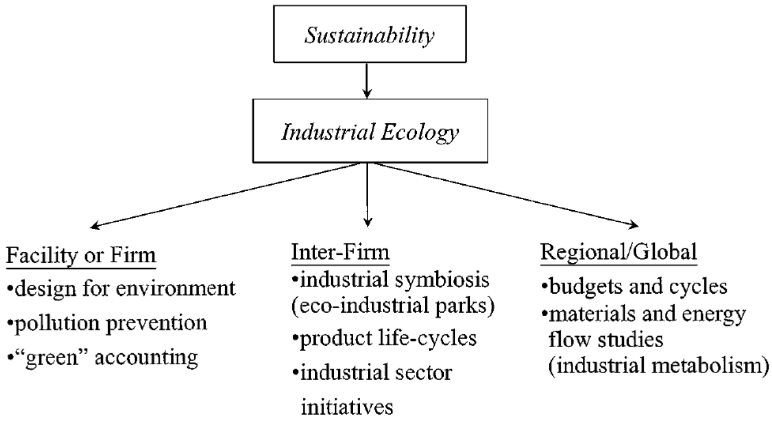
Table 1.6. Organizational hierarchies

Geographic/Political	Economic	Ecological
World	**Global human material & energy flows**	**Ecosphere**
Continent		**Biosphere**
Nation / Region	**Sectors (e.g., transportation, health care)**	**Biogeographic region / Biome**
State / County	**Corporations and institutions**	**Landscape / Ecosystem**
Town	**Product systems**	**Population**
Human population		**Organism**
Individual		

Source: Garner and Keoleian, 1995, p.1

Industrial ecology involves the study of the interaction between different industrial systems as well as between industrial systems and ecological systems at different system levels. In particular the primary goal of industrial ecology is to promote sustainable development at the global, regional and local levels. One of the key points of this field is the interrelationships among firms as well as their products, processes, at the local, regional national, and global system levels. These layers of overlapping connections resemble the food web that characterizes the interrelationship of organisms in natural ecological system (Garner and Keoleian, 1995). According to Reid Lifset and Thomas E. Graedel core elements in industrial ecology are: the biological analogy; the use of systems perspectives; the role of technological change; the role of companies; dematerialization and eco-efficiency; forward-looking research and practice. One way in which these elements can be integrated into a larger whole is to view industrial ecology as operating at a variety of levels (see Figure 1.15): at the firm or unit process level; at the inter-firm, district or sector level; at the regional, national or global level. The two authors affirm that much of industrial ecology focuses at the inter-firm and inter-facility level, for two reasons: firstly because a systems perspective emphasizes unexpected outcomes (and possibly environmental gains) to be revealed when a broader scope is used; secondly because pollution prevention, a related endeavor, has already effectively addressed many of the important issues at the firm, facility or unit process level (Lifset and Graedel, 2002).

Figure 1.15. The elements of industrial ecology seen as operating at different levels



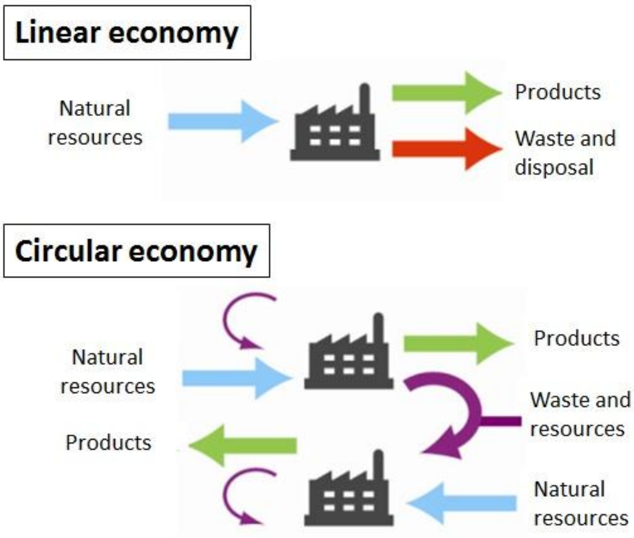
Source: Chertow 2000, p.315

According to Ezio Manzini and Silvia Pizzocaro in this interdisciplinary field the company participates in a production system in which all inputs are transformed into outputs, i.e. a zero waste and emissions system (*total throughput*). This result cannot be reached with the activity of a single firm, but new cross-sectorial integration approaches (*industrial clusters*) are needed in order to valorize the waste and effluent got by production processes(Manzini and Pizzocaro, 1995).

According to Marian R. Chertow and Jooyoung Park, "Industrial ecology is principally concerned with the flow of materials and energy through systems at different scales, from products to factories and up to national and global levels. Industrial symbiosis focuses on these flows through networks of businesses and other organizations in local and regional economies as a means of approaching ecologically sustainable industrial development" (Chertow and Park, 2011, p.199).

In 2000 Marian R. Chertow proposed the most cited definition of industrial symbiosis (see Figure 1.16): "Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow, 2000, p. 313). The term symbiosis is based on the concept of biological symbiotic relationships in nature where at least two otherwise unrelated species exchange materials, energy, or information in a mutually beneficial manner. This specific type of symbiosis is known as mutualism. So, too, industrial symbiosis consists of place-based exchanges among different entities that yield a collective benefit greater than the sum of individual benefits to be gained by acting alone (Chertow, 2004).

Figure 1.16. Industrial symbiosis in a circular economy



The term industrial symbiosis describes industrial practices that were already discussed by a large number of economic geographers, urban economists and regional scientists (Simmonds 1862; Marx 1894; Marshall 1898; Miller and Parkins 1928; Galloway Keller and Longley Bishop 1928; Weber 1929; Zimmermann 1933; Parkins 1934; White and Renner 1936; Lezius 1937; Gunnell 1939; Renner 1947, Mares, 1953; Isard 1960; Kolosovskiy 1961; Lambooy 1973). In light of some obvious similarities between natural and industrial systems, it is perhaps not surprising that the industrial ecology analogy was formulated as far back as the middle of the nineteenth century and the label industrial symbiosis was used by several writers in the following decades (Desrochers, 2005; 2009; 2010). Tthe most elaborate conceptual discussion on industrial symbiosis and the one closest to its current meaning can be found in fact in a work of geographers Charles Langdon White and George T. Renner in Geography: An Introduction to Human Ecology in 1936 (White and Renner, 1936).

In 2012 in based on their professional experience D. Rachel Lombardi and Peter Laybourn tried to redefine the term of industrial symbiosis in order to communicate its essence as a tool for innovative green growth: “Industrial symbiosis engages diverse organizations in a network to foster eco-innovation and long-term culture change. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs and value-added destinations for non-product outputs, as well as improved business and technical processes" (Lombardi and Laybourn, 2012, p.28). Through this provocative definition of industrial symbiosis the authors contest the use of commonplace terms (such as exchange for synergy) and concepts (such as the need for geographic proximity, equitable distribution of economic gains, or focus on materials and energy) (Lombardi at al., 2012).

It's important to note that drawing on industrial ecology industrial symbiosis incorporates many elements that emphasize the cycling and reuse of materials in a broader systems perspective. These elements include embedded energy and materials, life cycle perspective, cascading, loop closing, and tracking material flows.

Concerning *embedded energy and materials* in order to create a product, resources are used for extraction of materials, transport, primary and secondary production, and distribution. The total energy and materials used is the amount embedded in that product. Reusing by-products in an industrial symbiosis preserves the embedded materials and energy for a longer period as part of the cycling stressed in industrial ecology. Cogeneration is a specific means of cycling embedded energy by reusing waste heat to produce electricity or by using steam from electric power generation as a source of heat.

As regards the *life cycle perspective,* it does not focus on what happens inside of a plant or factory, rather it considers the entire set of environmental impacts that occur at each stage of industrial development and use across entities. In industrial symbiosis, a life cycle perspective is helpful in evaluating symbiotic opportunities in the product life cycle at which the by-product of concern may be considered for another use.

Cascading is a common strategy for industrial symbiosis because the company that produces the used resource can save on treatment or disposal and, if necessary, it can earn compensation in exchange of the value of the resource. The environmental benefits of cascading are numerous, including the reduced use of virgin resources, the avoided impact of resource extraction, and the reduced deposition of waste into the environment.

Loop closing occurs when a resource has a cyclical flow embedded in the industrial ecosystem and the resource, rather than becoming entirely degraded, reappears akin to its original form. Loop Closing is a general name for many different variations of reuse and recycling of resources.

Finally, as regards the *tracking material flows*, it concerns the tracking of material, water, and energy flows. This form of accounting captures instances of loop closing, cascading, and unidirectional flows. The results suggest opportunities for exchange of materials among firms as well as opportunities for more efficient resource use in the industrial ecosystem (Chertow, 2004)

According to Marian R. Chertow, Weslynne S. Ashton And Juan C. Espinosa in industrial symbiosis there are three primary means of resource sharing: 1) Utility/infrastructure sharing; 2) Joint provision of services; 3) By-product exchanges.

Utility/infrastructure sharing refers to the pooled use and management of commonly used resources such as steam, electricity, water, and wastewater. The main feature is that a group of companies jointly assumes the responsibility for providing utility services or infrastructure, such as water, energy or heat provision systems (i.e., co-generation plants), or wastewater treatment plants. This task is usually undertaken by municipal authorities or specialized companies.

The *joint provision of services* involves companies collectively meeting their ancillary needs, which relate to materials and services not directly related to the core business of a company but that have environmental effects (i.e. fire suppression, security, cleaning, catering, and waste management).

Concerning *by-product exchanges*, it can improve resource efficiency in a company taking advantage of the intrinsic economic value of waste. Some by-product exchanges can involve the cascading reuse of materials or energy through many different ways where each successive application requires a lower quality of the material (Chertow at al. 2008).

Industrial symbiosis leads to reduce environmental impacts and to a more efficient use of materials and it is a more sustainable means of industrial production (Chertow and Park, 2011). According to Murat Mirata industrial symbiosis offers potentials for environmental, economic and social benefits. Environmental benefits are linked to reductions in resource use, dependence on non-renewables, pollutant emissions, and waste handling needs. Economic benefits emerge from reductions in the costs of resource inputs, production, and waste management; from generation of additional income due to higher value of by-product and waste streams; from an improvement of relationships with external parties, and from development of a green image, new products and their markets. Social benefits by generating new employment and raising the quality of existing jobs, and by creating a cleaner, safer natural and working environment (Mirata, 2004; Mirata and Pearce, 2006). In particular the industrial symbiosis also helps industrial actors' profit maximization through spontaneous *internalization of their externalities* in the absence of external incentives such as pollution taxes or environmental regulations (Desrochers and Leppala, 2010). It's important to note that historically industrial symbiosis was implemented through eco-industrial parks (EIPs) in order to: revitalize urban and rural sites, including brownfield redevelopment; promote job growth and retention; encourage a more sustainable development (Chertow, 2007).

Industrial symbiosis can be implemented at different spatial scales. Increasing the distance among firms lessens the breadth of exchange opportunities because it is not cost effective to transport water and steam beyond regional boundaries, whereas by-products can often travel much farther. Chertow has devised a taxonomy of materials exchange types to consider spatial and organizational elements. These include through waste exchanges (type 1); within a facility, firm, or organization (type 2); among firms co-located in a defined eco-industrial park (type 3); among local firms that are not co-located (type 4); and among firms organized virtually'' across a broader region (type 5).

Regarding type 1 exchanges *(Through Waste Exchanges*), they are focused most often on the end-of-life stage of a product or process (e.g. contributions of used clothing for charity and collection of scrap metal or paper by scrap dealers or municipal recycling programs). Waste exchanges concern commercial opportunities by creating hard-copy or online lists of materials that one organization want to dispose of and another organization can need. The scale of trade can be local, regional, national, or global. Exchanges accomplish various input/output savings on a trade-by-trade basis rather than continuously. They feature exchange of materials rather than of water or energy.

As regards type 2 exchanges *(Within a Facility, Firm, or Organization*), they take place within the boundaries of a single organization, rather than being a collection of external parts. Indeed, large organizations often act as if they were separate entities and can approximate a multifirm industrial symbiosis approach.

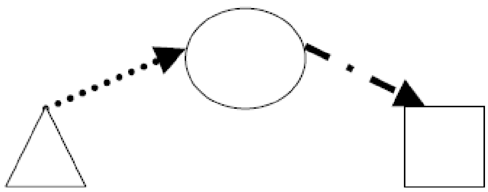
Type 3 exchanges (*Among Firms Co-located in a Defined Eco-industrial Park*) entail that companies and other organizations are located contiguously, so that they can exchange energy, water, and materials and can go further to share information and services such as permitting, transportation, and marketing. These types of exchanges take place mainly within the demarcated area of an industrial park or industrial area, but it is also common to involve other partners over the fence. The areas may be new developments and retrofit of existing ones.

Type 4 exchanges (*Among Local Firms That Are Not Co-located*) occur when companies are not located adjacent to one another but rather they are located within a small geographic area, where the main partners are within about a 2 miles radius from each other, as it happens for example in Kalundborg, in Denmark. In these types of exchanges existing businesses can take advantage of already generated material, water, and energy flows and there is also the opportunity to fill out new businesses based on common service requirements and input/output matching.

Finally, type 5 exchanges *(Among Firms Organized Virtually across a Broader Region)* depend on virtual linkages rather than colocation. these exchanges concerns a regional economic community where the potential for the identification of byproduct exchanges is greatly increased by the larger number of firms that can participate (Chertow, 2004).

It’s important to highlight that on following papers the author specifies that there is no agreement on the total number of firms constituting a symbiosis (Chertow and Ehrenfeld, 2012) To distinguish industrial symbiosis from other types of similar exchanges she adopts a *3–2 heuristic* as a minimum criterion (see Figure 1.17). Through this approach at least three different entities must be involved in exchanging at least two different resources to be counted as a basic type of industrial symbiosis. By involving three entities, none of which is primarily engaged in a recycling-oriented business, the 3–2 heuristic begins to recognize complex relationships rather than linear one-way exchanges (Chertow, 2007).

Figure 1.17. Example of 3–2 symbiosis involving a minimum of three different entities exchanging at least two different resources.



Source: Chertow 2007, p.13

There are several useful tools in industrial symbiosis in order to plan new symbioses or to augment existing exchanges. These tools are industrial inventories, input/output matching, stakeholder processes, and materials budgeting.

Industrial Inventories are useful to identify the area where to implement the industrial symbiosis, by conducting an inventory of local businesses and other resources, including utilities and relevant institutions. *Input/output matching* it is key tool to systematically match inputs and outputs so as to create links across industries. This can be done through written and/or oral surveys as well as through literature review. *Stakeholder processes* are important in industrial symbiosis because it involves different layers of unconnected participants, therefore a broad array of community involvement techniques need to be used. Whether and how to pursue specific covenants or conditions as a type of deed restriction is one topic of stakeholder meetings. Openness among participating companies and continued coordination by a stakeholder group such as an advisory council is important to implement industrial symbiosis. *Materials budgeting* is a type of materials tracking which is used to map energy and material flows through a chosen system. Materials budgeting is based on three concepts: 1) reservoirs, where a material is stored; 2) flux, which is the amount of material entering or leaving a reservoir per unit time; 3) sources and sinks, which are rates of input and loss of specific materials entering or leaving a system (Chertow, 2004).

According to Chertow in industrial symbiosis there are different approaches based on the extent to which a project is business-based or stream-based, that is whether companies or material/water/energy streams come first in planning industrial symbiosis; and whether the eco-industrial park begins with new or existing operations (Chertow, 2000).

The need of inter-organizational cooperation to develop industrial symbiosis creates both barriers and opportunities beyond those of more conventional development projects. Chertow identifies three main issues: technical; regulatory; and business. Regarding *technical issues*, symbiotic industrial facilities need to be in close proximity to avoid large transportation costs and energy degradation during transport. Supply security is important to the users of by-product flows, as would be the reliability of more conventional materials suppliers located farther away. The issue about aggregation of by-products to reach sufficient size is important because, even if the waste materials are collected from numerous facilities, the total volume may fall well below the necessary raw materials to support a new operation. As regards *regulatory issues*, industrial symbiosis is often at odds with environmental regulatory requirements, which may preclude by-product exchanges or at least serve as a very strong disincentive. In some instances, regulatory actions or very high tipping fees for waste disposal can encourage industrial symbiosis. Finally, tackling *business issues*, companies generally wish to address any issues not related to final products with the lowest cost and with the least use of resources. These objectives may not include the time or the desire to work with other firms, especially when low-value waste is concerned. These issues are compounded within eco-industrial projects by the need for multi-party planning and coordination and the attendant transaction costs, including the risk that a proposed partner will relocate. Industrial symbiosis raises the question of whether the desire to reuse waste streams comes at the expense of adhering to pollution prevention principles calling for the elimination of waste at the front end of the process. Some scholars argue that industrial symbiosis projects favor older dying industries and keep them going rather than fostering a new generation of green technology. Actually, there is a risk that industrial symbiosis could potentially discourage companies from updating their systems, plant, and equipment (Chertow, 2004).

It is important to note that we must also consider other important issues to implement the industrial symbiosis (Lowe et al. 1995; Ehrenfeld and Gertler 1997; Chertow 2000, 2003, 2007; Gibbs 2003; Mirata 2004). Among these, informational and motivational issues are particularly important: the former may make it difficult to find new uses for waste products, relating to poor information regarding the potential market and potential supply, whilst the latter concerns the willingness to co-operate and commit themselves by firms, public sector agencies and other stockholders (Gibbs et al. 2002; Chertow 2007).

Chapter 2

Industrial Symbiosis and Territory

The second chapter describes the main theories and models of regional economics explaining more effectively the industrial symbiosis. To this purpose, it firstly points out the different concepts of space in the economic theory and their most important features. Then it focuses, in particular, on two groups of economic theories, the industrial location theories and the local development theories, explaining the main drivers fostering a greater territorial competitiveness. Finally, it shows the role played by industrial symbiosis in the regional economics.

2.1 The concept of space in the economics

In order to explain the role of space in the economic theories we can start from the work of Roberta Capello, who describes the paths of development of the concept of space within the regional economics under an historical perspective (see Table 2.1) (Capello 2007, 2009a, 2009b, 2011).

Companies and other economic actors choose their location in the same way as they choose their production factors and their technology. Productive resources are distributed unevenly in space: they are often concentrated in specific places while they are absent - in whole or in part - in others. Space affects the way an economy works. In fact, it is a source of: (i) economic advantages (or disadvantages), such as high (or low) endowments of production factors; (ii) geographical advantages, such as the easy (or difficult) accessibility of an area and a high (or low) endowment of raw materials; (iii) advantages springing from the cumulative nature of productive processes in space, as spatial proximity generates economies that reduce production costs (i.e. the transportation costs of activities operating in closely concentrated supply chains) and transaction costs (i.e. the costs of market transactions due to information gathering).

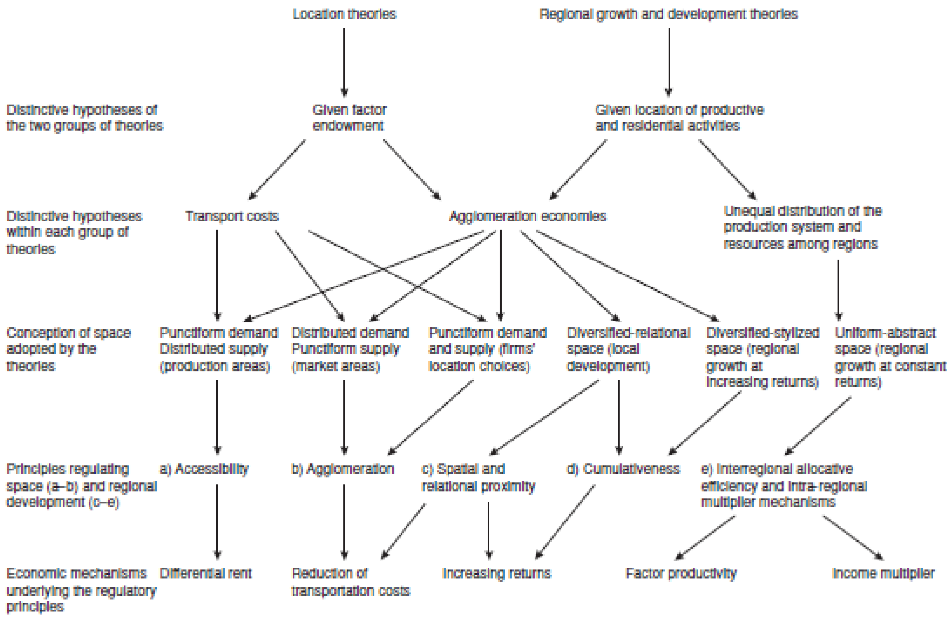
Following an historical perspective, we can distinguish two large groups of theories in regional economics (see Figure 2.1): *location theory*, and *regional growth (and development) theory*.

Table 2.1. Regional economic theories and different concepts of space

Theories / *Features*	*Location theories*	*Regional growth theories*	*Local development theories*	*Local growth theories*
Space	Physical-metric	Uniform- abstract	Diversified-relational	Diversified-stylized
Aim of the theories	Identification of market areas (demand extended on space; supply punctiform) Identification of production areas (demand punctiform; supply extended on space)	Identification of regional growth determinants, where growth is intended as: - Employment increase - Individual well-being	Identification of local development determinants, where development is intended as territorial competitiveness	Identification of local growth determinants, where growth is intended as territorial competitiveness
Nature of the theories	Quantitative and qualitative	Quantitative Constant returns to growth	Qualitative Increasing returns to growth	Quantitative Increasing returns to growth
Years of conception	1940s	1950s and 1060s	Middle 1970s onward	1990s onward
Main theories and authors	Industrial location choice theories (Weber, 1929; Hoover, 1933; Lösch, 1954) Allocation of land among producers and residents: industrial and residential location choice theories (von Thünen, 1826; Alonso, 1960; Fujita, 1989) Urban hierarchy (Christaller, 1933; Lösch, 1954)	Keynesian regional growth theories (North, 1955) Neoclassical regional growth theories (Borts and Stein, 1960)	Exogenous determinants of territorial competitiveness: The growth pole theory (Perroux, 1955); the role of multinationals on regional development (Lipietz, 1980; Blomstrom and Kokko, 1988) innovation diffusion (Hägerstrand, 1952) Endogenous determinants of territorial competitiveness: Industrial district theories (Becattini, 1979) Milieux innovateurs (Camagni, 1991; Maillat et al., 1993) Learning region (Lundvall, 1992)	Cumulative causation model (Myrdal, 1955 and Kaldor, 1970 as pioneering theories) New economic geography (Krugman, 1991) Endogenous growth model (Lucas, 1988; Romer, 1986)

Source: Capello, 2011, p.5.

Figure 2.1. The principles and hypotheses underlying theories of location and of regional growth and development



Source: Capello, 2007, p. 7.

The *location theory* is the oldest branch of regional economics. It is rooted in microeconomic, adopts a static approach and deals with the location choices of firms and households. It is important to highlight that the location theory adopts a purely geographical conception of continuous, *physical-metric space*, which can be defined in terms of physical distance and transportation costs. The irregularities of price and cost variation in space and their consequences in terms of location choices and the dividing of the market among companies is studied to this regard. The location theory explains the distribution of activities in space. This is analyzed by removing any geographical (physical) feature[14] so that location choices are interpreted by considering transportation costs, which push the diffusion of activities in space, and agglomeration economies, which instead are likely to promote concentration.

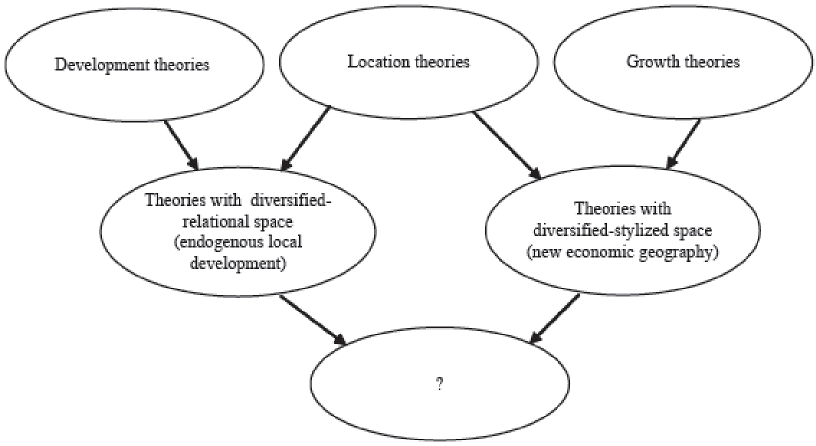
The *regional growth theory* focuses on the spatial aspects of economic growth and the territorial distribution of income. It is rooted in macroeconomic and adopts a dynamic approach. This theory conceives space as *uniform-abstract*, that is abstract and discrete. It means that space is divided into 'regions', i.e. areas of limited physical-geographical size (largely matching administrative units) considered to be internally uniform and therefore

[14] Geographical (physical) features are removed by assuming the existence of a homogeneous plain with equal fertility of land (Von Thünen, 1826) or uniform infrastructural endowment (Alonso, 1964; Palander, 1935; Hoover, 1948; Christaller, 1933 (1966); Lösch, 1954 (1940).

synthesizable into a vector of aggregate characteristics of a social-economic-demographic nature.

It's interesting to note that several cross-fertilizations have took place between these two branches of regional economics and they brought the traditional notions of space on each side closer. This convergence between them allowed us to identify two other concepts of space: *diversified-relational* and *diversified-stylized* (see Figure 2.2).

Figure 2.2. Convergence among theoretical approaches



Source: Capello, 2007, p.10.

According to the interpretation of space as *diversified-relational*, it generates economic benefits through large-scale mechanisms of synergy and cumulative feedbacks that operate at local level. In the early sixties, Perroux defines development as "a selective, cumulative process which does not appear everywhere at the same time but becomes manifest at certain points in space with variable intensity" (Perroux, 1955, p. 308). According to this definition there are *poles* where development concentrates because of synergic and cumulative forces generated by stable and enduring local input–output relations, facilitated by physical proximity. Therefore, space is intended as diversified and relational. The notion of diversified-relational space was studied more in-depth during the seventies through the studies on *bottom-up* processes of development, on districts and local *milieu*. The conceptual leap consists in interpreting space as *territory*, or in economic terms, as a system of localized technological externalities: a set of tangible and intangible factors which, because of proximity and reduced transaction costs, act upon the productivity and innovativeness of firms. In addition, the territory is conceived as a system of local governance which glues up the community, including a set of private actors and local institutions. The territory is “a system of economic and social relations, which make up the relational capital (Camagni 1999) or the social capital (Putnam 1993; World Bank 2001) of a certain geographical space” (Camagni, 2002, p. 2396). By focusing on the economic and social relations among actors in a territorial area, a more intangible concept of space is adopted. The diversified-relational space theories stressed for the first time the role of endogenous conditions and factors in local development. Based on a micro-territorial and micro-behavioural approach these theories are called *theories of development*.

Concerning the interpretation of space as *diversified-stylized*, it is typical of the models of new economic geography and endogenous growth (Romer 1986; Lucas 1988; Aghion and Howitt 1997; Krugman 1991, 1991b, 1991c; Krugman and Venables 1996; Fujita and Thisse 1996, 2002; Fujita et al. 1999; Nijkamp and Poot 1998; Nijkamp et al. 1998; Martin 1999). These theories anchor their logic on the assumption that productive activities concentrate around particular *poles* of development, so that the level and growth rate of income is diversified even within the same region. In addition, these models conceive areas as points or abstract dichotomies in which neither physical-geographical features (i.e. morphology, physical size) nor territorial ones (i.e. the local-level system of economic and social relations) play a role. Though diversified (inasmuch as there exist territorial poles of concentrated development), space in these models is designed into points devoid of any territorial dimension. The notion of space as a territory is then inevitably abandoned.

In the next few paragraphs I will focus particularly on the theories of regional economics describing more effectively the role played by industrial organizations working on territorial level: (industrial) location theory and the theory of local development. As to the first theory we will be highlighted above all the two great economic forces that influence the industrial organization in the space: agglomeration economies and transport costs. As for the second theory I’ll focus especially on the role played by some main factors in fostering a greater local development: infrastructure and new communication technologies (exogenous factors); and static and dynamic efficiency (endogenous factors). But before I’ll shortly introduce the theory of firm.

2.2 The theory of firm

In 1937 Ronald Coase recognized that the firm and the market were alternative ways of organizing production (Coase 1937). The author argued that a company would have internally produced an input until the costs of undertaking a transaction internally were just equal to the costs of using the market to handle that transaction. The costs of using the market for conducting business was called transaction costs. Later, Oliver Williamson studied this issue more deeply by writing about the importance of transaction costs and the type of organizational structures that have developed to minimize this kind of costs (Williamson 1975, 1979, 1981a, 1981b, 1985, 1989). According to Williamson, there are three production cost advantages through the market: 1) by aggregating the needs of many of these businesses for input, a single producer is able to achieve economies of scale and produce at a lower average cost; 2) markets can aggregate related needs, allowing realization of economies of scope that are not available for a single firm; 3) risk reduction. It is important to emphasize that according to Coase and Williamson there are also some costs of using the market and that in some circumstances these costs are high enough to overcome the cost advantages of market production. In particular, when the transaction costs are too high it is appropriate to turn to domestic production (Waldman and Jensen, 2014).

According to Carl J. Dahlman transaction costs can be divided into three broad categories: *search and information costs*; *bargaining and decision costs*; *policing and enforcement costs*. "Both *search and information costs* owe their existence to imperfect information about the existence and location of trading opportunities or about the quality or other characteristics of items available for trade. The case is the same for *bargaining and decision costs*: these represent resources spent in finding out the desire of economic agents to participate in trading at certain prices and conditions. What is being revealed in a bargaining situation is information about willingness to trade on certain conditions, and decision costs are resources spent in determining whether the terms of the trade are mutually agreeable. *Policing and enforcement costs* are incurred because there is lack of knowledge as to whether one (or both) of the parties involved in the agreement will violate his part of the bargain: if there were adequate foreknowledge on his part, these costs could be avoided by contractual stipulations or by declining to trade with agents who would be known to avoid fulfilling their obligations" (Dahlman, 1989, p.148).

According to the author these three types of costs are basically due to a lack of information.

Two important assumptions apply in transaction costs:

1) bounded rationality (ex-ante), that is, the recognition that the limits of knowledge, foresight, skill, and time, constraints the ability of individuals to solve complex problems (Simon, 1957; 1959). So a company cannot write a contract ahead of time that covers all contingencies and therefore the contracts are necessarily incomplete;
2) opportunism or moral hazard (ex post), that is, individuals act to maximize their utility (self-interest) thinking that their activities cannot be easily detected. For this reason economic agents are not completely reliable. It is important to stress that transactions costs increase when a contract that tries to eliminate the risk of opportunistic behavior is written. It is essential to focus therefore on three points of transactions: their *frequency*; the amount of *uncertainty* associated with transactions; and the degree of *specificity* of resources (Williamson 1989).

Regarding *Frequency* if a company needs of an input more frequently, it can save on transaction costs by internal production, because the transaction costs of using the market will be higher because of the frequent renegotiation costs. Concerning *uncertainty.* three types of uncertainty are identified: a primary uncertainty that arises because circumstances can change and cannot predict the future perfectly; a secondary uncertainty which is caused by the lack of communication; a behavioral uncertainty that results from strategic or opportunistic decisions about disclosure of information. Finally as regard the *asset specificity* it refers to the degree to which some assets are of value primarily to one firm. assets can be specific as result of geographic location, physical characteristics, or specialized human capital. Transactions that involve highly specialized assets are likely to be costly. once the investment in a specialized asset has been made, buyer and seller are in a bilateral relationship in which each side has few other options. This is likely to lead to difficult and expensive negotiations, possibly involving considerable bargaining and bluffs on each side. In general, ownership of the specialized asset by the user reduces the incentive for opportunistic behavior and lowers the associated transaction costs (Waldman and Jensen, 2014).

2.3 The industrial location theories

Through the theories of industrial location the notion of space was introduced into economic analysis. These theories were intended to explain the localization choices basing on two great economic forces that organize the activities in space: *agglomeration economies* and *transport costs*. These forces push business location in opposite directions (Isard 1956).

Agglomeration economies push for a spatial concentration because they concerns the economic advantages accruing to firms from concentrated location close to other businesses: i.e. a reduction in production costs due to large size of the plant; the presence of advanced and specialized services; the availability of fixed capital (e.g. infrastructure); the presence of qualified manpower and managerial skills, and a broad and specialized market of intermediate goods. There are three groups of benefits due to agglomeration economies (Hoover 1933, 1936, 1948; Isard, 1949, 1956):

1) Economies internal to the firm, also called economies of scale;
2) Economies external to the firm but internal to the sector, or localization economies;
3) Economies external to the firm and external to the sector, or urbanization economies.

Regarding *economies internal to the firm, also called economies of scale*, they derive from the processes of production on a large scale that get lower costs per product unit. In order to reap the advantages of the production a large scale, the company focuses all its facilities in one place. The advantages of this type are derived, not from the proximity to other companies, but by pure concentration of activities in space.

Concerning *economies external to the firm but internal to the sector, or localization economies* these arise from the location in a densely populated area by companies operating in the same sector. Whereas scale economies depend on the size of its plant, localization economies are determined by the size of the sector in a particular area with a wide range of specialized suppliers and in which specialized labor and specific management and technical skills are available.

About *economies external to the firm and external to the sector, or urbanization economies*: these spring from the high density and variety of productive and residential activities in an area; features that characterize urban environments. The benefits in this category accrue from the presence of large-scale fixed social capital (urban and long-distance transport infrastructures) and a wide and diversified intermediate and final goods market. These advantages increase with the physical size of the city.

It's important to highlight that there are also two forces which work in the opposite direction to concentration of economic activities in space and give rise to dispersed location: 1) increasing costs or diseconomies due to prices of less mobile and scarce factors (land and labour), and the congestion costs (noise and air pollution, crime, social malaise). These diseconomies are generated above a certain critical threshold; 2) *transportation costs* that is all the forms of spatial friction that give greater attractiveness to a location which reduces the distance between two points in space (e.g. production site and the final market; place of residence and the work-place; the raw materials market and the production site). Transportation costs are accordingly the economic cost of shipping goods (the pure cost of transporting and distributing them); the opportunity cost represented by the time taken to cover the distance which could instead be put to other uses; the psychological cost of the journey; the cost and difficulty of communication over distances; the risk of failing to acquire vital information.

It is important to stress that in conditions of perfect competition, perfectly mobile factors of production, fixed raw materials and demand perfectly throughout the country, the existence of transport costs can erode the benefits of agglomeration until activities are geographically dispersed and the market is divided among businesses, each of which caters to a local market. The transportation costs are therefore essential in the location theory because they differentiate space and enable to treat it in economic terms. They are also included in the concept of agglomeration economies as the costs of interaction and distance: if the transportation costs were zero, there would be no reason to concentrate the activities, because doing so would not produce 'economies'. In this sense, the economies of agglomeration are *proximity economies*: i.e., they are the advantages that derive from the interaction (often unintentional) among economic agents made possible by the low amount of spatial friction in a concentrated place (Cappello 2007)

2.4 The local development theories

The theories of local development identify all the tangible and intangible elements in a local area that determine its long-term competitiveness and enable it to maintain that competitive over time. These theories are therefore intended to identify those *exogenous* and *endogenous* factors that render the costs and prices of production processes lower than they are elsewhere.

Exogenous factors originate externally to the area and are transferred into it either fortuitously or deliberately: i.e. the fortuitous local presence of a dominant firm or a multinational company; the spread in an area of an innovation produced elsewhere; or installing new infrastructure decided by external authorities (Perroux 1955; Hägerstrand 1967; Aschauer 1989; Biehl 1991). Although these elements do not have anything to do with local features and productive capacities, once they are present in an area they may catalyse new economic activities and development. Following we will focus mainly on the role played by some exogenous factors in fostering a greater local development: infrastructure and new communication technologies

Together with geographical location and an agglomerative sectorial structure, *infrastructural endowment* (also called *public capital* or *social fixed capital*) is one of the factors that influence the development of an area. In fact, a better infrastructural endowment attracts new businesses in an area and it is a source of competitiveness for companies already operating in that area. It increases the productivity of production factors and by increasing accessibility, reduce purchase costs, thus generating positive externalities on local development (Barro 1990). Impact infrastructural endowment on local development largely depends on the type of public capital considered. *Economic infrastructures* (transport facilities, roads, motorways, railways, airports, and electricity-generating stations) are directly functional to firms and they give rise to greater increases in productivity compared to *social and civil infrastructures* (hospitals, schools, universities, public housing projects and sewerage systems). These latter infrastructures directly impact on the quality of life and human capital, but they influence production only in the longer run. It is important to point out that to ensure that infrastructure investment can generate economic development, it is necessary that infrastructure development must meet the needs expressed by the industrial specialization of the area where the infrastructure is to be installed. In fact, the idea that the creation of infrastructures alone in a weak economic region may generate economic growth, when there is no fertile production context where development may graft on, is misguided. Regarding *information and communication technologies* they open up broad avenues for innovation which encourage local development, i.e. product innovations (e-business, e-commerce), innovations in product distribution (on-line marketing), and process innovations (just-in-time production, functional integration) spring from the presence and exploitation of these technologies, giving the local production system greater competitiveness and efficiency. In order to appropriate the potential profits and higher levels of competitiveness offered by these technologies, knowledge and innovative and creative skills are needed. These ones, however, are certainly not uniformly distributed in space. It is important to highlight that similarly to what was said earlier about infrastructures in general: the mere adoption of these technologies is a necessary but not sufficient condition for local development.

Endogenous factors, instead, arise and develop within the area and enable it to initiate a process of self-propelling development. Endogenous factors are entrepreneurship and local resources for the production (labour and capital); and, in particular, the decision-making capacity of local economic and social subjects able to control the development process, support it during phases of transformation and innovation, and enrich it with external knowledge and information. All these factors have strengthened and improved by a concentrated territorial organization that generates: local processes of knowledge-acquisition and learning; networks of economic and social relations that support more efficient and less costly transactions; and advantages of economic and physical proximity among economic actors. The concept of space in endogenous local development isn’t longer a simple geographical container. In these theories space is conceived as an economic resource, as an independent production factor. It is the generator of static and dynamic advantages for firms, and a key determinant of a local production system’s competitiveness. Space become a source of increasing returns and positive externalities that take the form of agglomeration and localization economies. The highest growth rates are achieved by local production systems in which increasing returns act on local production efficiency to reduce production and transaction costs, improve efficiency of production factors and increase innovative capacity. Regional development therefore depends on the efficiency of concentrated territorial organization of production, not on the availability of economic resources or their most efficient spatial distribution. It's important to emphasize that this concept of space has at least two implications: 1) the space can only be one diversified space where it is possible to distinguish (also internally a region) the non-uniform distribution of activities. In this case the development comes about selectively in areas where the concentrated organization of production exerts its positive effects on the static and dynamic efficiency; 2) space is relational at the same time because economic and social relations that arise in an area play crucial functions to foster local development. Indeed, they shall ensure the smoother operation of market mechanisms, more efficient and less costly production processes, the accumulation of knowledge in the local market and a faster pace of innovation.

Theories of local endogenous development are divided into two broad strands: a) neo-Marshallian strand, where local growth results from externalities acting upon the static efficiency of companies; b) neo-Schumpeterian strand that interprets development as resulting from the impact of local externalities on the innovative capacity of firms.

The first systemic theory of endogenous development was elaborated in Italy by Giacomo Becattini through its study on the *Marshallian industrial district* published in the mid-1970s (Becattini, 1975; 1979 (1989), 2004; Brusco 1990). According to the author an industrial district is a socio-territorial entity characterised by the active presence of both a community of people and a population of firms in one naturally and historically bounded area (Becattini, 1990). Based on work of neoclassical economist Alfred Marshall, the theory of the industrial district was the first to conceptualize external economies (of agglomeration) as sources of territorial competitiveness (Marshall, 1920; Bellandi, 1987). In this theory, the economic aspects of development are reinforced by a socio-cultural system that feeds increasing returns and self-reinforcing mechanisms of development. The characterizing elements of a geographical area to be an industrial district are the following: *spatial proximity*, or geographical contiguity between companies; *social proximity*: a system of institutions, codes and rules shared by the whole community regulates the market; this system leads firms to co-operate and, in general, to resort to the local market, when activities, phases and services prove to be too expensive for them to produce internally; *a concentration of small businesses*, the main features of which are productive flexibility and rapid adaptation to market volatility; *marked industrial specialization of the area* in which all phases of the production chain are undertaken, i.e. from product design, through the production of all intermediate goods necessary for the manufacture of the product, to its global marketing.

The combined presence of these economic-territorial conditions, in purely economic terms, generates increasing returns in the form of agglomeration economies: more precisely, localization economies, or again *district economies*, which are the advantages in terms of lower costs or increased productive efficiency accruing to firms from proximity to other firms operating in the same sector. They enable small firms to overcome the obstacles linked to their size, without having to forgo the advantages. District economies arise through (see Table 2.2): *lower production costs*; *reduced transaction costs*; *increased efficiency of the production factors* by external economies; *increased dynamic efficiency* that is the innovative capacity possessed by firms operating in the district.

District economies are generated and reinforced by factors relating to the economic and social context. The most important factors are: 1) *inextricable interweaving of economic, geographical and social elements.* Defined as a shared code of behaviour and a set of common values penalizing opportunistic behaviour, social proximity is a typical feature of a district. it in fact penetrates the market, structures it around clearly-defined rules, and gives it efficiency. The strength of this organizational model is the close relationship between the economy and the social structure. In this regard, analysts have formulated the concept of a *community market* (Dei Ottati, 1987(2003); 1995); 2) *improving the efficiency of district firms is the integration between cooperation and competition*. In fact striking an appropriate balance between these two processes determines the survival of the district organizational model itself (Becattini 1990; Bianchi 1994; Dei Ottati 1995, 2003; Rabellotti 1997; Schmitz 1995, 1998); 3) the presence of a *governance* structure that is local agents and institutions, which buttresses the transactions regulation system, ensures the efficient operation of the community market by explicitly supporting forms of competition and cooperation.

The effects of space on economic activity do not consist only in improvements to the static efficiency of production processes that is, an increase in companies revenues or a decrease in their costs.

They are also manifest in the innovative and creative capacity of enterprises. In this case, space is a source of dynamic efficiency. In fact, areas with a high concentration of economic activity enjoy easy information exchange, frequent face-to-face meetings, the presence of research and development activities and advanced services, an availability of skilled labour, cooperativeness facilitated by shared rules and codes of behaviour, and local social capital, which facilitate and encourage innovation by the firms located within those areas.

Table 2.2. A district's genetic conditions and advantages: a taxonomy

Genetic conditions (sources)	*Spatial proximity*	*Social and cultural proximity*	*Concentration of small firms*	*Industrial specialization*
Advantages (effects)				
Reduction of production costs	Lower transportation costs for intermediate goods	System of local agents Recourse to external labour (home work) Outsourcing of production phases	Production flexibility	Availability of skilled labour Inter-firm division of labour
Reduction of transaction costs	Labour demand/supply match Broad local market upstream and downstream	Networks of interpersonal relations System of shared rules and institutions Common code of behaviour Sense of belonging Explicit capacity for inter-actor cooperation Informal contracts	Flexible, non-bureaucratized relationships among firms	Adequate technical knowledge for choice of suppliers
Increase in the efficiency of the production factors	Existence of a critical mass for specialized and infrastructural services Broad market for specialized inputs	Widespread industrial culture Mobility of tacit information Widespread entrepreneurial expertise	Flexibility in the quantity and quality of inputs to the production process	Information services for specialization sectors
Increase in innovative capacity (dynamic efficiency)	Localized accumulation of knowledge	Socialization to the risk associated with innovative activity Accumulation of shared knowledge	Competition-driven stimulus to innovation	Accumulation of specific knowledge

Source: Capello, 2007, pp. 188

Their primary aim of these theories was to identify the local endogenous determinants of innovations. They are increasing returns in the form of dynamic location advantages deriving from:

- *spatial, geographical proximity among firms*;
- *relational proximity among firms;*
- *institutional proximity*.

Regarding *spatial, geographical proximity among firms*, a concentrated location facilitates exploitation of technological and scientific knowledge developed by research centres and universities. It gives easier access to the knowledge needed for imitation and reverse engineering. It ensures the availability of skilled labour and advanced services. Moreover, the complex and systemic nature of innovative processes explains their cumulative character: clusters of incremental innovations follow an initially radical innovation which marks out a *technological trajectory* along which knowledge grows and develops within well-defined technological boundaries. Locally, the demand for and the supply of innovative factors interact and mutually reinforce each other. Advanced enterprises enrich the surrounding environment by diffusing their technological and organizational expertise, while the surrounding environment simultaneously sustains their activity. The outcome is a cumulative polarization of research and innovation activities which reinforces the natural tendency for innovation to focus on space. In a concentrated location, the beneficial effects of a firm's research and development activities are not confined within the boundaries of firms. They *spill over* into the surrounding environment, to the advantage of innovative activity by other firms.

Concerning *relational proximity among firms*, it is defined as interaction and cooperativeness among local agents and it is the source of collective learning processes and socialization to the risk of innovation (i.e. territorialized relationships among subjects operating in geographical and social proximity). For this theory, economic and social relations among local actors affect the innovative capacity and economic success of specific local areas termed *milieux innovateurs*. Synergies among actors are enhanced by spatial proximity and economic and cultural homogeneity. Therefore they produce dynamic benefits for small firms, linked to the underpinning processes of collective learning and socialization of knowledge. Within a milieu, economic and social relations take two different forms:

1) a set of mainly informal, 'untraded' relationships, among customers and suppliers, among private and public actors, and a set of tacit knowledge

transfers which take place through job-mobility chains and inter-firm imitation processes;

2) more formalized, mainly trans-territorial co-operation agreements, among firms, among collective agents, among public institutions, in the field of technological development, vocational and on-the-job training, infrastructures and services provision. It's important to underline that relations of the former type constitute the *glue* which creates a milieu effect; they are complemented by the latter, more formalized, kinds of relationship, which can be interpreted as *network relations* proper.

Both sets of relationships can be seen as tools or 'operators' that assist the (small) company in its competitive endeavour, improving its creativeness and reducing the dynamic uncertainty intrinsic to innovation processes.

According to this theory relational capital is defined as the set of norms and values which govern interactions among people, the institutions where they are incorporated, the relationship networks set up among various social actors and the overall cohesion of society.

It has the same role in milieu theory as spatial proximity has in the knowledge spillover theory because it generates dynamic advantages (see Table 2.3) i.e. collective learning and socialization processes; reduction in the risk and uncertainty associated with the innovation process; and the ex-ante coordination of routine and strategic decisions made possible by reduced transaction costs.

These functions are performed in a large firm by its R&D department, and they are facilitated by internal diversification and complexity. A small firm finds the same functions in a highly specialized territory.

In milieu innovateur theory, therefore, collective learning is the territorial counterpart of the learning that takes place within companies. In large companies, knowledge and information are transferred via internal functional interaction among the R&D, production, marketing and strategic planning departments (Camagni, 1991; Capello, 1999; Keeble and Wilkinson, 1999; 2000; Lawson and Lorenz, 1999; Cappellin, 2003).

In milieux, and in local small firms systems, this function is performed by the high level of people mobility, by intense innovative interactions between customers and suppliers, and by companies spin-offs (see Table 2.4).

Table 2.3. Functions of the local milieu

FUNCTIONS / CONDITIONS	Geographical proximity	Relational proximity
Reduction of uncertainty	• Information collection/selection • Vertical integration within "filierès" • Local signalling (collective marketing)	• Information transcoding • Selection of decision routines • Risk sharing among partners
Reduction of coordination costs	• Information collection • Reduction of transaction costs (à la Williamson) • Ex-ante co-ordination of day-to-day decisions (à la Marshall)	• Reduction of control costs through trust and loyalty • Social sanction of opportunistic behaviours • Ex-ante co-ordination in strategic decision-making
Durable substrate for collective learning	• Labour turnover inside the milieu • Imitation of innovation practices	• Co-operation in industrial projects • Tacit transfer of knowledge • Public/private partnership in complex development schemes

Source: Camagni and Capello, 2002, p.20

Table 2.4. Preconditions and channels for learning processes in innovative milieu

Preconditions	Continuity	Dynamic synergies	
Context			
Firms	R&D functions	Functional interaction Tacit transfer of knowledge	INTERNAL LEARNING
Territory	Low mobility of the labour force outside the milieu	High mobility of the labour force within the milieu	COLLECTIVE LEARNING
	Stable linkages with suppliers and customers	Co-operation for innovation with suppliers and customers Local spin-off	
Networking	Stability as a consequence of the complexity of strategic alliances	Transfer of knowledge via co-operation	LEARNING THROUGH NETWORKING

Source: Camagni and Capello, 2002, p.21

There is a third and complementary channels of learning available to companies in the Milieu theory, that is learning through network cooperation (see Table 2.4). By developing strategic alliances and/or non-equity cooperation agreements, firms acquire in fact some of the strategic assets that they require externally, so avoiding the costs of developing the internally. It's important to note that collective learning is not the only dynamic advantage generated by the milieu for local companies. Additional factors that facilitate the innovative capacity of firms are: reduction of the uncertainty that accompanies innovative processes; reduction of the costs of *ex ante* coordination among decision-making units; facilitation of *collective action* (undertaken to furnish collective goods or simply to integrate private investment decisions).

Finally, regarding the *institutional proximity*, i.e the set of norms, codes and rules of behaviour which help economic actors (people, individual firms, public and private institutions) to adopt forms of organization that facilitate interact learning, it facilitates cooperation among actors and thus the socialization of knowledge and it assists economic actors (individual people, businesses and local institutions) to develop organizational forms that support interactive learning processes. It's interesting to note that the theory of the milieu innovateur has been paralleled by the international development of wide-ranging analysis of the endogenous factors at the basis of local innovative capacity. This approach has shifted its focus on institutional aspects, and in particular on the set of social, economic and cultural rules embedded in a territorial setting. Thus the innovative process is strongly localized ad resulted from the variety of traditions, norms, habits, social conventions, and cultural practices that constitute what has been called *institutional thickness* (Amin and Thrift, 1994). Therefore, innovation cannot be properly understood unless it is examined within the socio-cultural and institutional context in which it takes place. In areas where there is institutional proximity the innovative process occurs more rapidly and gives competitiveness to the economic system In this sense a *learning region* is a region: where norms of social and institutional behaviour support interactive learning; and with an *organized market* where implicit and generally shared rules of behaviour ensure the tacit exchange of information and the creation of knowledge. So a 'learning region' is a socio-economic system able gradually to develop forms of interactive learning. It is on this 'learning ability' that the competitiveness of a region depends. Therefore It is a concept that identifies the condition necessary for an the competitiveness of an economic system as a process (learning) more than a state (the stock of knowledge) (Capello, 2007; 2009b).

2.5 Industrial symbiosis and agglomeration economies

Industrial symbiosis can be conceived as the most explicit insertion of a geographical perspective in industrial ecology. Industrial symbiosis differs from the traditional 'greening' industrial initiatives because it is realized through the cooperation among companies, without focusing on actions at individual company level. In this field, companies are viewed as nodal points within an ecosystem network (Gibbs, 2008, Desrochers and Leppälä, 2010).

It is interesting to notice that, despite its obvious relevance for the regional science, economic geography and urban economics, literature on industrial symbiosis is based mostly on engineering and business-school studies and it has generated little interest among economists, geographers and regional scientists with a few exceptions (Andrews 2001; Considine 2001; Deutz and Gibbs 2008; Gibbs 2008, Gibbs and Deutz 2005; Gibbs et al., 2005; Hewes and Lyons 2008; Jacobsen and Anderberg 2005; Korhonen and Snäkin 2005; Kronenberg and Winkler 2009; Lyons 2007; Roberts. 2004; Ruth 1998, 1999; Sterr and Ott 2004; Van den Bergh and Janssen 2004). This situation is paradoxical because both the processes described in the industrial symbiosis literature and the concept itself were discussed in some depth by several economists and geographers since the middle of the nineteenth century (Desrochers and Leppälä, 2010).

In the past, the regional economic literature has been supporting the idea that the implementation of the by-product links were mainly stimulated by two factors: increasing profitability; and removing nuisances that could result in legal actions and their attending costs and/or injunctions. Other specific conditions are: a practical commercial process of manufacture; actual or potential market outlets for the new proposed by-products; adequate supplies of the waste used as raw material, gathered in one place or capable of being collected at a sufficiently low cost; cheap and satisfactory storage; and technically trained operatives (Clemen, 1927). Compared to recent writings, it is likely that in the past economists and geographers thought that by-product linkages (bilateral or multilateral) were widespread; they were also more keen to emphasize that these phenomena could occur at different geographical scales and were based much on creative destruction; and finally their writings were essentially descriptive rather than normative. While this latter feature can perhaps be explained in some instances by personal inclinations toward laissez faire, it is also probably the case that earlier geographers and economists had a better sense of the multiple factors affecting the locational decisions made by industrial managers than later writers who typically came to the topic without any background in spatial analysis. Interestingly, it is perhaps not a coincidence that some recent discussions of Industrial symbiosis are becoming increasingly indistinguishable from descriptions of agglomeration economies. A prime example of this can be found in the work of Chertow who now describes, among other things, the main benefits of industrial symbiosis are: by-product reuse; utility/infrastructure sharing; Joint provision of services (Desrochers and Leppälä, 2010).

Yet in *Industrial symbiosis in Puerto Rico: Environmentally related agglomeration economies*, Chertow writes that although advantages of co-locating businesses is nothing new to economic geographers and regional development specialists, "the concept of industrial symbiosis enhances the concept of agglomeration economies by expanding its scope to include environmental benefits, thus lessening the impact of negative agglomeration externalities while increasing production efficiency" (Chertow et al., 2008, p.1303). Basing on three mechanisms - sharing, matching and learning - through which agglomeration economies accrue (Duranton and Puga 2003) the author explains how (see Figure 2.5). By *utility sharing*, companies can reduce production costs and also ensure provision of reliable water, energy and heat, all key resources to most businesses and critical for the stability of their operations. Under the industrial symbiosis framework, utility sharing includes management by involved firms and can be considered a private cost (for operating the service) as well as a private benefit encompassed by traditional agglomeration economies (shared fixed costs, economies of scale, and improved business stability). At the same time, the industrial symbiosis framework recognizes the public benefits that ensure such as fewer emissions from energy systems, increased use of cleaner or renewable energy sources, and reduced demand and impact on water systems. *Joint service provision* is also a common theme in the agglomeration economies literature. Cost reduction, higher efficiency, and increased product and service quality are considered typical benefits of joint service provision. These initiatives can lead to public environmental benefits as a result of reductions in both overall resource use and emissions. Material and energy intensity can be reduced through joint service provision as individual firms do not have to own ancillary infrastructure and equipment when using a common external provider, and resource productivity may increase as those providers, whose core business is precisely that of the ancillary activity, are presumed to use resources more efficiently. Environmental benefits from joint service initiatives could not be substantial at a firm level, but they can add up to significant savings at the regional level. Companies engaging in *by-product exchanges* with neighboring companies can achieve benefits such as reduced transport (Parr, 2002) and transaction costs (Enright 2003), lower inventory requirements and a potential for just-in-time delivery, or the possibility to suit inputs to customer requirements better through collaborative agreements (Feser, 2002). This type of exchange can lead to other financial and environmental benefits. Using by-products as raw material substitutes can reduce input costs and overall materials and energy requirements as a result of increased cycling. Selling wastes rather than paying to dispose of them brings additional revenues to firms, reducing waste management costs, and most often reduces the environmental impact of these materials (Desrochers, 2002; Ehrenfeld and Gertler, 1997; Lowe and Evans, 1995; Mirata, 2004; Schwarz and Steininger, 1997).

Table 2.5. Industrial symbiosis and environmentally related agglomeration economies

		Types of industry concentrations		
		Localization economies	Urbanization economies	Static/dynamic agglomeration
Mechanisms	Sharing	Industry-specific services	Utility sharing and non-industry-specific services	Static agglomeration gains from increased efficiency through shared resource management
	Matching	By-product exchanges from core industry companies with other regional actors	By-product exchanges among companies in multiple industries	Static agglomeration gains from increased efficiency through cycling of resources
	Learning	Continuous pursuit of industry-specific collaboration to improve resource efficiency and the sustainability of operations	Continuous pursuit of broad-based partnerships to improve the resource efficiency and sustainability of operations	Dynamic agglomeration gains from increased learning and collaboration around sustainability issues

Source: Chertow, 2008, p.1304

Chapter 3

Industrial Symbiosis Initiatives

The third chapter shows at first the main important policies on circular economy at international level. After that it presents some successful cases of industrial symbiosis at different spatial scale. For this purpose it describes above all two experiences of industrial symbiosis at local level (or primarily organized within a community): Kalundborg in Denmark and Guigang Group in China; and two at regional level (or primarily organized within a broader regional area): National Industrial Symbiosis Programme (NISP) in UK, and ENEA experiences of industrial symbiosis in Italy.

3.1 Circular economy strategies

In the last few years circular economy and industrial symbiosis are becoming more and more an important part of the global, national, regional and urban institutions' agendas for economic growth, innovation, economic and industrial development, and resource efficiency (G7 Germany, 2015c).

According to United Nations industrial symbiosis supports a number of the Sustainable Development Goals (see Table 3.1), a new set of global goals that are the successor to the Millennium Development Goals (MDGs), which expired at the end of 2015 (United Nations, 2016). Industrial symbiosis achieves in particular Goal 12, because ensure sustainable consumption and production patterns through the sustainable management and efficient use of natural resources by 2030 (target12.2), and substantially reduce waste generation through prevention, reduction, recycling and reuse (target 12.5) (Arden-Clarke C., 2015; United Nations, 2015; 2016).

According to Organisation for Economic Co-operation and Development (OECD) industrial symbiosis is a radical and systemic eco-innovation for a green growth (Beltramello et al. 2013; OECD, 2009; 2010; 2012).

Table 3.1. Industrial symbiosis and UN Sustainable Development Goals

SDG 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG 9	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
SDG 12	Ensure sustainable consumption and production patterns
SDG 14	Conserve and sustainably use oceans, seas and marine resources
SDG 7	Strengthen the means of implementation and revitalise the global partnership for sustainable development

Source: Arden-Clarke C, 2015

In June 2015, the G7 Leaders, under the German presidency, established in Schloss Elmau (Germany) a G7 Alliance on Resource Efficiency as a forum to share knowledge and create information networks on a voluntary basis. In the Leaders' Declaration G7 Summit: *Think Ahead. Act Together. An morgen denken. Gemeinsam handeln* (G7 Germany, 2015a; 2015b), they stated in fact that the protection and efficient use of natural resources was vital for sustainable development. They undertook to improve resource efficiency, which they considered crucial for the competitiveness of industries, for economic growth and employment, and for the protection of the environment, climate and planet. Based primarily upon *Kobe 3R Action Plan*: Reduce, Reuse, Recycle (G8 Environment Ministers, 2008) G7 Leaders maintained that would have continued to take ambitious action to improve resource efficiency as part of broader strategies to promote sustainable materials management and material-cycle societies. In order to reach this goal, the G7 Alliance on Resource Efficiency would have collaborated with businesses, SMEs and other relevant stakeholders including from the public sector, research institutions, academia, consumers and civil society, on a voluntary, nonbinding basis. The Alliance would have benefited from actively engaging, with, for example, relevant business initiatives and supporting networks. The G7 Alliance on Resource Efficiency aims to promote an exchange of concepts on how to address the challenges of resource efficiency, to share best practices and experience, to create information networks and foster innovation. It's also important to underline that the G7 Leaders asked the UNEP International Resource Panel to prepare a synthesis report highlighting the most promising potentials and solutions for resource efficiency; and they further invite the OECD to develop policy guidance supplementing the synthesis report. As follow-up of this declaration G7 leaders established that a series of workshops on best practices are organized. Subjects to be addressed in workshops under the G7 Alliance on

Resource Efficiency also included industrial symbiosis. After that the G7 Alliance for Resource Efficiency was inaugurated in Berlin on 2 October 2015, the UK and Germany jointly hosted the industrial symbiosis workshop in Birmingham on 28 and 29 October This event was attended by over 100 policy makers, industry representatives and academic pioneers from countries within the G7, G20 and emerging economies (International Synergies, 2016).

The law enacted by Germany in 1996 "Closed Substance Cycle and Waste Management Act" is considered as the starting point at the international level for the implementation of a circular economy. This law envisaged a closed cycle of waste management and ensured environmentally compatible waste disposal. The legal framework developed by Japan in 2002 for establishing a recycling-based society was another important international reference point because it gave quantitative targets for recycling and dematerialization of Japanese society (METI, 2004; Morioka et al., 2005; Van Berkel et al., 2009).

A common feature of policies for a circular economy of both countries is to prevent further environmental degradation and to conserve scarce resources through effective waste management (Su et al., 2013).

It is interesting to note that China has focused much on the concept of circular economy as well, paying particular attention to the 3R principles (Ren et al., 2005; UNEP, 2011a). During the 16th Congress of the Chinese Communist Party in 2002, China adopted a strategy of economic development for a new type of industrialization in the 21st century. This strategy is based on the following points: industrialization pushed forward by information technology; sustainable development created through the promotion of circular economy with optimal use of resources and energy; and the maximization of profit integrated community. This strategy is implemented at three spatial scales (see Figure 3.1): 1) at the *macro-level* where the development of a circular economy stresses adjusting industrial composition and structure, creating resource recycling systems, and improving these recycling systems; 2) at the *meso-level* where the circular economy is developed by applying industrial ecology concepts, including: promoting networks among businesses and communities to optimize the use of resources; and planning of eco-efficient energy cascades; 3) at the *micro-level* where byproducts are identified in individual enterprises and used effectively either internally through cleaner production or externally by other industries (Fang at al., 2007).

Figure. 3.1. Structure of the circular economy practices in China.

	Micro (single object)	Meso (symbiosis association)	Macro (city, province, state)
Production area(primary, secondary, and tertiary industry)	Cleaner production Eco-design	Eco-industrial park Eco-agricultural system	Regional eco-industrial network
Consumption area	Green purchase and consumption	Environmentally friendly park	Renting service
Waste management area	Product recycle system	Waste trade market Venous industrial park	Urban symbiosis
Other support	Policies and laws; Information platform; Capacity-building; NGOs		

Source: Su et al., 2013, p.217

Toward this direction in August 2008 the 4th session of the Standing Committee of the 11th National People's Congress of the People's Republic of China adopted the Circular Economy Promotion Law of the People's Republic of China the first law of its kind in the world which came into effect on 1 January 2009 (People's Republic Of China, 2008). The first article states that this law is formulated for the purpose of promoting the development of the circular economy, improving the resource utilization efficiency, protecting and improving the environment and realizing sustainable development. According to article 2 of this law, the term circular economy is linked to reduction, reuse and recycling activities conducted in the process of production, circulation and consumption. Although it was inspired by legislation in other countries (such as Germany and Japan) rather than being regarded as an incrementally improved environment management policy, the law in China seems to be the first in the world to make circular economy a national strategy of economic and social development introducing a more sustainable new development model (Geng and Doberstein, 2008; Mathews and Tan, 2011; Su et al. 2013; Zhu, 2008). The Chinese law assigns multiple government departments' responsibilities to plan, supervise and evaluate national circular economy development through setting up national targets and building indicator systems to quantify the effectiveness of the circular economy development. It's interesting to note that at the eco-industial park level, two governmental agencies (NDRC and MEP) have issued two different indicator evaluation systems. The former one focuses exclusively on the implementation of 3R principles and the latter additionally considers eco-industrial park's impact on economic, environmental and social aspects (Su et al., 2013; Wang et al, 2015). Additional specialized circular economy policy frameworks are as follows: the Law on Cleaner Production Promotion; Management and taxation policies for comprehensive utilization of wastes and used resources; Green procurement by government agencies and public institutions (UNEP, 2011a).

According to the European Commission the transition to a circular economy is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. In order to achieve this objective, in December 2015 the European Commission adopted an ambitious new Circular Economy Package to stimulate Europe's transition towards a circular economy in order to boost global competitiveness, foster sustainable economic growth and generate new jobs. The aim is to extract the maximum value and use from all raw materials, products and waste, fostering energy savings and reducing Green House Gas emissions. The proposed actions contribute to *closing the loop* of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy (European Commission, 2015b; 2015e). It's important to remember that in July 2014 the EU has already released another document *Towards a circular economy: A zero waste programme for Europe* (European Commission, 2014a) where it began to establish a common and coherent EU framework to promote the circular economy.

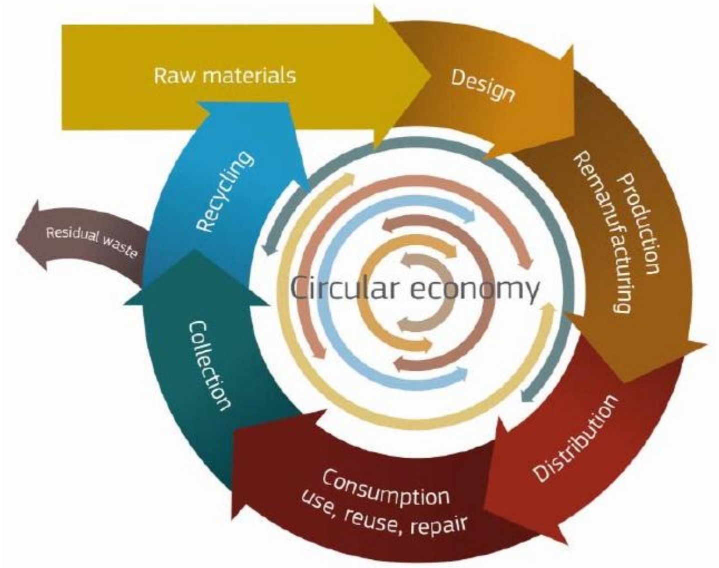
Circular Economy Package includes revised legislative proposals on waste (European Commission, 2015c; 2015d; 2015h; 2015i; 2015j; 2015k), as well as a comprehensive *Action Plan* setting out a concrete mandate for this Commission's term of office. The *revised legislative* proposal on waste sets clear targets for reduction of waste and establishes an ambitious and credible long-term path for waste management and recycling. To ensure effective implementation, the waste reduction targets in the new proposal are accompanied by concrete measures to address obstacles on the ground and the different situations across Member States. The *Action Plan on the Circular Economy* complements this proposal by setting out measures to *close the loop* of the circular economy and tackle all phases in the lifecycle of a product (European Commission, 2015a).

According to European Commission "in a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value[15]" (see Figure 3.2) (European Commission, 2015a, p.1). "It may involve: increasing the time products deliver their service before coming to the end of their useful life (durability); reducing the use of materials that are hazardous or difficult to recycle (substitution); creating markets for recycled materials (standards, public procurement); designing products that are easier to repair, upgrade, remanufacture of recycle (eco-design); incentivising waste reduction and

[15] It's important to note that according to EU even in a highly circular economy there will remain some element of linearity as virgin resources are required and residual waste is disposed of (European Commission, 2014a).

high-quality separation by consumers; incentivising separation and collection systems that minimise the costs of recycling and reuse; facilitating industrial clusters that exchange by-products to prevent them from becoming wastes (industrial symbiosis); Encouraging wider consumer choice through renting or leasing instead of owning products (new business models)"(European Commission, 2014a, p.4).

Figure 3.2. Conceptual diagram of a circular economy model



Source: European Commission, 2014a, p.5

EU stated that it does not want to base its future on a linear model of economic growth on which it relied on in the past and it is no longer suited for the needs of today's modern societies in a globalised world. The main reason behind this choice is that it is increasingly being understood that a linear model based on the assumption that resources are abundant, available, easy to source and cheap to dispose of threatens the competitiveness of Europe. On the contrary many natural resources are finite and it's necessary to find an environmentally and economically sustainable way of using them. It is also in the economic interest of businesses to make the best possible use of their resources .The commission estimates in fact that a circular economy could bring net savings of €600 billion, or 8% of annual turnover, for businesses in the EU, while reducing total annual greenhouse gas emissions by 2-4 %. (AMEC Environment & Infrastructure and Bio Intelligence Service, 2013; European Commission, 2014a; 2015a).

In the last years EU have already provided some tools and incentives to move toward a circular economy model. In 2005 European Union adopted the *Lisbon Strategy* *for Growth and Jobs* (European Commission, 2005b), which gave high priority to more sustainable use of natural resources, and called upon the EU to take the lead towards more sustainable consumption and production in the global economy. This one was followed by the adoption of the European *Thematic Strategy on the Sustainable Use of Natural Resources* (European Commission, 2005a) under the 6th Environmental Action Program (6th EAP). This recognizes decoupling of both resource use and its impacts from economic growth (UNEP, 2011a). In 2008 the *waste framework directive* (European Union, 2008) defines the basic concepts and definitions related to waste management, such as definition of waste, recycling, recovery. It also defines the end-of-waste criteria which specify when waste ceases to be waste and obtains the status of a product or a secondary raw material. This is important to facilitate and promote recycling of products and reducing the amount of wastes sent for disposal. These end-of-waste criteria are also of key importance for companies to be able to engage in industrial symbiosis. Furthermore, the directive also specifies the priority order for waste and the waste management hierarchy (see Figure 3.3) to be followed in all Member States policies and regulations: 1) *Prevention of waste*; 2) *Preparing for re-use*; 3) *Recycling*; 4) *Recovery*; 5) *Disposal*. It follows that the impact of industrial symbiosis to waste management in Europe is a high priority, given its potential contribution to waste prevention (Bilsen et al., 2015).

Figure 3.3. Waste Management Hierarchy

Source: European Commission, 2016a

In general in recent decades, the EU has adopted several policies and instruments already providing tools and incentives in line with the circular economy model (European Communities, 1999; 2000a; 2000b; European Union, 2006; European Commission, 2011b 2012, 2014b).

3.2 Local industrial symbiosis experiences

Kalundborg in Denmark

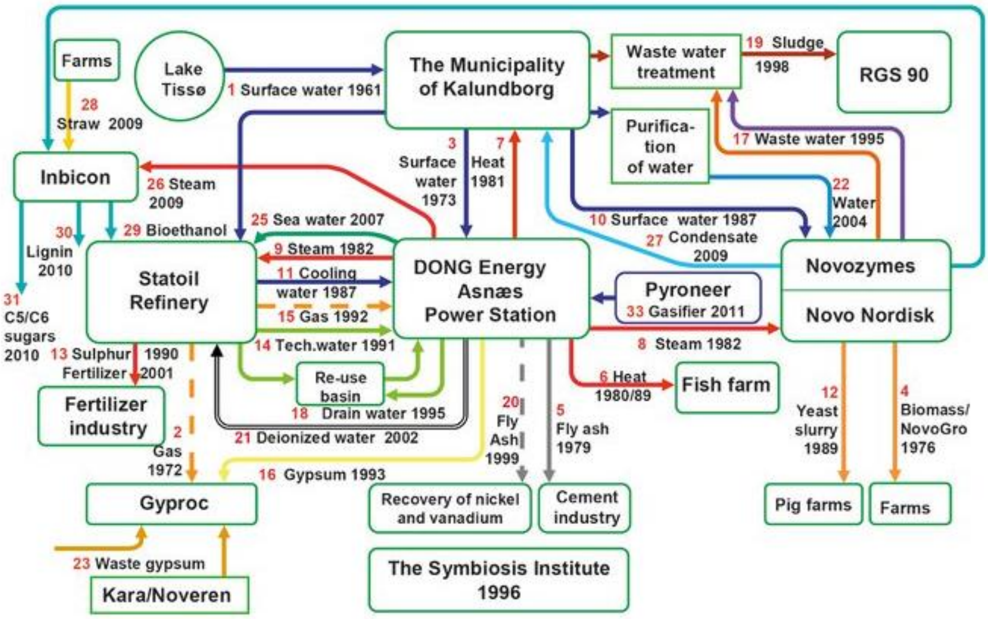
The model of industrial symbiosis was fully realized for the first time in the eco-industrial park of Kalundborg, Denmark (see Figure 3.4). The term industrial symbiosis was coined there in 1989 and knowledge of the Kalundborg system has become foundational to industrial ecology. It is in fact a concrete realization of the industrial ecosystems Frosch and Gallopoulos theorized (Chertow, 2000; Chertow, 2007; Chertow and Ehrenfeld, 2012).

Figure 3.4. Industrial area of Kalundborg in Danmark

Source: Kalundborg Institute, 2015

The Kalundborg Symbiosis began in 1961, when Statoil (then Esso) needed water for their refinery near Kalundborg. The first conduits pipes in Kalundborg Symbiosis were laid between Statoil and the nearby lake, Tissø. In 1972, Statoil entered into an agreement with Gyproc, a local gypsum production enterprise, for the supply of excess gas from Statoil's production to Gyproc. Gyproc used the gas (today, natural gas) for the drying of the produced plasterboard in their ovens. The following year, 1973, Dong Energy (then, the Asnæs Plant) was connected to the Statoil water pipe. Over the years more and more businesses were linked into the Kalundborg Symbiosis (see Figure 3.5) (Kalundborg Institute, 2015).

Figure 3.5. Industrial ecosystem of Kalundborg[16]



Source: Kalundborg Institute, 2015

"In addition to natural resources such as water, companies also became willing to share other assets for mutual benefits, such as personnel, equipment, and information. In a broader view, the system of exchanges described as industrial symbiosis converts negative environmental externalities in the form of waste that used to be discarded into positive environmental externalities such as the spillover benefits of decreased pollution and reduced need for raw material imports" (Chertow and Ehrenfeld, 2012, p. 15). It is important to note that "rather than a static system of locked-in firms and technologies, individual participants in the symbiosis have changed significantly over time, and the ecosystem as a whole has adapted. Over the past several years, Kalundborg's Statoil Refinery doubled its capacity based on North Sea claims, the Asnæs Power Station switched from coal to orimulsion to comply with mandated carbon dioxide (CO2) reduction, and the pharmaceutical plant split into two ventures, eliminated some product lines (including penicillin), and increased others. Although each individual business change alters the makeup of the industrial symbiosis, the changes collectively have not diminished the overall nature of the symbiosis. In fact, in the case of the power station's flue gas desulfurization program that creates calcium sulfate (or gypsum) used by the plasterboard plant, the change in fuel at the power station from coal to orimulsion led to

[16] "The Kalundborg industrial symbiosis. Actors and exchanges of materials and energy. Exchanges are numbered from 1 to 33 and the years shown indicate when an exchange began. Discontinued links are shown as dotted lines" (Chertow and Ehrenfeld, 2012, p.17).

the creation of even more gypsum, thereby increasing the benefits for the participants. Rather than tie themselves to a single supplier, the symbiosis participants try to insulate themselves from supplier interruptions by diversifying sources to reduce business risk, just as in traditional supplier–customer relationships" (Chertow, 2004, pp.408-409).

Today the main partners (public and private enterprises) in the Kalundborg area are: (Kalundborg Institute, 2015): Novo Nordisk: the world's largest producer of insulin (around 2600 employees[17]); Novozymes: the world's largest producer of enzymes (around 500 employees.); Gyproc (french-owned): It produces gypsum board (around 165 employees); Kalundborg Municipality: it handles, among other things, the water and heat supply for Kalundborg's approximately 50.000 inhabitants; Asnæs Plant (Dong Energy-owned): the biggest power plant in Denmark (around 120 employees); Statoil: it owns Denmark's biggest oil refinery (around 350 employees); Kara/Novoren: it is a waste treatment company (around 15 employees); Kalundborg Forsyning A/S: it supplies the citizens of Kalundborg city with water and district heating, as well as disposing of waste water from the entire municipality. (around 66 employees). Several local firms outside the area also participate in the symbiosis as recipients of materials or energy (Ehrenfeld and Gertler, 1997; Cherow, 2004).

According to Jørgen Christensen[18] the industrial symbiosis developed in Kalundboorg is "a *non-project* made by a *non-organization*" (Christensen, 2012, p. 7). It evolved organically over many decades, not according to a joint plan, but spontaneously, and initially as quite independent projects (Christensen, 2012; Randers, 2014). It is important to emphasize in fact that Kalundborg Symbiosis wasn't invented, but it came into being as a result of private conversations between a few enterprise managers from the Kalundborg region in the '60s and '70s. Over the years more and more businesses were linked into the Kalundborg Symbiosis, and in 1989 the term industrial symbiosis was used to the describe the collaboration for the first time (Kalundborg Institute, 2015). In fact until some local high school students prepared a science project in 1989 in which they made a scale model of all the pipelines and connections in their small community, the unique aspects of the project went largely unnoticed. It is interesting to note that participants became conscious of the environmental characteristics of their exchanges over time (Chertow, 2007).

According to Ehreinfild and Gertler the strength of the Kalundborg approach is that business leaders have done the *right thing* for the environment in the pursuit of rational

[17] Employment data of the eight companies concern the venues of Kalundborg.
[18] Jørgen Christensen is the former Chairman of Novo Nordisk in Kalundborg

business interests (Ehrenfild and Gertler, 1997). The industrial ecosystem at Kalundborg is a resource and environmental network, self-organized over time, consisting of thirty-third-some economically attractive, bilateral and commercial agreements between the various enterprises. (Chertow, 2004; Christensen, 2006; 2012; Randers, 2014; Kalundborg Institute, 2015). In this way high levels of environmental and economic efficiency by the participants have been achieved through an evolutionary process that began more than 40 years ago (see Figures 3.6 and 3.7) (Chertow 2009; Chertow and Ehrenfeld, 2012; Ehrenfeld and Chertow 2002; Engberg 1993; Gertler 1995; Jacobsen and Anderberg 2005; Kalundborg Institute, 2015).

Figure 3.6. Annual environmental benefits of Kalundborg IS network[19]

Resource/ emission flow	SAVINGS per year
Ground water	2,9 mill m3
Surface water*	1,0 mill m3
Liquid sulphur	20,000 Tn
Biomass	319,000 m3
Biomass (yeast slurry)	42,500 Tn
CO2 emissions**	64, 460 Tn
SO2 emissions***	53 Tn
NOx emissions***	89 Tn
Waste water ****	200,000 m3
Gypsum	170,000 Tn

Source: Domenech and Davies, 2011, p. 81

Figure 3.7. Economic parameters of the IS network

Investment/ savings	Amount
Investments	US$ 78.5 mill.
Annual savings	US$ 15 mill.
Accumulated savings	US$ 310 mill.

Source: Domenech and Davies, 2011, p. 82

It' important to note that Danish regulatory framework has encouraged the evolution of industrial symbiosis in Kalundborg: i.e. the national ban on placing organic waste streams into landfills caused the pharmaceutical company to seek arrangements to apply its sludges on agricultural lands" (Chertow 2004; Ehrenfeld and Gertler, 1997).

[19] "Data is based on different baseline years, but it is mainly based on calculations made by Christensen in 1998 (personal communication); However, ground water savings incorporates further savings achieved after 2004 by the substitution of ground water by treated surface water at Novozymes. *Surface water substituted by sea water at Asnaes** Reductions in emissions are calculated as an estimation of the reduction of heavy fuel oil derived from the combined heat and power generation (20,000 tn heavy fuel oil * 3,223 conversion factor CO2). *** SO2 and NOx are based on 2002 data, Jabobsen (2006). These values are expected to be lower, since unit 5 from Asnaes is no longer fuelled with oriemulsion; CO2 emissions may, on the contrary, be higher, as a result of the fuel substitution (coal for oriemulsion); **** This value is calculated as an estimation of waste water recirculation at Asnaes" (Domenech and Davies, 2011, p. 81).

In the development of the Kalundborg Symbiosis, the most important element was healthy communication and good cooperation between the participants (Kalunborg Institute, 2015). Also according to Christensen the reasons for the development of industrial symbiosis in Kalundborg, beyond the industrial potential existed, several large industries, limited physical distances, *a good fit*, economic incentive existed, no legal barriers, was in particular good communication. According to Christensen in fsct communication was more important than technology. The good communication in Kalundborg was due to: the size of the community; no competitors involved; Managers already acquainted - many in the same Rotary club; Open management style (not secretive); One project (steam) involved four partners. All this has led to a *short mental distance* between the participants. (Christensen, 2006). In general social cohesion in the Kalundborg symbiosis is considered as a key element of success (Chertow, 2004). A key coordinating role is played by the Kalundborg Center for Industrial Symbiosis, formed in the 1996 by the symbiosis partners under the auspices of the Industrial Development Council of the Kalundborg region "which tries to increase exchange and improve internal and external communication" (Chertow, 2000; 2004).

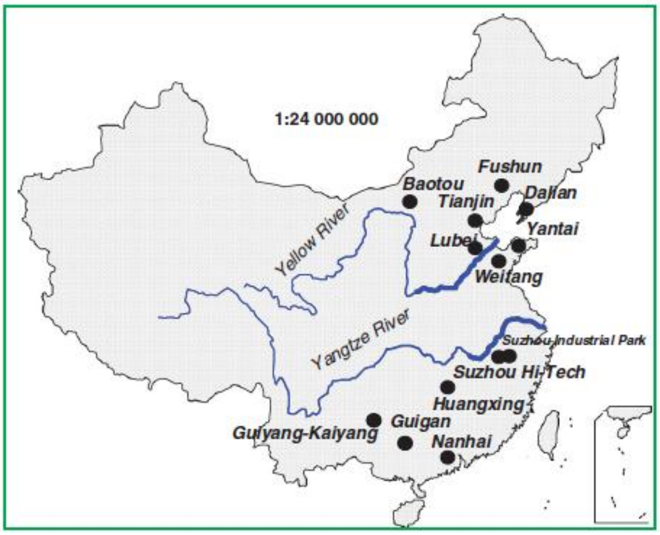
Guigang Group in China

According to Chertow we can identify two different contrasting industrial symbiosis approaches: a self-organization and a planning approach. The s*elf-organizing symbiosis model* is an industrial ecosystem emerges from decisions by private actors motivated to exchange resources to meet goals such as cost reduction, revenue enhancement, or business expansion. The individual initiative to begin resource exchange faces a market test and if the exchanges are successful, more may follow if there is on-going mutual self-interest. In the early stages there is no consciousness by participants of *industrial symbiosis* or inclusion in an *industrial ecosystem*, but this can develop over time. The projects can be strengthened by post facto coordination and encouragement[20]. *Planned EIP model* includes instead a conscious effort to identify companies from different

[20] In addition to Kalundborg, for a deepening about other case study, see: Schwarz and Steininger 1995, 1997; USPCSD 1997; Kincaid 1999, 2005; Korhonen et al. 1999; Alberta's Industrial Heartland Association 2000; Ashton 2003; Côté 2003; Van Berkel 2004; Barchard 2005; Chertow and Lombardi 2005; Sustainable Gladstone 2005; Van Beers at al 2007; Chertow et al 2008.

industries and locate them together so that they can share resources across and among them[21] (Chertow, 2007).

Figure 3.8. Location map of 13 state-level eco-industrial development projects ratified by SEAP until early 2005 in China



Source: Fang et al., 2007, p.318

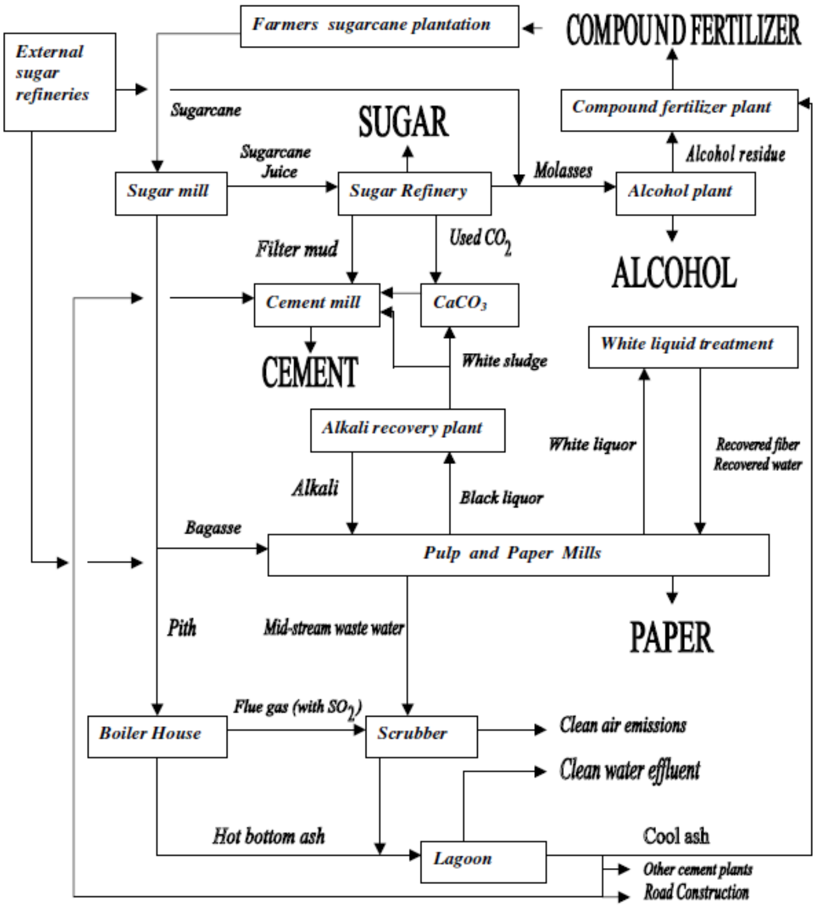
It's important to note that formal planning is much institutionalized in countries such as China, Korea, and Singapore (Chertow, 2007). China's case is particularly interesting. It is a large densely populated country undergoing rapid industrialization and is becoming one of the world's biggest consumers of natural resources. It's important to highlight that China's natural resource base is relatively limited. So china's rapid industrialization is inevitably resulting in serious conflicts between economic development and environmental performance (Ren 2003, Ma 2004, Fang at al. 2007). In order to cope with conflict between economic growth and natural resource shortages and heavy pollution at the end of the 1990s, China has also developed programs for fostering eco-industrial parks or eco-industrial park as an important component of implementing the Circular Economy strategy (Shi et al., 2003, Fang et al., 2007). In 2001, the Guangxi Guigang Group, a state-owned sugar company based in southern China (see Figure 3.8), became the first national pilot eco-industrial park approved by SEPA[22] (Feng, 2004;

[21] The empirical research in industrial generally seems to find that attempts to plan eco-industrial parks particularly from scratch, that involve significant material and energy exchanges have rarely come to fruition in a sustainable way, particularly in Europe and North America (Ehrenfeld and Gertler 1997; Chertow 1999, 2007; Gibbs 2003; Baas and Boons 2004; Heeres et al. 2004; Gibbs and Deutz 2005, 2007; Korhonen and Snaikin 2005).

[22] In Mar 2008, EPA was upgraded to the Ministry of Environmental Protection (MEP) (Zhang et al, 2010).

Zhang et al., 2010; Zhu et al., 2007) SEPA categorizes this industrial park as a *sector-specific group*[23] namely as a park "with primarily one main sector or anchor tenant (i.e., one firm serving as the driver of some of the main material and energy flows and as a possible organization around which the control and management of these flows could be arranged). Usually in such a park there is an anchor company, whereas others are suppliers and service providers (Geng et al., 2009). As Zhue, Lowe, Wei and Barnes note it would be more appropriate to call the industrial symbiosis initiative of Guigang Group an eco-industrial network, being led by one enterprise (Lowe 2001, 2005, Zhu et al,. 2007).

Figure 3.9. Industrial symbiosis in Guitang Group.



Source: Zhu et al., 2007, p.34

[23] "SEPA categorized industrial parks into three groups [...] the sector-integrated group, the venous group, and the sector-specific group, each with slightly different criteria and indicators. The *sector-integrated group* refers to those parks with multiple industrial sectors, especially the development zones, which are the main form of Chinese industrial park (Festel and Geng 2005). The *venous industrial park* particularly refers to those resource recovery parks where environmental technology companies and firms making green products coexist. The term venous reflects its biological usage, in which blood flow returns to the heart for reuse following restoration in the kidney" (Geng et al., 2009, p.17).

According to Chertow we can consider the case study of the Guitang Group as an example of self-organizing symbiosis model, where some parts of symbiosis are planned but others are appeared opportunistically (Zhu et al. 2007, Chertow 2007). Established in 1954 by the state, the Guitang Group operates one of China's largest sugar refineries, with over 3,000 workers and a complex covering more than 2 km^2 (Zhu and Cote 2004; Zhu et al., 2007).

It has developed an embryonic eco-industrial development by applying an integrated approach to green supply chain management. In fact this company has implemented a systematic approach that integrates inputs and outputs of different actors among two major supply chains to effectively use available resources. This approach can also be seen as integrated life cycle management, which connects the material life cycles in increasingly complex networks, developing eventually into an eco-industrial park, a particular type of industrial ecosystem. Two main supply chains were formed among the Guitang Group, namely, the alcohol chain and the paper chain (see Figure 3.9). The alcohol chain consists of a sugar refinery, an alcohol plant, and a fertilizer plant. Along the chain, each downstream plant uses wastes from its up-stream plant as raw materials. For instance, the alcohol plant uses the used molasses from the sugar refinery as its raw material to produce alcohol. The alcohol residue from alcohol plant is usually discharged into rivers in most of the sugar refineries. But in the Guitang Group, it is used by the fertilizer plant to make fertilizer. The principle of using wastes from the upstream plant as raw material for the downstream plant is also adopted in the second supply chain. The pulp plant uses the bagasse generated from the sugar refinery, and the downstream cement mill uses its wastes, the white sludge, as raw material for the production of cement. In the Guitang Group, they take full advantages of most co-products such as the molasses and by-products such as white sludge. Thus, the Group not only reduces the wastes but also improves their financial performance. In addition, the Group has successfully treated the residual products, and even partly realized waste recovery. Three approaches can be seen to treat the residual products, namely, re-use, volume reduction and disposal (see Figure 3.9). The waste liquid from alcohol production is re-used. After being treated, it is used to produce fertilizer that is sold to the raw material producer, the sugarcane farmers. The second approach is to reduce the amount of residual products by employing cleaner production technologies. Wastewater produced during paper making is difficult to dispose. The Group has worked on the development of new technologies to improve water efficiency, which is expected to reduce the wastewater between 30% and 40%. At the same time, the wastewater generated in the pulp-making plant is filtered in the boiler house using the boiler slag. After this filtration, the wastewater is further treated to meet national standards and is then discharged into rivers. As for the filter mud produced during sugar refinery, it is one of the most severe pollution problems for the sugar industry. Since 1998, the Group has collected the mud after being dried, and began to use it as a raw material for cement production (Zhu and Cote, 2004). The internal symbiosis of the Guitang Group operations has resulted in increased efficiency and productivity productivity per unit of input. The annual total production in 2003 includes plantation white sugar (150,000 tonnes), raw sugar (300,000 tonnes), pulp (150,000 tonnes), paper (200,000 tonnes), alcohol (10,000 tonnes), cement (330,000 tonnes), alkali (35,000 tonnes), and fertilizer (30,000 tonnes). The Guitang Group recovered its investments in the paper mills and fertilizer plant in six to eight years. In addition to the internal symbiosis described above, the Guitang Group has evolved a network of external relationships including the government, customers, suppliers, and competitors that affects the overall operation of the complex.

Regarding the *relations with the government*, the latter acted as an intermediary between factories and farmers, seeking resolution of issues in matters such as price and quantity. It’s important to emphasize that in the contemporary Chinese social and economic system, government entities play an active role in the conduct of business and markets. The Guigang city government establishes a floor price that the company must agree to pay the farmers. This direct price support provides greater income and security for the farmers, in line with national policy of helping rural populations share in the benefits of China’s rapid and continuing economic expansion. The government’s rationale for setting the higher price was twofold: a policy determination to increase farmers’ income and a pragmatic determination to provide added incentive to encourage farmers to plant sufficient sugarcane to meet the needs of the sugar processors, because a number of farmers in the region had switched to other, presumably more profitable crops. Beyond setting the floor price, the city government used other policies to manage the scale of sugarcane production and to restrict the area in which the Guitang Group may buy sugarcane. Farmers who planted sugarcane on reclaimed marginal or barren land that was not being farmed received a reduction in local taxes. The government also encouraged local banks to provide no- or low interest loans for farmers who planted on a larger scale and provided employment opportunities to farmers whose land had been purchased by larger scale farmers. It’s important to note that although the Guigang government actively intervened in sugarcane production, it also set policies that supported symbiotic relationships by requiring smaller sugar producers to send their by-products (bagasse and molasses) to the Guitang Group as inputs for the production of paper and food

Regarding the *relations with customers* the Guitang Group has achieved some success in expanding its sugar sales based on the quality of its products. The higher quality of its carbonation-refined sugar, compared with the sulfitation-refined sugar of its competitors, has enabled the GG to gain significant contracts with major soft drink companies, including Coca-Cola and Pepsi-Cola, as well as with Wahaha, the largest domestic beverage producer in China. For the past few years, Guitang Group's greatest success in the market has been in paper manufacturing, which has become its major profit center. Again, the quality of its office and publishing paper enabled the company to establish a presence in the paper market, with opportunities for higher profits than its sugar business.

Regarding the *relations with suppliers/farmers* the company has signed long-term contracts with farmers for sugarcane production. The company has also provided seeds and some organic fertilizer at a nonprofit price, as well as technological support to sugarcane farmers in the area. In 2000, the company announced plans for helping farmers convert to organic production as a strategy for increasing competitiveness and profit margins. Lacking funding for an immediate conversion to organic farming in the region, it has focused its research and provided support for farmers to move towards this goal. The company has worked with farmers to establish the use of a pheromone-based pesticide and has developed and distributed two organic fertilizers. Both are made from alcohol residue, with one mixed with nitrogen, phosphorus, and potassium, whereas the other includes white sludge and bottom/fly ash derived from the Guitang Group's production processes.

Regarding the *relations with competitors* the construction of new paper mills has resulted in production capacity that exceeds the supply of locally available bagasse. This has led the Guitang Group to source two-thirds of the bagasse it uses from local competitors, which had been discarding or incinerating the by-product (Zhu et al., 2007)

It can be stressed in conclusion therefore that the industrial symbiosis initiative led by Guitang Group not only created business benefit to the same company but it also generated financial and environmental benefits throughout the local economy (Zhu and Cote 2004; Zhu et al., 2007).

3.3 Regional industrial symbiosis experiences

The National Industrial Symbiosis Programme (NISP) in United Kingdom

The National Industrial Symbiosis Programme (NISP) in UK adopts a regionally-based eco-industrial network approach rather than focusing solely on eco-industrial park (Gibbs, 2009). This programme engages "different industries (of different sizes and capacities), government bodies and research organizations in order to identify and facilitate economically viable solutions to business challenges" (Lombardi and Laybourn, 2015, p.20). Thanks to work with the willing, the NISP has successfully facilitated industrial symbiosis in UK and produced significant economic and environmental benefits for both participants and the country as a whole (see Figure 3.10) (Jensen et al., 2012).

Figure 3.10. Resource (material/substance) Exchange Network by NISP in UK

Source: Jensen et Al., 2011, p.706

In 2003 NISP was started by International Synergies in UK through successful regional pilot schemes in Scotland, West Midlands and Yorkshire & Humberside. In

2005, UK government funded it via Defra enabling the roll out of NISP as a national programme - the first in the world (Laybourn and Morrissey, 2009). The NISP was constituted across all 12 UK regions until 2010, and after 2010 across the 9 English regions (Gigli, 2014) The model has to date been replicated in 21 countries world-wide (International Synergies, 2015). "Key objectives of NISP are: increasing the profitability of businesses through reduced landfill costs and additional sales; creation of new markets for existing waste products and by-products (through the often needed secondary processing or treatment to turn by-products into materials that are suitable for use); expanding of production; reducing negative environmental and climate change impacts and improving resource efficiency (such as CO2 equivalents, waste landfill, water consumption, hazardous materials, raw material consumption etc.); foster innovation through networking and transfer of knowledge between traditionally separate industries and access to network partners; enabling companies to enhance their corporate social responsibility activities" (Gigli, 2014, p.7).

In order to promote industrial symbiosis development in UK the government introduced an effective mix of economic, regulatory and voluntary instruments for its implementation (Costa et al., 2010, Wang et al, 2015). The UK waste policy is issued by Defra whitin EU requirements. In order to improve resource efficiency and move towards a Zero Waste Economy (ZWE) a twofold strategy has been adopted: discouraging landfill and supporting for industrial symbiosis (Defra, 2011). A key tool to reach these objectives has been the annual increase of the landfill tax since its introduction in 1996 (Seely, 2009). This tax is paid by landfill site operators for every tonnage of waste that is landfilled. Although the tax does not encourage any specific alternative to landfill, it has reached a level where alternative options become financially viable (MT Waste Management, 2011) such as industrial symbiosis activities. Using the landfill tax, Defra has supported business resource efficiency activities and programmes, such as in 2000 the Waste Resource and Action Programme (WRAP) aiming to support recycling by developing markets for recycled materials (Seeley, 2009; WRAP, 2015). Through this programme is also funded the NISP proposed by International Synergies Ltd (Defra, 2009). The NISP has stimulated growth in the UK, creating new jobs and helping companies in moving toward a more sustainable economy (see Table 3.2). This program has had a positive impact on state finances as well. According to an independent economic analysis (Manchester economics ltd, 2009) NISP has generated €1.7 billion to €2.9 billion of Total Economic Value Added (TEVA) equating to a multiplier effect on Government investment of between 53:1 and 88:1. NISP has also increased Income Tax, Corporation Tax and Value Added Tax (Lombardi and Laybourn, 2015)

Table 3.2. Externally verified results from NISP England, 2005-2013

Externally Verified NISP Outputs (England)	*2005 - 2013*	*5-Year Persistence*	*Investment per unit of output*
Additional Sales	€251 M	€1,255 M	3.6 cent per € income
Cost Savings	€257 M	€1,285 M	3.6 cent per € income
Jobs Created	10,000	N/A	N/A
CO_2 Saved	8 Mt	42Mt	74 cents per t
Water Saved	15 Mt	73Mt	43 cents per t
Waste Diverted from Landfill	9 Mt	47Mt	67 cents per t
Hazardous Waste Eliminated	420 kt	2Mt	€14.99 per t
Virgin Material Saved	12 Mt	60Mt	53 cents per t
Private Investment Leveraged	€380+ million	N/A	N/A

Source: Lombardi and Laybour, 2015, p.21

According to Rachel D. Lombardi and Peter T. Laybourn there are three success factors of NISP (Lombardi and Laybourn, 2015): an extensive network of organizations; expert practitioners dedicated to facilitating the opportunities; a fit-for purpose data management system.

NISP methodology is organized into four main phases (Gibbs, 2009).

1) *Awareness Raising and Recruitment*: in this first step a range of means have been used to raise business awareness to become involved in the industrial symbiosis activities, such as leaflets and an on-line promotional video. Regional synergy workshops are held periodically with interested businesses. During the these workshops, details of successful case studies and the potential benefits of the industrial symbiosis are introduced. Attendees from companies are required to fill in the resource/waste available information, and exchange the information with others to identify the potential to co-operate with other businesses. Following these workshops the regional co-ordinator and steering group members work with the identified businesses to achieve synergies.

2) *Data Collection*: in this second step quantitative and qualitative information on material/energy flows of the participating companies in workshops are collected by NISP. These data are confidential and are stored into SYNERGie Management System a special designed information database which enables NISP to identify potential synergies at the regional scale.

3) *Analysis and Identification of Synergies:* in this third step the database is used to process input information, and then generate the matching of supply to demand in the

network based on analysing each company's needs in terms of the supply and demand for materials, resources and facilities.

4) *Implementation and Support*: in this fourth step specialists help companies to identify potential technical, financial barriers and solutions. Implementing industrial symbiosis at a regional scale with the assistance of a coordinating body. Although the ICT database can be useful in identifying potential symbiosis and exchanges, face to face communication and direct engagement with companies is still crucial.

It is important to highlight that the International Synergies stresses in particular the key role of the industrial symbiosis practitioners in order to facilitate all stages of a synergy: building the industrial symbiosis Network; carrying out quick wins workshop; resource mapping: utilizing SYNERGie Management System; facilitating synergy: implementing synergy and output Laybourn, 2011).

In the end, it's important to notice that NISP has been identified by the European Commission as the most effective resource efficiency policy amongst 120 reviewed worldwide (COWI, 2011). NISP was cited as best practice under the EU Waste Framework Directive (European Commission, 2009) and incorporated as best practice in the Resource Efficiency Flagship Initiative (European Commission, 2011a), part of the Europe 2020 growth strategy for Europe whose vision is a smart, sustainable and inclusive Europe (Lombardi and Laybourn, 2015).

The ENEA experiences of Industrial Symbiosis in Italy

From 2011 to 2015 ENEA (National Agency for New Technologies, Energy, Sustainable Economic Development) has developed and implemented two projects of industrial symbiosis in Italy, where wide areas were involved through a network approach: *Eco-innovation* in Sicily; *Green-Industrial Symbiosis* in Emilia Romagna.

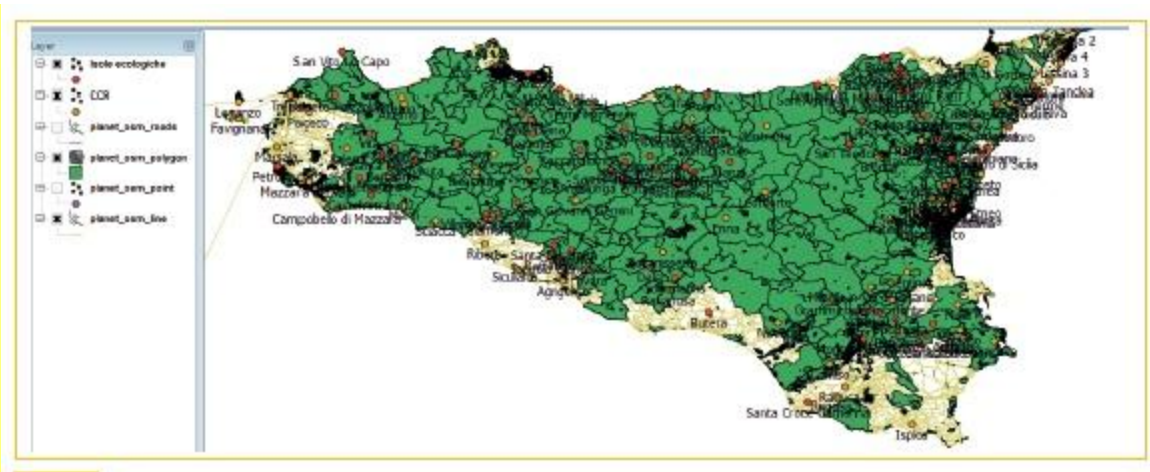
The project *Eco innovation* in Sicily started in May 2011 with funding from the Italian government (art.2- c.44, Italian Stability Law 2010). The project aimed to facilitate the promotion of coordinated projects in the field of environmental protection and industrial development of Southern Italy. Namely, the project focused on developing eco-innovation technologies and methodologies in two strategic sectors in the national and Sicilian contexts: recycling industry; sustainable tourism with a pilot project in the Egadi islands. All activities carried out by ENEA followed a holistic approach, through a strong co-operation with the main industrial local stakeholders, particularly SMEs, as well as the

Regional and Local public Authorities (Repubblica Italiana 2009; Markianidou 2014; OECD 2014; Peronaci at al., 2014).

The project also aimed at creation of the first regional platform of industrial symbiosis in Sicily: *Symbiosis* (www.industrialsymbiosis.it) (ENEA, 2016). The goals of this platform were (Cutaia et al., 2015b): to provide a methodology and an instrument for industrial symbiosis implementation at regional scale; to implement a IS Platform as a support to SMEs to individuate symbiosis opportunities in the region. The idea was to create a tool enabling companies in sharing resources (materials, energy products, water, services and expertise) and able to offer other operational tools (regulation and BAT databases, quick LCA and Eco-design tools, etc.) to companies and stakeholders cooperating and using that platform (Cutaia et al., 2014a, 2015d).

The methodology included several activities for platform operation (Cutaia et al., 2014a, 2015a, 2015b): design and the implementation of the platform architecture, ICT and database tools; network activation and promotion activities by means of stakeholders involvement at regional level (in Sicily) and at national and international level; analysis of productive sectors in the Region and realization of a broad database (DB) of companies in Sicily; operative meetings finalized to involve companies in the project, to have from them input-output related information, looking for potential synergies.

Figure 3.11. GIS interface in ENEA Industrial Symbiosis Platform



Source: Cutaia et al., 2014b, p.79

Regarding the *ENEA Industrial Symbiosis Platform architecture,* the Industrial Symbiosis Platform is based on a Central Manager (at the moment ENEA itself) and on an integrated system of an ICT and DBs tools for the management of singles users (companies), their data (even on shared resources), and the connection between all those information (including synergies that can be found between users). In this platform there is a GIS system (see Figure 3.11), where many different databases can be uploaded. One of these databases is related with registered companies, which, through the website can upload their general information (name, address, activity sector and so on). Doing this the GIS system can localize registered companies in the map. Then companies can go further and look for cooperation in terms of industrial symbiosis potential. In order to look for industrial symbiosis potential registered companies can become associated companies, providing their own information about inputs and outputs they want to share within the industrial symbiosis network. In this way, users are encouraged to go from the registered company level to the associated one, in order to be allowed to use all the tools provided by the platform (queries, DBs, industrial symbiosis matching). The relation between associated companies, their own input-output and possible synergies among companies goes through a connection string, named <origin, destination> which links one output with its potential productive destination sectors. These <origin, destination> strings are uploaded in a specific database, which can be updated according to new case studies and know-how coming not only from the central manager but also, and hopefully, from the network (Cutaia et al., 2014a).

The information about resources is collected using Input-output tables (see Figure 3.12) (Cutaia et al., 2015b). ENEA input-output table foresees a taxonomy for the inventory of input-output data of companies, taking into account "materials, energy, services, skills" as resources and using code systems officially used in Italy (according EU regulation) for different kind of inventories (e.g. Nace codes, ATECO codes, ProdCom, EWC) with which companies normally deal with (Cutaia et al., 2015d).

Figure 3.12. Input-output data collection table

OUTPUT / INPUT	Resource (description)	Resource (trade name)	Resource (type 1)	Risorsa (if type 1-a)	Resource [CER - if waste]	Resource [ProdCom - if by-product]	Resource [NACE - if skill or service]	Availability of resource	quantity	unit	notes
output			a) material	waste	01 01 02 rifiuti da estrazione di minerali non metalliferi			batch			
output			b) energy	by-product		07100000 estrazione di minerali metalliferi ferrosi		yearly			
input			c) service				A1.1.5 - Growing of tobacco				
input			d) skill				A2.4.0 - Support services to forestry				

Source: Cutaia et al., 2015b, p.1524

Concerning *network activation and promotion activities*, several activities were launched for network activation. These initiatives were addressed to enterprises, authorities and stakeholders, with the aim to involve and sensitize them on IS environmental and economic benefit, on project developments and so on, both at regional (in Sicily) and at national level. For sensitization and dissemination purposes, in 2011 ENEA registered the domain www.industrialsymbiosis.it and other equivalents and more in general, the reference website for the promoted activities. At national level ENEA organized, starting from 2012, at Ecomondo Exhibition a series of national Conferences on the theme of industrial symbiosis aimed at collecting all the experience made on this topic by different institution and researchers and at sensitizing all political and institutional stakeholders in order to allow applications overcoming regulatory procedural barriers. In 2015 ENEA established the first Italian Industrial Symbiosis Network (SUN: Symbiosis Users Network; www.sunetwork.it). This network aims at being the Italian reference point in the field of Industrial Symbiosis through the support of scientific/research bodies as well as the participation of operative stakeholders (companies and institutions) and the cooperation with the General States of the Green Economy. Local stakeholders' involvement is carried out through contacts with Sicilia Region (Regional waste Agency), meetings and specific framework agreement signed between ENEA and Confindustria Sicilia (Sicilian association of Industrials) and ENEA and University of Catania (Cutaia et al., 2015a)

About a*nalysis and database of the Sicilian industries* the Platform operates with the cooperation of companies (associated users) who have the core information needed for implementing the industrial symbiosis: data on outputs they have or inputs they want to have. Companies' involvement can be on-line, through the website or on-site, with specific meetings. In order to know and understand the Sicily's productive system, a DB containing information on more than 2000 companies was developed collecting data from regional productive districts, chambers of commerce, industrial associations and companies' web sites. Starting from this comprehensive DB, groups of heterogeneous companies were selected and invited to take part to operative meetings (Cutaia et al., 2015e). The main information collected into the database was: geographic localization, name of the company, name of the owner, productive sector, number of employees and contact details (email and phone). The productive sectors were represented by the classification of economic activities ATECO (ISTAT, 2009) or NACE (EUROSTAT, 2008) codes. Companies listed in the compiled database are representative of part of the overall companies operating in Sicily, with a particular focus for the provinces of Catania, Siracusa (where operative meetings were held). Starting from this DB an analysis of productive sectors and an evaluation of quantity and dimension of companies were made to identify the most productive areas in the region with a sectors diversification more suitable for the organization of operative meetings to begin symbiosis paths. Then, considering sectors, employees and location, groups of heterogeneous companies were selected and invited to take part to operative meetings aimed at sharing information about resources flows and wastes and looking for potential synergies. All the sectors were considered to contact companies in order to have a diversified composition. A threshold value on the number of employees has been fixed. This value varies according to the business sector (Cutaia et al., 2015b).

Regarding *operative meeting* they were three in Sicily: two in Syracuse (March 28th and November 4th 2014) and in Catania (October 24th 2014). Companies and delegated participating as well as shared resources and identified potential synergies are listed in Table 3.3 (Cutaia et al, 2015c). Collected data were loaded on the ENEA IS platform (Cutaia et al., 2015a, 2015b), were georeferenced and have suggested new synergies in addition to that emerged during the working groups of all three locations in Sicily. In the case of the round table of Syracuse 2 there were no synergies, data recorded were included in the platform so that it can be processed again for further synergies.

Table 3.3: Operative meetings held in Sicily in 2014. Summary of results.

	COMPANIES	DELEGATES	SHARED RESOURCES	POTENTIAL SYNERGIES IDENTIFIED DURING MEETINGS
SIRACUSA 1 (28/03/2014)	36	44	+200	+160
CATANIA (24/10/2014)	36	42	+200	500
SIRACUSA 2 (4/11/2014)	11	12	29	0

Source: Cutaia et al, 2015c, p.2

Resources are classified as: materials; energy; expertise or consultancy and service; logistics and transports; land; capacity and equipment. Data collected from the operative meetings are listed in the following tables for each category of resource. Materials and Expertise are the categories with higher shared resources (see Table 3.4).

After the meetings ENEA made a selection of the most interesting potential synergies, or group of synergies, based on the number and amount of shared resources. Because of the scale of the project ENEA chose to focus on two categories of resources:

agro-industrial waste; construction and demolition wastes, residues of ornamental stone processing and other residue to be utilized in construction field. For each one of these selected synergies specific operative handbooks have been prepared. In particular ENEA collected, analyzed and systematized information on technical, regulatory, logistic, economic and other issues influencing the possibility to actually realize the proposed synergy, as well as quantities of materials or other resources involved In July 2015 ENEA organized in Catania a further consultation meeting with companies involved in these handbooks. This meeting aimed to discuss all aspects contained in these operative handbooks and to update these ones with the information obtained by companies.

Table 3.4. Resources shared during the meetings and potential matches

Resources	*Siracusa meeting (%)*			*Catania meeting (%)*		
	input	*output*	*matches*	*input*	*output*	*matches*
Materials	52	129	88	34	124	267
Energy	6	4	7	5	4	36
Expertise, consultancy, services	28	74	61	32	43	164
Logistic, transportations	1	9	6	3	3	5
Land, capacity	1	2	2	2	5	13
Equipment		1	1	15	8	44
Total	88	219	165	91	187	529

Source: Cutaia et al., 2015b, p.1529

In the end it is important to note that ENEA Industrial Symbiosis Platform cited as *selected eco-innovation areas and new trends* and Ecoinnovation Sicily as *Good practice examples* in *Eco-Innovation Observatory- EIO. Country report 2014. Eco-innovation in Italy* (Markianidou 2014). The whole project was also indicated as greening industry policy in *OECD Science, Technology and Industry Outlook 2014* (OECD, 2014).

Green-Industrial Symbiosis project in Emilia Romagna region. In the Green Industrial Symbiosis was the first industrial symbiosis pilot project in the Emila Romagna (see Figure 3.12) organized by Unioncamere Emilia-Romagna and ASTER. Enea was the technical and scientific coordination. Another scientific and technological expertise was the Emilia Romagna High Technology Network.

The main objective of this project was the development of cross-relations between production sectors, industrial research and territory and boosting circular economy. It focused on the chain of reuse and enhancement of agro-industrial waste and residues, with particular (but not exclusive) interest towards solutions aimed at the production of materials with high added value. The green Industrial symbiosis was implemented along the following steps: phase I, 05.2013 – 03.2014; phase II, 10. 2014 – 10.2015. Main steps of the project were: selection of companies and research laboratories (13 companies and 7 laboratories); organization of a Focus Group (10 participating companies); filling-in input-output tables for sharing information on resources used and waste/by-products generated by the production processes (the tables already used by Enea in the Industrial Symbiosis platform in Sicily); association of codes to each company and resource for the privacy; providing indications about how to valorise resources shared by companies; suggesting technologies and valorisation processes for a productive reuse of industrial scraps using the ENEA's know-how and tools (<origin-destination> string's logic); ENEA processing data in order to identify potential synergies between companies; showing results to companies and laboratories in order to have their feedback and their actual interest; an further data elaboration according to feedback given; showing final results of project in a meeting with other also regional stakeholders.

Figure 3.12. The geo-location of companies involved in the project

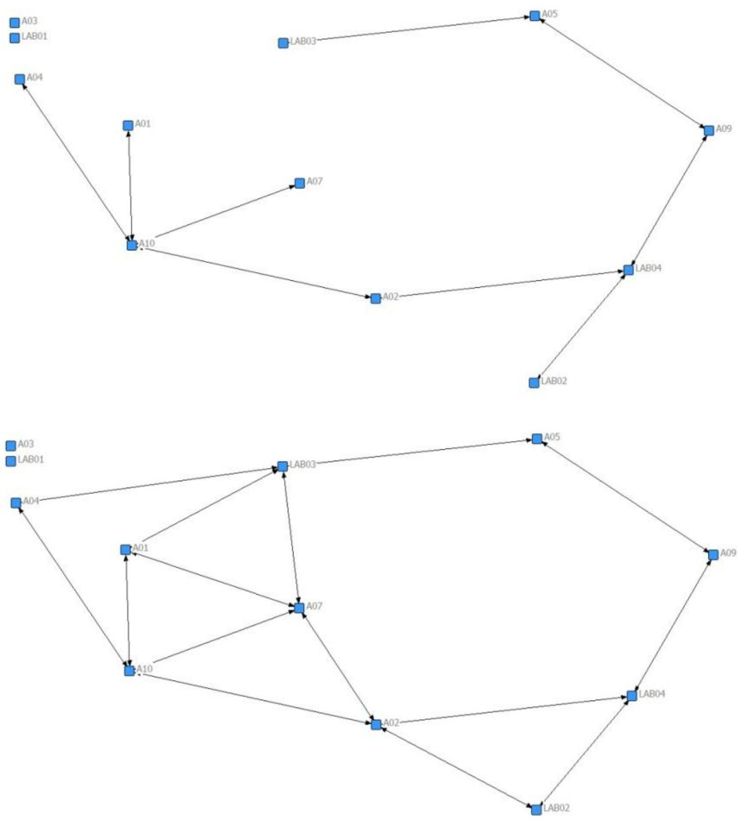
Source: Cutaia and Scagliarino, 2014c, p.9

At the end of the first phase of the project eight main resource flows (agro-food scrap, industrial lime, packaging, building construction and demolition waste, textile waste, oil refining and natural gas purification waste, waste of woodworking, digestate) and almost 90 potential synergies both between the 10 participating companies and between these and other companies located in the surrounding area were identified.

During the second phase the most interesting synergies identified during the first phase were selected, in order to go from the identification of potential synergies to its actual implementation. In particular, 3 paths of industrial symbiosis were chosen, in which waste food industry outputs were destined to three different types of exploitation (production of biopolymers, nutraceuticals, energy recovery). Regulatory, technical, logistical and economic issues have been examined and reported in three Operational Manuals for each industrial symbiosis pathway identified. Later each manual has been given to the companies involved in the symbiotic path.

It's interesting to highlight that the methodology used in the *project Green - Industrial Symbiosis* has impacted in positive way on information obstacles reducing the difficulty in finding other companies with which to realize the industrial symbiosis; and on the creation of new partnerships and business networks fostering in general a strengthening of territorial cohesion (see Figure 3.13) in the particular geographic space where it was made (Cutaia, 2015e; 2015f; Iacondini et al, 2014).

Figure 3.13. Inter-firm network before and after the project Green-Industrial Symbiosis



Source: Cutaia et al., 2015f

Chapter 4

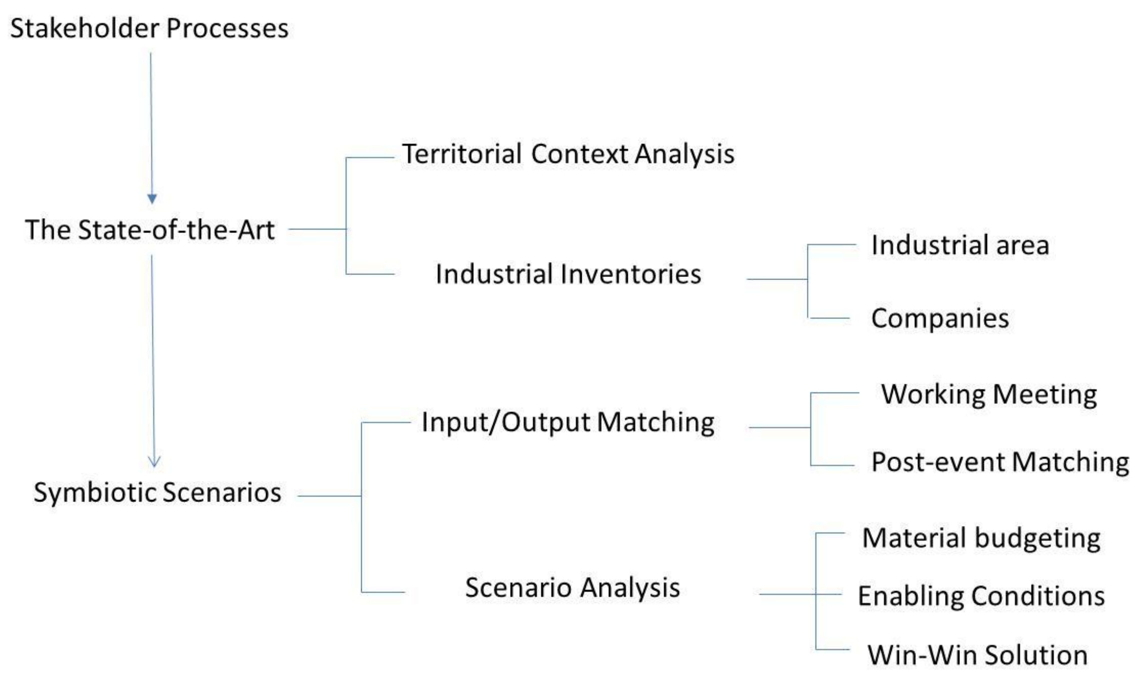
Methodology

In the fourth chapter I explain the methodology used to verify whether some industrial symbiosis pathways can be implemented in the industrial area of Rieti-Cittaducale. At first I describe the research methodology used. It is mainly based on three steps: carrying out a stakeholder process; representing the state-of-the-art of the territory; and identifying possible symbiotic scenarios in the industrial area. After I show how this methodology was applied to the industrial area of Rieti-Cittaducale.

4.1 Research methodology

In order to verify whether industrial symbiosis pathways can be implemented on an industrial area the following research methodology can be applied (see Figure 4.1).

Figure 4.1. Pathway for identification of industrial symbiosis



A methodology based on three main steps was used to achieve this goal:

1) carrying out a *stakeholder process;*
2) representing a *state-of-the-art* of the territory;
3) identifying some possible *symbiotic scenarios* in the industrial area;

Some tasks are based on the tools indicated by Marian Chertow in her works (stakeholder processes, industrial inventories, input/output matching and materials budgeting) which are presented in first chapter of this thesis.

Regarding the *stakeholder processes* it aims to promote awareness processes and active participation of the various stakeholders in the symbiosis pathways and to identify shared choices among different actors at local level.

Throughout the period of activity, managing institution of the industrial area and the companies located in the productive site need to be involved and periodically informed. During this step key issues are:

- with regard to the managing institution of the industrial area, to organize meetings in order to explain the objectives and activities to be carried out in the area for the implementation of industrial symbiosis and to conclude a collaboration agreement. Then managing institution appoints some of its representatives to support the activities to be carried out in the industrial area. Finally it is key that there is a regular information, communication and sharing of objectives and activities to be performed in the area during the different steps to achieve industrial symbiosis;
- with regard to companies located in the production site is important to explain to them the objectives and activities related to the initiative industrial symbiosis to carry out in industrial area; to push them to participate in the meeting in order to identify the input / output matches among different companies. Finally it is also crucial that respect to the potential synergies identified, companies are involved and take part actively to the identification of potential synergies to be implemented in order to identify and possibly overcome any issues with their collaboration.

It is important to emphasize that this process lasts for all steps of pathway for industrial symbiosis implementation.

As regards the *state-of-the-art* of the territory it describes the main qualitative and quantitative characteristics of the area which is the subject of research. it is based on mainly two tasks:

- a meso-territorial analysis through a *territorial context* analysis;
- a micro-territorial analysis through an *industrial inventories.*

A *territorial context analysis* focuses on the region where the industrial area is located. It is based on mainly the following issues:

- geography:
- population;
- infrastructure;
- economy;
- waste management;
- green economy and industrial symbiosis.

In order to highlight the main features of a region quantitative and qualitative tools are used. Regarding quantitative analysis bases mainly on a description from a uniform-abstract point of view comparing the region where the industrial area is located with other ones. For this purpose it uses statistics on territorial scale also obtained by new elaborations on secondary data collected in databases, reports or documents. Qualitative analysis mainly bases on international, national, local documents, acts, directives, regulations, guidelines and position papers issued by public or private actors.

The *industrial inventories* of industrial areas focus on two points: managing institution of the industrial area and companies located in the production site. To drew up the industrial inventories are based on two types of analysis as well: a qualitative analysis to do through documents and reports, web sites and formal and informal conversations about industrial area; and a quantitative analysis to do through local databases. A key issues is to create a database of companies. To create this one it is important that:

- companies database of the industrial area is requested at the managing institution;
- in this database are picked some fields;
- the company database is integrated also through the inclusion of other fields using other databases, web mapping and websites of individual companies;
- the company database is also integrated and updated through researches at the archive of the managing institution venues;
- the new companies database is geo-referenced using a geographic information system.

With respect to the *symbiotic scenarios*, they aim to identify, analyze and evaluate the potential of the industrial symbiosis paths in an industrial area. This is based on two tasks:

- an *input/output matching*;
- a *scenario analysis*.

Regarding *input/output matching* it aims to find matches between the demand and the supply of resources among companies. It is based on:

- *meeting* with companies;
- *post event matching*.

As regards to *meetings* organization we could distinguish two phases:

a) Pre- meeting;

b) Meeting

c) *Post-meeting*:

Pre-meeting organization is based on:

- engaging companies;
- logistics and tools for meeting.

In order to engage companies the following steps should be followed:

1) to select companies to be invited at meetings;
2) to send an invitation email to selected companies containing a short explanatory text about industrial symbiosis initiatives and a booking request by an expiry date through its company delegate;
3) after the booking expiry date:
    - in the event that a company does not respond to call this company by telephone to make sure that he received invitation emails;
    - for companies booked, to send an email to company delegate in order to fill out input-output table to be returned it before the meeting;
4) to send the meeting agenda to companies booked.

For the logistics and tools for meeting the tasks are the following:

5) to establish the date, the venue, the title and the agenda of the meetings;
6) to prepare the necessary tools to carry out the activities planned in meetings.

Regarding the *meeting*, it is based on the conduct of the activities planned on the agenda aimed at the collection of companies data through input-output tables.

Concerning the *post-meeting* it is based on:

- to set the data collected during meeting;

- to send mail to each company delegate which he has participated so that he can check his data and to be inform about some main outcomes obtained during the meeting.

As regards *post-event matching*, it concerns the analysis of the input/output table of all companies participated at the meetings in order to identify new matches.

Scenario analysis aims to identify possible industrial symbiosis pathways in industrial area. It is based on three tasks:

- *material budgeting*;
- *enabling conditions;*
- *win-win solutions*.

Regarding the *material budgeting* it is focused on analyzing data collected; integrating this data through additional information from the companies; drawing the resources flows between companies.

Regarding *enabling conditions* it's a step that is carried out simultaneously with material budgeting. This is focused in identifying the main factors that promote synergies. It bases on thematic analysis, information obtained from the companies or from experts in the field; or information collected on the industrial area.

Through this last two stages, most of the issues that can hinder a synergy can emerge and eventually be brought to the attention for clarification. In this way the matches identified at the input / output matching step are selected as potential synergies.

As for *win-win situation*, the possible synergies are identified through economic and environmental analysis and assessment. The economic assessment is based on a profitability analysis of synergies both for the companies involved and for the industrial area. The environmental assessment is based mainly on European waste hierarchy.

In this way possible pathways in the industrial area of Rieti-Cittaducale are identified in case both of the following conditions are met:

- at least two companies (one in input and one in output) obtain potential economic benefits;
- there is an improvement (or not a worsening) in waste management hierarchy.

4.2 Methodology applied to the industrial area of Rieti-Cittaducale

The main objective of this research was to verify whether industrial symbiosis pathways could be implemented in the industrial area of Rieti-Cittaducale, managed by Consorzio di Sviluppo Industriale della Provincia di Rieti (Consortium for industrial development of the Province of Rieti). In order to achieve this goal, in my research I have carried out the following methodological steps.

Stakeholder processes. Stakeholder processes in industrial area of Rieti-Cittaducale lasted from July 2014 to May 2016. They have involved:

- Consorzio di Sviluppo Industriale della Provincia di Rieti, the managing institution of the industrial area;
- companies located in the industrial area.

It's important to remember that during the XXVIII cycle of the PhD in Economia e Territorio (Economics and Local Development), the Tuscia University of Viterbo created a collaboration with ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) on topics concerning "Tecnologie ambientali per lo sviluppo sostenibile del territorio" (Green technologies for a sustainable local development) (Università degli Studi della Tuscia, 2013). The purpose of this collaboration was to study, analyze and assess the territorial impact of possible industrial symbiosis pathways in a circular economy. Through these agreement, the Tuscia University provided theoretical and methodological tools to support advanced analytics in the fields of local development and use of resources. ENEA is the leading research institution in Italy on issues related to industrial symbiosis and circular economy, having written numerous publications on these subjects and being promoter of numerous and significant national and international initiatives on these topics (ENEA, 2016).

With regard to Consorzio di Sviluppo Industriale della Provincia di Rieti, in the first stage two meetings were organized with its President Mr. Andrea Ferroni:

- one on 25 July 2015 at ENEA Research Center Casaccia (Rome);
- another one on 12 November 2015 at the headquarters of Consorzio di Sviluppo Industriale della Provincia di Rieti in the industrial area of Rieti-Cittaducale.

During the former meeting, the objectives and the potential benefits that could be achieved from implementing industrial symbiosis pathways in an industrial area were explained. A first proposal of activities en titled “La simbiosi industriale come opportunità di sviluppo del territorio reatino” was also presented. During the latter meeting, some issues were examined in depth, and a draft operational plan about the possible activities to be undertaken in the months following in the industrial area was presented to the Consortium. At the conclusion of this meeting it was decided to start a collaboration agreement among the Consortium, the Tuscia University and ENEA to verify, by means of an empirical research, whether industrial symbiosis pathways could be implemented in industrial area of Rieti-Cittaducale.

Following this meeting, on 14 November 2015 Tuscia and Enea jointly sent a formal letter to the Consortium entitled “Collaborazione fra Consorzio per lo Sviluppo Industriale della Provincia di Rieti, Università della Tuscia e ENEA per Dottorato di Ricerca" and the Consortium appointed two representatives to support this industrial symbiosis initiative (Mr. Marco Mostarda and Mrs Rosalba Rosati).

During the activities carried out in the industrial area there were many and continuous contacts with the President, the representatives of the consortium and other employees of the consortium to get more information on the industrial area, for updates on the activities carried and to organize the various activities in the area. these aspects as well as the involvement of the companies located in the production site of Reiti-Cittaducale will be better presented in the following sections.

State of-the-art of the territory. As regards the state-of-the-art of the Rieti territory it lasted from 14 November 2014 to 3 May 2015. For this step:

- I analyzed *territorial context* of industrial area of Rieti-Cittaducale;
- I drew up an *industrial inventories* of industrial area of Rieti-Cittaducale.

Concerning *territorial context analysis* of industrial area of Rieti-Cittaducale, I focused mainly on the province of Rieti, partially on Lazio region as well. I mainly analyzed the following issues: physical and political geography; population (residents and density population); demographic trends; infrastructures (transport and social infrastructures); economy (economic trends); production structure; industrial areas; waste management: regional and local waste management plan; green economy and industrial symbiosis (trends, guidelines and position papers).

I mainly based my quantitative analysis on the comparison of the province of Rieti with other provinces of Lazio: Frosinone, Latina, Rome, Viterbo; Lazio region; and Italy. To this purpose, I used statistics on territorial scale obtained by my elaborations on secondary data collected in databases (ISTAT) or reports (ISPRA, Rieti Chamber of Commerce and Istituto G. Tagliacarne, Unioncamere Lazio) or documents (Lazio Region).

I based my quantitative analysis mainly on documents, acts, directives, regulations, guidelines and position papers of European (European Union, European Court of Justice), national (Bank of Italy, Italian Republic; Italian Competition Authority), regional (Lazio Region) and local (Consorzio per lo Sviluppo industriale della Provincia di Rieti, Province of Rieti, Province of Viterbo) entities, public administrations partnerships (Cartesio Network) and agencies (Invitalia).

I drew up an *industrial inventories* of industrial area of Rieti-Cittaducale based on:

- a qualitative analysis through documents and reports on productive site, the Consortium web site (http://www.consorzioindustriale.com/), companies' web sites and informal conversations with the offices of the Consortium;
- a quantitative analysis through a geo-referenced Consortium companies database. To do this:
  a) I requested the companies database of industrial area of Rieti-Cittaducale at Consortium;
  b) I picked some fields from the database of the Consortium companies (for each company: consortium archive number; company name; legal form; municipality, street address and phone number production site; municipality, street address and phone number registered office, certified mail, company email, web site, date of settlement, commencement of business operations, Ateco[24] 2002 class, Ateco 2007 section, Ateco 2007 class, class Ateco 2007 description, employees);
  c) I integrated the database by including other fields (latitude and longitude production site, date of incorporation, vat number, chamber of commerce number, revenue from sales, net income, total assets, employees from AIDA database, income statement, balance sheet, economic and financial indices) using other databases (AIDA, ISTAT), web mapping (Google Maps; Google Earth) and websites of individual companies;

[24] The classification of economic activities ATECO is a type of classification adopted by the National Institute of Italian Statistics Institute (ISTAT) for national statistics surveys of economic nature. It is the Italian translation of the Nomenclature of Economic Activities (NACE), created by Eurostat, It was adapted by ISTAT to the specific characteristics of the Italian economic system. ATECO 2007 version is currently in use in Italy. NACE rev. 2 version is currently used by Eurostat.

d) I integrated and updated the database through research in the archive of the Consortium headquarters. To do so, I worked in the archives of the consortium with the support of Mr. Marco Mostarda for 6 days: 11 and 12 December 2014; 28 and 29 January 2015; 11 and 12 February 2015; 24 March 2015.

e) I geo-referenced the new Consortium companies database using a geographic information system (QuantumGIS).

Following are the main results about territorial context analysis of industrial area of Rieti-Cittaducale, an industrial inventory of the industrial area of Rieti-Cittaducale was developed.

Symbiotic scenarios. Identification of possible symbiotic scenarios in the industrial area of Rieti-Cittaducale lasted from 4 May 2015 to May 2016.

Regarding *input/output matching* it lasted from 4 May to 29 November 2015. With support of Consorzio per lo Sviluppo Industriale della Provincia di Rieti, Tuscia university and ENEA I organized two *meetings with companies* of the industrial area:

- the first meeting was 25 June 2015;
- the second meeting was 11 September 2015.

It's important to highlight that the second meeting was not initially programmed. It was organized on demand of the President of the Consortium after the first meeting results.

The first pre-meeting organization lasted from 4 May to 2 August 2015, the second one from 3 August to 10 September 2015. In order to engage Consortium Companies followed these steps I selected in new consortium companies database some companies to be invited to meetings. I based it on two criteria in order to select consortium company to be invited:

- Ateco 2007 (Nace rev.2) sections: A, B, C, D, E; some classes of F, G, I, N and P; some companies in H section.
- Active companies.

It's important to note that before sending the invitation emails to the companies selected, it was decided that Consortium sent an its information email to these ones about future industrial symbiosis activities in industrial area[25]. Specifically from 19 May to 10 June 2015 the Consortium sent the invitation email for the first meeting to each company; from 5

[25] These emails were sent by Marco Mostarda through his own consortium email account with my university e-mail in copy.

to 6 August 2015 the invitation were sent for the second meeting[26]; after that I sent an invitation email[27] to selected companies, containing a short explanatory text about the meeting, a booking request and an attachment explaining industrial symbiosis. Specifically, from 21 May to 10 June 2015 I sent an invitation email to companies' certified email and eventually to company email for each firm selected for the first meeting; on 19 August 2015 I sent an invitation email to the company email addresses for each company selected for the second meeting. The name of a company delegate, his/her email address and his/her telephone number was necessary for booking a company. It's important to note that during the second pre-meeting organization, a specific email was also sent to company delegates that participated in the first meeting to inform them about the organization of a second meeting and give the possibility to join if they wished[28].

After the booking expiry date, whenever a company had not already responded negatively, I called the company by telephone to make sure that the emails had been received. If needed, I sent the two emails once again. Specifically, I followed these steps from June 3 to 23 June 2015 for the first meeting; from 24 August to 9 September 2015 for the second meeting.

I used the following criteria to determine the order of priority for calling to firms:

- number of company for ATECO 2007 (Nace rev. 2) section (from the largest to the smallest);
- total assets (from largest to smallest) and/or number of employees (from largest to smallest);
- the difficulty to contact the production site (from easiest to hardest).

Regarding companies booked, I sent an email to their delegate to thank own company and request some data[29]. In this email in fact the following attachments were added:

- ENEA input-output table in Excel format;
- ENEA PowerPoint presentation on ENEA input-output table.

In the email I requested them to view and to fill in the ENEA input-output table in advance and to re-send this completed table by e-mail within an expiry date in any case before meeting. Specifically, I have sent e-mails to company delegates: from 15 June 2015

[26] We changed from company certified mail to company mail because it was more effective to invite consortium company.
[27] The emails were sent from my university account with Marco Mostarda's consortium email in copy.
[28] This email was sent on 19 August 2015.
[29] In the event that the companies booked could not communicate a name for their company delegate before their meeting the emails were sent to their company email.

for the first meeting; from 25 August 2015 for the second meeting. In the event that a company did not return the input-output table within the deadline, I called it by telephone to check the reason.

Before the meeting I sent the agenda to companies booked. Specifically from 23 June 2015 for the first work meeting; from 7 September 2015 for the second work meeting.

Fig.4.1 Corriere di Rieti's article on meeting 25.06.15

Al Consorzio industriale tavolo di lavoro per le imprese organizzato dall'Enea

Percorsi di simbiosi per essere più competitivi

▸ RIETI

Si tiene questa mattina, al Consorzio industriale di via dell'Elettronica snc, alle 9.30, il tavolo di lavoro "Economia circolare e simbiosi industriale - Percorsi operativi per le imprese dell'Asi di Rieti", organizzato dall'Enea e dall'università degli studi della Tuscia in collaborazione con il Consorzio per lo sviluppo industriale della provincia di Rieti. Il tavolo di lavoro è rivolto alle imprese dell'area industriale e mira a creare opportunità per condividere risorse e attivare una rete per favorire percorsi di simbiosi industriale per generare vantaggi competitivi delle imprese coinvolte, ottimizzare l'uso delle risorse, ridurre gli impatti ambientali. Ai lavori prenderanno parte più di 30 delegati in rappresentanza di quasi 30 aziende. Esperienze similari sono state già realizzate dall'Enea in Sicilia e in Emilia Romagna, riscontrando grande successo tra le imprese.

Il tavolo di lavoro si tiene questa mattina al Consorzio industriale

Source: Corriere di Rieti, 2015

Fig. 4.2. Il Messaggero's article on meeting 25.06.15

Imprese, unione delle risorse per il rilancio

▸Incontro all'Asi per favorire un maggiore legame tra le attività presenti nel territorio

L'INIZIATIVA

Un futuro di rilancio con unione di tutti gli attori in campo. E' quanto emerso dal tavolo di lavoro sull'economia circolare e la simbiosi industriale che si è tenuto all'Asi di Rieti. «La simbiosi industriale - si sottolinea - è una importante strategia di ottimizzazione dell'uso delle risorse che, in una prospettiva di green economy, coinvolge industrie tradizionalmente separate. Il tutto per generare vantaggi competitivi per le imprese, attraverso il trasferimento di materia, energia, acqua e sottoprodotti tra le aziende coinvolte». L'iniziativa è stata organizzata dall'Enea - Unità tecnica tecnologie ambientali e dall'Università della Tuscia, in collaborazione con il Consorzio per lo sviluppo industriale della Provincia di Rieti. Ad aprire i lavori, il presidente del Consorzio, Andrea Ferroni, seguito da Silvio Franco dell'Università della Tuscia e da Laura Cutaia dell'Enea.

I SETTORI

Alla giornata hanno preso parte 18 imprese dell'Asi reatina di diversi comparti produttivi (elettronica, farmaceutica, meccanica, alimentare). I delegati delle aziende sono stati coinvolti in tavoli di lavoro moderati da Marco La Monica, dottorando dell'Università viterbese e da Erika Mancuso dell'Enea. Dai primi risultati, è emerso che le aziende presenti hanno messo in condivisione più di 72 risorse (materiali, servizi, sottoprodotti energetici e logistica) e, attraverso il confronto tra le aziende, sono state individuate più di 38 possibili sinergie, a cui andranno ad aggiungersi quelle che verranno individuate successivamente dall'attività di ricerca dell'Enea e dell'Università della Tuscia. «Le imprese presenti - conclude una nota - hanno manifestato un particolare interesse e consenso verso l'iniziativa».

Source; Il Messagero, 2015

The day before the first meeting Consortium sent an email to the companies booked to thank them for their cooperation and issued a press release about meeting. These activities were carried out at the conclusion of the first meeting as well (see Figures 4.2 and 4.3).

In order to arrange logistics and tools for the meetings, I mostly relied on the ENA methodology.

It was first established the date, the venue, the agenda and the title of meetings with the Consortium, Tuscia university and ENEA. It was decided to carry out both the meetings at the conference hall of Consortium headquarters in the industrial area of Rieti-Cittaducale from 09.30 to 13.00. The first meeting was on June 25th, 2015, while the second was held on September 11th. The title of the meeting was *Economia circolare e simbiosi industriale - Percorsi operativi per le imprese dell'Asi di Rieti* (see Figure 4.4).

Fig.4.4. Meeting front page

The two meeting agenda (see Figure 4.5) were divided in the same way:

a) welcome coffee and registration of delegates;
b) speeches from invited speakers;
c) round table with Consortium companies;
d) first results and next steps.

Fig. 4.5. Meeting agenda

The welcome coffee and the registration were organized in a room before the conference hall. The welcome coffee was offered by the Consortium to companies' delegates; the registration desk provided delegates with a registration card where they had to note their name, surname, email address, telephone number and signature.

One completed the registration, a badge and a folder were given to corporate delegates[30]. Their own full name, company name and an company identification code was reported on badge of each company delegate. Within each folder there were a front page, an agenda of the day, a confidentiality charter; two empty input/output tables forms[31] (see Figure 4.6); a feedback form; facilitator emails; a list of the companies' delegates; a summary report

[30] A badge with their own full name and the name of own organization had been given to three speakers, two practitioners and to Marco Mostarda of Consortium that has supported activities carried out.
[31] For companies that had already filled out ENEA input/output table in Excel format in advance and sent it via email the same printed table was given to the company delegate.

about one of the meetings for industrial symbiosis held by in in Sicily[32]; some blank sheets and a pen.

Fig. 4.6. ENEA Input/Output table form

ENEA SYMBIOSIS

Tavolo di Lavoro - "Economia Circolare e Simbiosi Industriale - Percorsi operativi per le imprese dell'Asi di Rieti" - 25 Giugno 2015

CODICE AZIENDA:			*Scheda raccolta dati INPUT / OUTPUT*							AZIENDE INTERESSATE
n	INPUT OUTPUT	RISORSA (descrizione)	RISORSA*	RIFIUTO o SOTTOPRODOTTO	BATCH o ANNUALE	QUANTITA'	UNITA' DI MISURA	ATTUALE DESTINAZIONE	Note	CODICE AZIENDA
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										

* Specificare se la risorsa è un Materiale o un Sottoprodotto energetico o un Servizio o una Competenza o Capacità

The company identification codes had the function to ensure the data confidentiality provided by companies. This code was formed by the letter "A" followed by a number following the alphabetical order of booked companies[33].

Concerning the speeches, the speakers were (see Figure 4.7):

- Mr. Andrea Ferroni the President of Consortium about greeting delegates and introducing the event;
- Prof. Silvio Franco of Tuscia University about circular economy as a new strategy for business competitiveness;
- Eng. Laura Cutaia of ENEA about ENEA industrial symbiosis experiences[34].

[32] For the second meeting the first meeting summary report was put into the folder.

[33] In the second meeting for new business booked I decided to continue numbering by assigning numbers after the letter "A" to new businesses following always an alphabetical order.

Fig. 4.7 Invited speakers at the meeting on 25.06.2015

Regarding the round tables with companies, it took place as follows: my explanation about ENEA input/output tables in paper form and the round tables; and carrying out round tables.

On this last point, companies' delegates had to sit in two tables assigned. Each table had a different name[35] and was run by a facilitator[36].

Each facilitator had an own folder containing: a front page; a company delegate list with their own company identification codes; synergies tally where he could mark the matches of his round table and writes eventual notes; a table plan with company identification codes; a notebook and a pen.

The main tasks of each facilitator were the following:

- to manage round table;
- to support to companies' delegates;
- to facilitate the matches among the companies resources;
- to report the number of matches and of company input and output resources on synergy tally, namely a specific paper where to write that.

[34] Due to a commitment in the second meeting Eng. Cutaia could not give a speech on ENEA industrial symbiosis experiences. Dr. Grazia Barberio of ENEA gave a speech on this topic.
[35] The round table names were:"Terminillo" and "Velino" for the first meeting and "Tancia" and "Turano" for the second meeting.
[36] Practitioners were Dr. Erika Mancuso of ENEA and me for the first meeting: and Eng. Antonella Luciano and me for the second meeting.

Fig. 4.8. The round tables during the first meeting (25 June 2015)

Fig. 4.9. The round table during the second meeting (11 September 2015)

Company delegates were divided equally between the two round tables[37] (see Figure 4.8 and 4.9). This division was based on three criteria in principle:

- different Ateco 2007 (Nace rev.2) sectors o eventually classes;
- the same municipality where the productive site was located (Rieti or Cittaducale);
- different size of their companies based on total assets and number of employees.

[37] Because of the number of delegates present during the second meeting there was only one round table.

The following steps were carried out in each round table:

a) each facilitator and company delegate introduced briefly themselves and their company;
b) each facilitator explained again ENEA input/output table; c) each company delegate filled out ENEA input/out table (see figure 4.6).
   First, they noted the company identification code. Then, they listed the outputs of their company (resource name, type of resource, if it was waste o by – product, European Waste Catalogue – EWC - if output was a waste; Prodcom code if output was a byproduct; quantity, units of measure, frequency, current destination, note); and finally they filled out inputs (resource name, type of resource, quantity, units of measure, frequency, note).
   If needed, the facilitator helped company delegate in filling out ENEA input/output table;
c) once the tables were filled out, each of the delegates read aloud the outputs. In the event that one or more companies' delegates thought one of these outputs could have been useful in their company, they marked their own company identification code on the input/output table of the reading company delegate;
d) then, all delegates read aloud their inputs. In the event that one or more companies had these inputs available, their delegates marked their own company identification code on the input/output table of the reading company delegate;
e) facilitators put all the tables in an envelope to bring it to the other round table;
f) the process was then repeated on the other table, by searching for possible matches of the inputs/outputs with the companies sitting at the first table. The company identification codes of companies willing to receive other companies' outputs, or willing to provide inputs to other companies, was noted on the respective input/output tables;
g) the final input/output tables were collected by the facilitators
h) each company delegate filled out his own feedback form, where mainly they could evaluate and write an opinion on the meeting.

Finally, the raw data (number of companies, companies' delegates, matches and shared input and output resources) and the activities foreseen in the following months were shown to company delegates.

Fig.4.10. The Summary report of the first meeting

Regarding the *post-meeting* organization the first one lasted from 26 June to 2 August 2015, the second one from 12 September 2015 to 4 October 2015. In both cases I developed the following activities:

a) I have created and filled out, or integrated ENEA input/output table in Excel format for each company registered at meeting with data collected through ENEA input/output table in paper form which had been filled out during the meeting;
b) I sent an email to each company delegate to thank them for their presence at meeting and to request to check, modify and integrate their own updated ENEA input/output table in Excel format by an expiry date (specifically I have sent these emails for the first meeting from 26 June 2015; for the second meeting from 14 September 2015);
c) in the event that companies' delegates did not respond to my email by the expiry date, I contacted them by phone (or eventually via email) to check whether they had actually received my email. I have carried out this activity for the first meeting from 3 July 2015; and for the second meeting from 25 September 2015;

d) I created a summary report on meeting (see Figure 4.10);

e) I sent an email to each delegate company with first results upgraded and attached the summary report and eventual press review on meeting (specifically I sent these emails for the first meeting: 30 June 2015; for the second meeting: 15 September 2015);

f) I sent an email to each to thank the delegates and attached summary report to upload eventually on the Consortium web site;

g) in the second post-meeting I sent an e-mail to companies registered in the first meeting to inform them about the results of the second meeting and attaching summary report on this last meeting.

Concerning the *post-event matching* it lasted from 5 October 2015 to 29 November 2015. It was based on ENEA input/output table analysis of all companies participated in two meetings in order to identify new matches. I followed these steps:

- I matched some unpaired inputs and outputs to matches already identified by company delegates in meetings;
- I identified new matches by filling in two columns of an sheet with remaining input and output and matching them;
- I put together matches of same type.

Regarding *scenario analysis* it lasted from 30 November 2015 to May 2016. During this step I've analyzed and assessed the matches identified in the input/output matching step in order to find possible industrial symbiosis pathways in the industrial area of Rieti-Cittaducale.

With regard to the *material budgeting* I carried out the following activities:

- I analyzed data collected through ENEA input/output tables on quantity, units of measure and frequency of outputs and inputs for each type of match;
- I called or sent e-mails to companies' delegates to get more information on input or output for each match in which they were involved. The main information requested was about input or output specifications. If necessary, I asked for pictures of the inputs and outputs, to be sent to the matched companies. It's important to highlight that during this activity the matching company name was not communicated to other companies involved in the same synergy.
- I have represented graphically flows among matched companies.

Concerning *enabling conditions* for implementation of identified synergies I've divided them into regulatory, technical, logistical, regulatory and business factors. As for :

- regulatory factors, I have deepened the legislation on the identified combinations, identifying any obstacles or highlighting unclear points of the legislation;
- technical and logistical factors, I have highlighted any key issues that emerged from the analysis of material budgeting and from the comparison on synergies with business and with the consortium;
- business factors, through comparison with company delegates, I understood the real business interest and the economic relevance of the matches and resources for companies involved.

It's important to highlight that through these two last tasks I could to eliminate some matches or some companies initially involved in the matches because of logistical, technical, regulatory and business issues; and to identify new matches or other companies of industrial area of Rieti-Cittaducale to be involved.

As for *win-win situation* I analyzed and assessed potential synergies identified both economically and environmentally.

I assessed the economic benefits for the companies involved in the potential synergies and the economic impacts of these on the entire industrial area through an analysis of profitability. This economic assessment was based on:

- collection of economic data through phone calls or email to the companies' delegates to ask:
    - companies providing inputs to estimate the cost of such inputs (or, eventually, sales price of service provided to collect input) including or not including transport costs that the potential synergy could replace;
    - companies providing outputs to estimate the cost of giving away output involved in the potential synergy (or, eventually, selling price of output) including or not including transport costs;
- literature or online research to estimate missing data.

I assessed environmental benefits of the potential synergies through the European waste hierarchy and eventually through other environmental criteria such as greenhouse gas emissions or energy consumption avoided.

This assessment was based on:

- the analysis of data collected through ENEA input/output tables on current destination and EWC or Prodcom code;
- the requests for further information to the delegates of the companies involved in the potential synergies;
- literature or online research for further details on regulatory issues;
- EcoTransIT World web site to evaluate eventually greenhouse gas emissions and energy consumption avoided related to the lower freight transport.

Basing on the environmental and economic benefits obtained from this evaluation I have identified the possible pathways in the industrial area of Rieti-Cittaducale (see Figure 4.11).

Fig. 4.11. Milestones for industrial symbiosis in the industrial area of Rieti-Cittaducale

Stakeholder processes: July 2014 - May 2016

- *"Collaborazione fra Consorzio per lo Sviluppo Industriale della Provincia di Rieti, Università della Tuscia e ENEA per Dottorato di Ricerca" (14/11/2014)*

State-of- the-Art: 14 November 2014 - 3 May 2015.

- *Territorial Context Analysis*
- *Industrial inventories*

Symbiotic Scenarios: 4 May 2015 - May 2016

- *Input/output matching*
  - 2 Working Meeting Organization: 25/06/15 and 11/09/15
  - Post-event matching
- *Scenario analysis*
  - Material budgeting
  - Enabling conditions
  - Win-win solution

Chapter 5

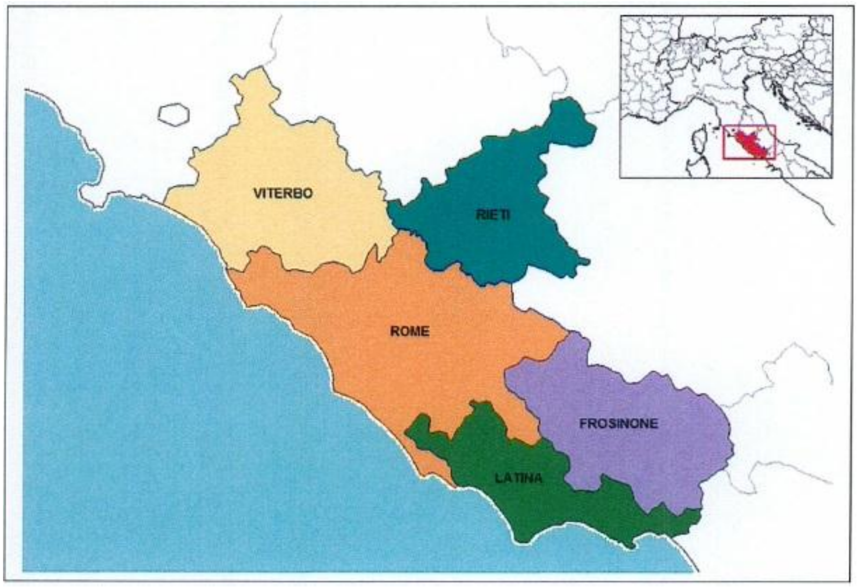
Case study: Industrial Area of Rieti-Cittaducale

In this chapter I introduce the case study of industrial symbiosis in industrial area of Rieti-.Cittaducale. At first, I describe the industrial cluster and its territorial context; then, I show the input/output matching of companies and the scenario analysis of the matches identified.

5.1 State-of-the-art of the industrial area of Rieti-Cittaducale

Geography. Lazio is one of the 20 administrative regions of Italy, situated in the central peninsular section of the country (see Figure 5.1).

Figure 5.1. Provinces of Lazio



Source: Invitalia, 2010, p.5

It has borders with Tuscany, Umbria, and Marche to the north, Abruzzo and Molise to the east, Campania to the south, and the Tyrrhenian Sea to the west. Its capital is Rome, capital and largest city of Italy. The region is mainly flat and hilly, with small mountainous areas in the most eastern and southern districts. Lazio comprises a land area of 17.232 km^2 (5,7% of Italy) divided into the provinces of: Frosinone (18,84% of Lazio), Latina (13,09%), Rieti (15,96%), Roma (31,12%), and Viterbo (20,98%). The province of Rieti has an area of 2.749 km2. Its capital is the city of Rieti. Located in the northeast of the Lazio region in the heart of Italy, Province of Rieti is bordered to the west, along the Tiber, with the Province of Viterbo and the Province of Rome, to the north by the Umbrian provinces of Perugia and Terni, and to the east by province of Ascoli Piceno in the Marche region, and with the provinces of L'Aquila and Teramo in the Abruzzo region. The territory is mostly mountainous. There are also several protected areas in the province.

Population. In 2013 Lazio is the third most populated region of Italy with a total resident population of 5.557.276 (9,3% of the Italian population). They live in 378 municipalities divided as follows: 91 in province of Frosinone, 33 in province of Latina, 73 in province of Rieti, 121 in province of Roma and 60 in province of Viterbo. Lazio is a region characterized by a strong heterogeneity in the distribution of the population: almost 73% of residents are concentrated in the province of Rome and especially in the municipality of Rome where over 2.6 million people live, representing 47% of the regional population. In the province of Rieti 156.521 people live (2,82% of the Lazio population). The most populated municipality is the town of Rieti with a total resident population of 47.153 (ISTAT, 2016). It's important to note that the demographic dynamics of the population in the province of Rieti, after several years of expansion, since 2011, when it exceeded 160.000 residents, has shown a first major turnaround, until the 156.521residents counted in 2013. Since many years the province is also characterized by the strong presence of an elderly population. The evident aging of Rieti province population negatively affects productivity and creativity that the active population (particularly young people) can make to the local economic activities (Camera di commercio di Rieti and Istituto G.Tagliacarne, 2014).

Infrastructures. Infrastructures. Lazio road system was born as a radial system with the municipality of Rome as the center point. The Lazio road network is characterised by a dense motorway network that connects it to the main national directions and by a mesh of state roads of regional interest that also affects the viability of the neighboring regions. (Regione Lazio, 2012). It's interesting to note that Lazio is also integrated into the EU Trans-European networks (TEN-T). In particular, its territory is crossed by Corridor I (Berlin-Palermo), that connects major European nodes along the north-south and plays a key role in communication with the central and southern Europe (Inviatalia, 2010). The radial structure is also visible in the rail network (Invitalia, 2010). Because of its central position in Italy

Lazio is crossed by some of the most important railway corridors (Regione Lazio, 2004). Lazio's port system consists of three poles: Civitavecchia; Fiumicino-Anzio; Pontino (Gaeta-Formia-Terracina), to which the port facilities of the islands of Ponza and Ventotene also belong (Regione Lazio, 2004). In particular Civitavecchia and Formia, are involved in EU Motorways of the Sea network (Invitalia, 2010). There are 13 interchanges in Lazio (Regione Lazio, 2004). As for the communication network in the province of Rieti, the road network seems almost an X where the intersection point is the municipality of Rieti with arteries that connect to north-eastern, northwest, southeast and southwest sides. The most important road of province of Rieti is the Via Salaria SS 4 (Regione Lazio, 2004). It's important to underline that infrastructure system in the province of Rieti has more than one critical element that negatively affect local economic development processes. In particular the rail network is lacking. As a result the traffic is secured almost solely by road infrastructure (Camera di commercio di Rieti and Istituto G.Tagliacarne, 2014).

Economy. In 2013 economic activity in the Lazio continued to decrease due to the reduction in household consumption and a further fall in business investment. Exports were slightly negative as well. In the latter part of 2013 there was a gradual weakening of recessionary trends thanks to support provided by domestic demand. In 2013 production, sales and investments have still had a small reduction in Lazio's manufacturing. In construction, economic activity has continued to decline, with particularly negative trends in the non-residential sector. Private service sector was affected by reduction in household consumption. According to Banca di Italia economy of Lazio depends on public spending by more than the national average, while impact of foreign trade is much lower. This means that economy of Lazio seem more akin to economies of South rather than economies of North.

According to ISTAT 9th Industry And Services, Institutions And Non-Profit Organisations Census in 2011 economy of Lazio showed a specialization focused on services, especially those with high knowledge-intensive, while manufacturing had a lower weight. In 2011 manufacturing had only 8.3 percent of the total number of employees in local units of Lazio, over 11 percentage points lower than the Italian average. In Lazio only the share relating to high-tech sectors (pharmaceuticals, aerospace) is slightly higher than the national average, while the share of low and medium-technology industries is significantly lower (Banca d'Italia, 2014).

According to Censis, Lazio has 13 regional production poles: Roma; Latina; Frosinone-Sora; polo dei Castelli romani; Bretella Nord; Pomezia-Santa Palomba; Civita Castellana-Viterbo, polo Sud pontino, Litorale Nord, polo di Cassino, Rieti-Cittaducale, Bretella Sud, polo di Fiano Romano-Formello. The biggest pole and with greater force of attraction is represented by municipality of Rome (Unioncamere Lazio et al. 2010).

In the thirteen regional production poles there are almost all regional productive activities and employment: 92.2% of regional employees; 86.6% of regional population; 119 municipalities of Lazio. These poles generate almost all of the added value linked to manufacturing, wholesale trade, transportation and high-tech and ICT activities. In the thirteen-pole there is in fact: 96,8% of hi-tech and ICT companies; 92,8% of the wholesale business; 92,2% of logistics and transport business. 87,1% of manufacturing companies in the region. The most important industrial concentrations in addition to Roman one with its 82.000 employees are those of Pomezia-Santa Palomba, Latina and Frosinone-Sora, each with an average of 20.000 employees and a significant number of manufacturing companies. In remaining poles instead industrial employment does not exceed 7,000 employees despite the manufacturing industry has quite significant relative incidence in Cassino and in area of Rieti-Cittaducale. Based on an analysis of the main manufacturing chains the lack of specialization and diversification of production are observed in these production sites. With rare exceptions it is instead difficult to detect in them an incidence of a specific sector preponderant over all other. It’s important to underline that in Lazio the most significant industrial aggregation models are: Industrial districts, local production systems and technology districts; Consortia for industrial development; Consortia of companies. Regarding Industrial Districts and Local Production Systems they are regulated by the Regional Law n. 36 of 2001 (Regione Lazio, 2001). Lazio Region has recognized 10 organized production systems: 3 industrial districts and 7 local production systems. They are as follows: Ceramics industrial district in Civita Castellana; Marble and stone industrial district; Textile and clothing industrial district in Valle del Liri; Sailing production system; Audiovisual production system in Rome; Chemical-pharmaceutical production system of southern Lazio, Local production system of Tiburtina electronics area Paper production system of province of Frosinone; Local production system of Rieti Innovation Area; Pontine agro-food productive food system. In these industrial area there are more than 4.400 companies and more than 84,000 employees (Regione Lazio, 2008). Ministry of Education, University and Research has recognized three technology district in Lazio: Aerospace Technology District; Bioscience Technology District ; Cultural Heritage and Activities Technology District (Rieti area is part of Aerospace Technology District). As regards the consortia for the industrial development, five of these are active in Lazio: Consorzio per lo Sviluppo Industriale della Provincia di Rieti; Consorzio per lo Sviluppo Industriale Roma-

Latina; Consorzio per lo Sviluppo Industriale di Frosinone; Consorzio per lo Sviluppo Industriale Sud Pontino; Consorzio per lo Sviluppo Industriale del Lazio Meridionale (Unionecamere Lazio, 2010).

Concerning the economic situation of Rieti, in recent years it showed a considerable setback after nearly fifteen years of growth favored by migratory flows coming from Roma in search of better living conditions. The 2008 economic crisis has produced its effects in the Rieti province only starting in 2011 as a result of poor local economy sensitivity to the trend of the world economy. This is mainly due to three factors: 1) the lack of openness to foreign trade; 2) the lack of infrastructure; 3) a business system not very competitive and productive.

It should be noted that from 2009 to 2012 all Rieti productive sectors showed negative trends. The construction sector, which has a significant weight within Rieti economy in terms of value added, had a real collapse. In line with recent years also in 2013 the entrepreneurial activities of the Rieti province has shown a negative trend. As it is also revealed at regional and national level there has been a reduction of companies in the primary sector and the secondary sector to the benefit of the tertiary sector. In particular agriculture, forestry and fisheries, trade, construction and manufacturing activities showed a greater reduction. The contraction of firms in agriculture, forestry and fishing industry is lower than the regional and national average. This reduction is however importance especially considering that the sector is undoubtedly the most important one for the economy of Rieti.

In province of Rieti in the last five years there has been a contraction of active enterprises: from 13.321 in 2009 down to 13.156 in 2013 with an average rate of change year of -0,3%. Given this overall decrease, we see a strengthening of the local production system thanks to the increase of capital companies. Despite the highlighted trend the sole proprietorship is still the main corporate legal form with 74,7% compared to 55,9% of Lazio and to 61,7% in Italy (Unioncamere-and Istituto Guglielmo Tagliacarne, 2014).

Regarding to labor market adverse economic phase and the weakness of the economy of Rieti led to strong negative employment effects. Labor market of the province of Rieti is affected by the strong crisis that began in 2010, the year in which effects of the structural growth initiated in 1995 with the transfer to the province of many Roman workers who have decided to go away for have a better quality of life are over. From 2009 to 2013 only female employment rate (including youth) shows some signs of recovery with rates below the average. From an industrial point of view, the occupation of the province reflects the vocations of the local economy. The overall employment in the province of Rieti is almost

57,000 of which over 71% in the tertiary sector, 22,9% in the secondary sector and 5,6% in the primary sector. It should be noted that employment in the primary and secondary sectors is higher than at regional scale (17,3% and 1,9%) (Unioncamere-and Istituto Guglielmo Tagliacarne, 2014).

Waste management. In 2012 Lazio Region approved regional waste management plan (Regione Lazio, 2012) in order to update last plan approved in 2002 to the numerous regulatory changes, including:

- Legislative Decree 36/03 (Repubblica Italiana, 2003), so-called "Landfills Decree", which imposed a ban on the disposal of waste in landfill untreated and reduction of disposal of biodegradable waste;
- Legislative Decree 152/06 (Repubblica Italiana, 2006b) so-called "Environmental Code", which regulates in greater detail numerous issues relating to authority, programming and regulation on waste, which were not clear in the old legislation (Repubblica Italiana, 1997);
- Directive 2008/98/CE (European Union, 2008), and its transposition into Italian legislation through Legislative Decree 205/2010 (Repubblica Italiana 2010), which establishes the legislative framework for the handling of waste in the European Union. It establishes major principles such as an obligation to handle waste in a way that does not have a negative impact on the environment or human health, an encouragement to apply the waste hierarchy and, in accordance with the polluter-pays principle, a requirement that the costs of disposing of waste must be borne by the holder of waste, by previous holders or by the producers of the product from which the waste came. It also defines key concepts such as waste, recovery and disposal and puts in place the essential requirements for the management of waste, notably an obligation for an establishment or undertaking carrying out waste management operations to have a permit or to be registered and an obligation for the Member States to draw up waste management plans.

  It's important to note that according to Legislative Decree 152/06 (art.199) this is a authority of Italian regions in accordance with general criteria established by the Italian State (Repubblica Italiana, 2006b).

At the same time, the Lazio region has not fulfilled certain regulatory obligations and thus an infringement procedure was initiated by the European Commission (Court of Justice of the European Union, 2007) to which last plan wants to be a response. Economic and social changes also led to new requirements and the need for new approaches. The increasing pressure on the environment by economic activities determined the reorientation of the regional strategy on waste production, efficiency and recovery: In Lazio the waste will have to be more and more inputs in a recovery chain and their disposal will have to be marginal. Considering also some remarks made by Italian Competition Authority to the Region (Autorità Garante per la Concorenza e del Mercato, 2009), possible solutions to adopt in Lazio must take into account the growing role attributed to the market for waste management in some its stages of the supply chain. Following the current European Community's trend on concessions and procurement, the “Environmental Code” severely limits in fact the role of the Public Administrations. Public administrations just have programming authority aimed only to orient or to influence. Instead the content of programming has little coercive and prescriptive power. In this context, the Region plays a regulatory role leading the market to respect above all the environmental social health regulations.

The Waste Management Plans of Region Lazio aims to provide solutions that are based on environmentally friendly, technological efficiency, economic sustainability and legality. The Plan is structured in two sections. The first section is about the Municipal Waste Plan. The second section is about special waste and there are also references to the other Plans. In both cases, the programming time is until 2017. The Plan provides for the organization of the collection system through the OTA (Optimal Territorial Area) and residual use of landfills. Plan identifies one Optimal Territorial Area for the management of municipal waste coinciding with the entire region and 5 sub OTA: Frosinone; Latina; Rieti; Roma; Viterbo. So the Plan identifies 5 sub OTA for the management of municipal waste, corresponding, with a few distinctions, to five provinces of Lazio where: to organize the collection services of municipal and assimilated wastes; to achieve self-sufficiency of the plants for unsorted municipal waste (so-called plants for mechanical biological treatment). It’s important to highlight that in case of lack of installations in a sub OTA, this one can use the equipment available in the closer ATO in order to reduce the movement of waste according to the principle of proximity as laid down by Legislative Decree no. 152/2006 and subsequent amendments and additions (Regione Lazio, 2012; Repubblica italiana, 2006b).

In 2008 the Province of Rieti approved the Provincial Plan for the organization of the collection, recovery and disposal of municipal solid waste and assimilated (Provincia di Rieti, 2008).

Lazio has set three specific objectives to achieve by 2017:1) reduction of municipal waste generation; 2) a separate collection rate in line with national targets; 3) an integrated system for the recovery and disposal of waste that is efficient, has the best available technologies and is self-sufficient.

Regarding Objective 1, policies for the reduction of municipal waste production established by the Lazio Region aim to plan on the entire of the waste management cycle and enable prevention, recovery and reuse initiatives to reduce the municipal waste production respect to inertial growth. To date the real reduction of municipal waste generation is better than expected in Lazio waste management plan.

Concerning Objective 2, according to the Legislative Decree no. 152/2006 and subsequent amendments and additions each optimal territorial area must achieve a separate collection of municipal waste at least equal to the following minimum percentages (Repubblica Italiana, 2006b): 35% by 31 December 2006; 45% by 31 December 2008; 65% by 31 December 2012. Law 296/2006 also introduced interim targets separate collection at least equal to the following minimum percentages (Repubblica Italiana, 2006a); 40% by 31 December 2007; 50% by 31 December 2009; 60% by 31 December 2011. In the waste management plan Lazio foresees to achieve 65% of the separate collection on total waste production by 2017 through effective regulatory instruments, identification of specific resources, collaboration of provinces and municipalities and citizen participation (Regione Lazio, 2012). To date these targets are not reached.

It's important to highlight that in order to archive a circular economy the UE Commission set a common EU target for recycling 65% of municipal waste by 2030 (European Commission, 2015b).

With regard the Objective 3, in order to achieve this goal Lazio has planned a plant system for the treatment, recovery and disposal of waste organized into: mechanical biological treatment plants; composting plants; waste to energy plants or gasification plants; landfills. In 2010 the operating plants for the municipal waste management in Lazio are: 7 mechanical biological treatment (MBT) plants; 19 composting plants; 3 waste to energy plants or gasification plants; 10 landfills for non-hazardous waste. In 2010 in Lazio there were also (Regione Lazio, 2012): 18 landfills for inert waste; l landfill for hazardous waste. It's important to highlight that in 2010 there was no facilities for the treatment and disposal of metropolitan waste in Rieti sub OTA For this reason in accordance with the proximity principle laid down by Legislative Decree no. 152/2006 and subsequent amendments and additions (Repubblica Italiana, 2006b) in Lazio waste management plan (Regione Lazio,

2012) and Viterbo province municipal waste management plan (Provincia di Viterbo, 2008) it is provided that waste generated in the provinces of Viterbo and Rieti is landfilled in Viterbo sub OTA.

It's important to note that in the Lazio region there are overall 770 waste management facilities. Almost 50% of them is located in the province of Rome. In the province of Rieti there are 50 facilities for waste treatment. The municipality with the largest number of facilities is Rieti and the highest number of facilities are for non-hazardous waste. In 2013 the percentage of all waste landfilled compared to the waste produced is 18%. It's important to highlight that in order to archive a circular economy the UE Commission set a binding landfill target to reduce landfill to maximum of 10% of all waste by 2030 (European Commission, 2015b).

Green economy and industrial symbiosis. Between 2008 and 2013 almost a quarter of Rieti companies (23.6%) invested or planned investments in green economy. It is important to highlight that this data is higher than regional (21.2%) and national average (22.0%) and by comparison with all the other provinces Rieti has a greater propensity to invest in green economy. Investments of the Rieti companies were mainly concentrated on reducing consumption of raw materials and energy (82,8%, compared to 77,8% in Lazio and 76,9% in Italy) or on sustainability of the production process (19,9%, compared to 17,7% in Lazio and 18,6% in Italia). In 2013 the enterprises of Rieti had planned about 260 recruitment in the green economy, accounting for 42.1% of total recruitment. This data is slightly lower than the regional average (44.3%, strongly influenced by the capital) but higher than the national average (38.4 %) (Unioncamere-and Istituto Guglielmo Tagliacarne, 2014).

It's important to highlight that Lazio Region aims to achieve a sustainable regional development model by combining the sustainable growth and social progress with the objectives of the 2014-2020 cohesion policy (Regione Lazio, 2016a). The Lazio region has included industrial symbiosis in its smart specialization strategy for smart, sustainable and inclusive growth in 2020 (Regione Lazio, 2014). In Lazio's Regional Operational Programme industrial symbiosis is considered an effective action for improving SMEs competitiveness (TO3) in particular to convert industrial area into Environmental Equipped Industrial Area (EEIA) (Regione Lazio, 2015c). It's important to underline that based on EU regulation No 761/2001 "Allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS)" (European Communities, 2001) in 2007 Lazio

Region joined Rete Cartesio[38] (Regione Lazio, 2007). For Rete Cartesio, the Environmental Equipped Industrial Area are one of the topics of greatest interest. In that regard a round table between the regions concerned was launched that have elaborated a “Carta per lo sviluppo delle Aree Produttive Ecologicamente Attrezzate in Italia”(Carta APEA) that is a *Position paper for the development of EEIAs in Italy*. In 2015 Lazio Region joined the Carta APEA (Regione Lazio, 2015a) committing to: define a common vocabulary for EEIAs; define common minimum criteria for EEIAs for a comparison among regions; create a register of EEIAs for citizens, local authorities and economic agents; using the most appropriate regulatory and financial instruments to promote technologies for energy efficiency and environmental improvement in the industrial areas, also encouraging development of new eco-businesses, industrial symbiosis solutions, environmental management and resource saving and reuse ; develop and implement administrative simplification for businesses located in the EEIAs as required by Legislative Decree. n. 112/1998 (Repubblica Italiana, 1998); making regional policies to promote industrial area sustainability in which implementation of the EEIAs has a prominent role.

Then Regions with its own laws regulate industrial areas and EEIAs. Lazio regulated EEIAs (Regione Lazio, 1999) by approving the “Linee Guida Apea per lo Sviluppo delle Aree Produttive Ecologicamente Attrezzate nel Lazio" in 2015 (Regione Lazio, 2015b). In order to promote economic development environmentally sustainable and an industrial management model oriented to improvement competitiveness and environmental, industrial and social performance including through the reduction of administrative burden EEIAs have the objective of encouraging: industrial symbiosis and sustainable industrial and technological development; circular economy; recycling and recovery of waste; protection of health, safety and environment even from landscape point of view; health and hygiene in the workplace; prevention and reduction of air, water and soil pollution; wastewater treatment; reduction of energy consumption and its effective use; prevention, monitoring and management of risks of serious accidents; adequate and rational accessibility for people and goods; key elements of improvement environmental, industrial and competitive program.

According to point 2 of the Lazio EEIAs guidelines, an Environmental Equipped Industrial Area is “un'area destinata ad attività produttiva industriale, artigianale,

[38] Rete Cartesio “is promoted by following Italian regional authorities: Emilia Romagna, Lazio, Liguria, Lombardia, Sardegna and Toscana and is open to public and private actors. The network is aimed to reach and diffuse collective solutions in cluster sustainable management. Clusters are both industrial and urban areas and collective sustainable solutions are directed to improve existing synergies. Cartesio topics are: Green Public Procurement, Eco-industrial parks, product supply chain policies and climate change” (Rete Cartesio, 2016).

commerciale, agricola e alle ulteriori attività previste dall’articolo 1, comma 1, lettera i), del DPR 160/2010 [Repubblica Italiana, 2010], anche in forma mista, caratterizzata dalla gestione integrata di infrastrutture, servizi centralizzati e risorse atti a garantire gli obiettivi di sostenibilità ambientale ed economica dello sviluppo locale e aumentare la competitività delle imprese insediate(Regione Lazio, 2015b, p.5). It is important to note that industrial symbiosis is an enabling condition for EEIAs in Lazio.

The industrial area of Rieti-Cittaducale. The industrial area of Rieti-Cittaducale is managed by Consorzio per lo Sviluppo Industriale della Provincia di Rieti[39]. This Consortium is a public economic entity established in 1965 as a result of the law n. 634/57 (Consorzio per lo Sviluppo Industriale della Provincia di Rieti, 2005; Repubblica Italiana, 1957, 1965, 1991; Regione Lazio 1997). It is the first consortium instituted in Lazio (Unionioncamere Lazio et al. 2010). Consortium was born to hinder depopulation of province of Rieti and to promote industrialization so to cope with limits of agricultural, forestry and pastoral economy prevailing in Rieti area at that time. From its birth until today the entity's mission has been “Favorire l’insediamento e la crescita di attività economiche nel territorio della provincia di Rieti, in un’ottica di concertazione con gli enti pubblici e organismi privati interessati” (Consorzio per lo Sviluppo Industriale della Provincia di Rieti, 2016).

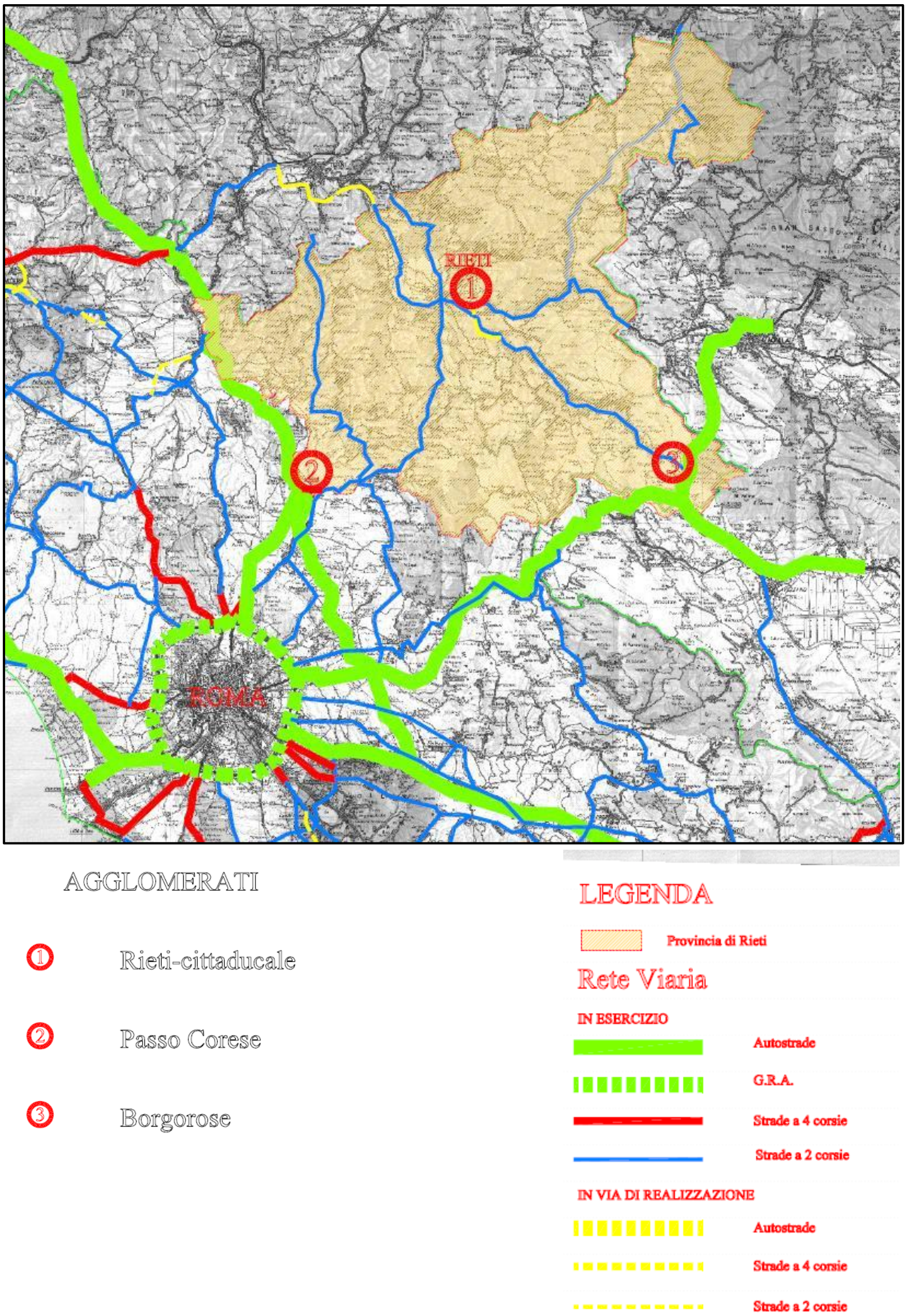
According to its statute Consortium aims to promote conditions necessary for creation and development of productive activity. For this purpose Consortium has exclusive competence on: a) drawing up regulatory plan for industrial areas; b) assigning areas to companies; c) managing production areas identified by the planning instrument; d) acquiring areas and equip them; e) managing consortium services by charging users; f) supporting business development; g) implementing and managing activities for settlement of productive activities and in particular: implementing and managing infrastructure; organizing real services to companies and local authorities; implementing and managing service activities; promoting expropriation of land and properties for equipping areas and for industrial location; taking any appropriate initiative to achieve institutional purposes; carrying out activities and functions given by the Lazio Region.

Consortium is formed by following bodies: the President, who is legal representative of Consortium; the Board of Directors; the Board of Auditors; the General Meeting. These

[39] When this institution was established in 1965 it was called "Consorzio per il Nucleo di Industrializzazione di Rieti-Cittaducale". In 1997 consortium name has been changed to adapt its Statute to Regional Law 13/97 on industrial consortia.

bodies remain in office for three years (Consorzio per lo Sviluppo Industriale della Provincia di Rieti, 2005). Offices of Consortium are: presidency; general direction; general Secretariat; technical office; administrative office. Consortium is in partnership with: AeA, ASI.FORM; Bic Lazio; PST Parco Scientifico e Tecnologico Alto Lazio; Sabina Universitas. Consortium provides the following services: Congress centre; business incubator" Incubatore Bic Lazio"

Figure 5.2. Industrial areas of Consorzio per lo Sviluppo Industriale della provincia di Rieti



Source: Regione Lazio, 2016b, p.2

Table 5.1. Spatial plan of industrial areas according to regulatory plan of consortium

Consorzio per lo Sviluppo Industriale della Provincia di Rieti											
			Zoning								
Industrial area	**Municipality**	**Surface (ha)**	**Industrial (ha)**	**Mixed industrial (ha)**	**Craft (ha)**	**Agrifood pole (ha)**	**Fair-Exhibition (ha)**	**Agricultural-naturalistic park (ha)**	**Public use and interest zone**	**Existing urban cores**
Rieti-Cittaducale	Rieti and Cittaducale	539	211	51	10,6	0	0	70	Yes	Yes
Borgorose	Borgorose	135	61,6	0	3	24,4	2,7	0	Yes	No
Passo Corese	Fara in Sabina	190	88,8	0	4	0	0	0	Yes	No
Total	4	864	361,4	51	17,6	24,4	2,7	70	Yes	Yes

Source: Own elaboration of data from Regione Lazio, 2016b

The headquarters of the consortium “Centro servizi L. Leonardi” is in Rieti within industrial area of Rieti-Cittaducale. At the beginning Consortium managed only the industrial area of Rieti-Cittaducale, later it has expanded its management also to areas in Borgorose, Fara Sabina (Passo Corese) and Osteria Nuova, thati is over entire province of Rieti[40]. Industrial areas of Consortium activated are the following (see Figure 5.2 and Table 5.1): Rieti-Cittaducale; Borgorose; Passo Corese.

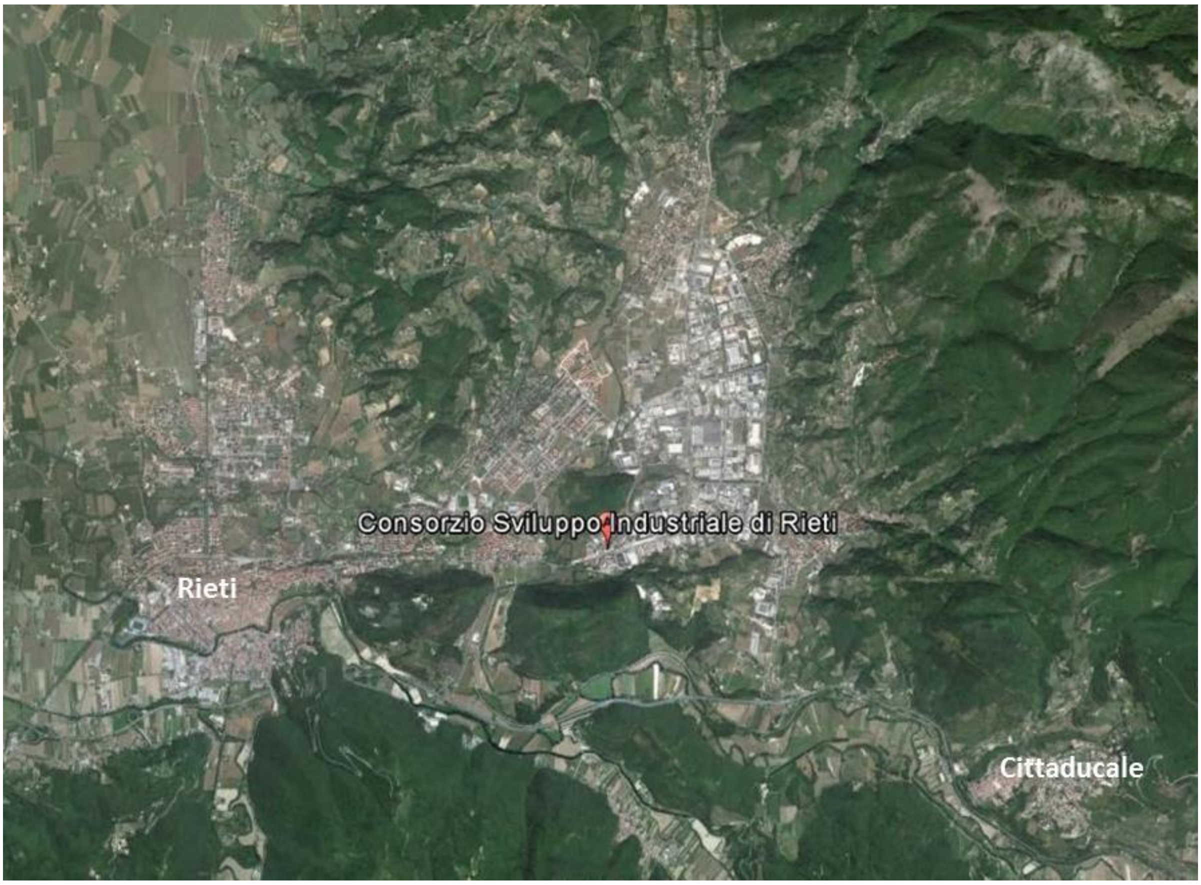
It’s important to note that although Consortium carries out similar activities in each of these areas, these areas are different from each other. Regarding the industrial area of Rieti-Cittaducale is a consolidated agglomerate and long since the lots are occupied by companies. It is instead necessary to complete urbanization works to locate companies in Fara Sabina (Passo Corese). Other investments are ongoing in the area of Borgorose to allow further development. With regard to Osteria Nuova and Montelibretti regulatory plan adopted by the Consortium has not completed its legislative procedure yet (Consorzio per lo Sviluppo Industriale della Provincia di Rieti, 2016).

Lazio Region considers industrial area of Rieti-Cittaducale as a Local Productive System - Innovation Area. This industrial area it is located between the municipalities of Rieti and Cittaducale (see Figure 5.3).

Rieti is the capital of province of Rieti. It is traditionally considered the geographical center of Italy (Umbilicus Italiae). In 2015 It had s a resident population of 47.729 and an area of 206,52 km^2 (ISTAT, 2016). The town centre rests on a small hilltop, commanding a wide plain at the southern edge of an ancient lake and at the foot of Mount Terminillo. The area is now the fertile basin of Velino river[41]. Cittaducale is a municipality in province of Rieti. In 2015 it had a resident population of 6.870 and an area of 71 km^2 (ISTAT, 2016). Cittaducale borders with Rieti.

[40] It is important to note that recently with membership of municipality of Montelibretti, located in Province of Rome, area managed by Consortium is also extended outside province of Rieti.
[41] Velino is the river that runs through Rieti.

Fig. 5.3. Localization of the Consorzio per lo Sviluppo Industriale della Provincia di Rieti



Source: Google Earth, 2016

Industrial area of Rieti-Cittaducale is the first settlement of the Consortium in province of Rieti. The site is located about 5 km from Rieti center and 3 km from Cittaducale center (Invitalia, 2010). It is 400 m. above sea level, in a seismic zone 2 and in climate zone E (Sforza et al 2006). According to its regulatory plan the industrial area of Rieti-Cittaducale has a surface of 539 hectares of which 260 ha are in the municipality of Rieti (48%) mand are 279 ha in municipality of Cittaducale (52%). About 272,6 ha of surface of industrial area is zoned for production purposes (Region Lazio, 2016): 211 ha for industrial use; 51 ha for mixed industrial use: 10,6 ha for craft use;and 70 ha for a naturalistic-agricultural park (To date it is not active). In industrial area there are also public use and interest zones, existing urban cores, a hospital and a prison. It’s important note that almost whole area is subject to restrictions related to Law 1497/39 and it is regulated by Landscape Territorial Plan n.5. the zone of naturalistic-agricultural park is subject to hydrogeological restrictions. A part of the area adjacent to the Via Salaria is defined as archaeological. None of these restrictions imply a priori no-activity in these areas but prescribed opinions are required (Regione Lazio, 1998a, 1998b, 2004; Repubblica Italiana, 1999).

Consortium gives authorization to companies to settle in industrial area, to connect to water and firefighting networks, to discharge into sewer, to driveways and to dig or to implement any work on Consortium's propriety. Consortium also gives an urban opinion on project submitted to municipally in charge.

Main infrastructure and utilities of industrial area are the following.

As regards the electricity it is supplied by a 150 kV line that runs through area, while domestic distribution takes place almost entirely through underground cables. Consortium manages public lighting. As regards methane it is supplied through a distribution network that spread along the road network of consortium (Invitalia, 2010; Sforza et al., 2006).

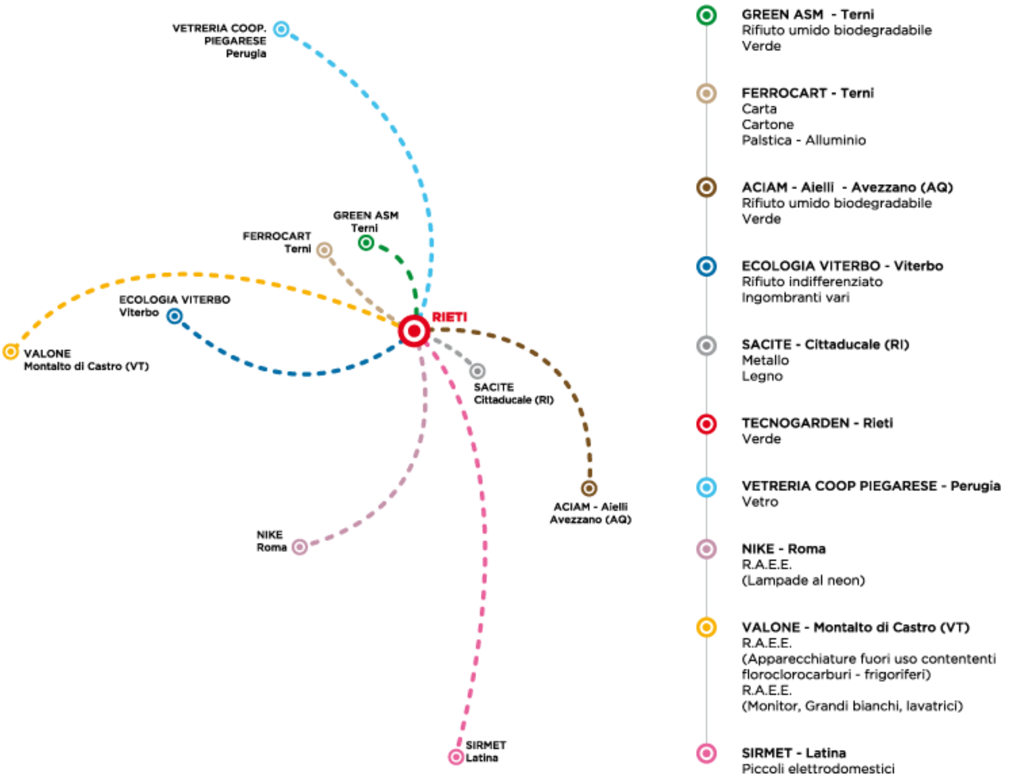
Regarding water cycle (aqueduct, sewage and water treatment) it is managed by Consortium through its company AeA. Water is supplied through an independent aqueduct from the municipal pipeline drawing water from two wells owned by Consortium. Water supply is guaranteed by two wells of the flow rate of 100 l/ sec fishing to 120 m deep in limestone and a 5.000 m^3 water tank. These facilities are located outside industrial area. They feed internal distribution network that is spread along road network providing drinking water and water for industrial use.

As for the management of waste water in industrial site there are: a sewerage network than has separate pipelines for white and black waters and is spread along the road network; a wastewater treatment plant owned by Consortium where all waste water of municipality of Rieti and a part of waste water of municipality of Cittaducale are also purified. This plant is authorized to treat for third parties civil and industrial unpiped wastewater. Wastewater treatment plant is located outside industrial area. After being purified waters end up in river Velino. (Sforza et al, 2006; AeA, 2016). Companies can get information on own water service on the consortium's website using a username and password. Concerning firefighting system it is spread in industrial area parallel to the internal water distribution network (Sforza, 2006). This network is managed by Consortium through AeA.

As regards municipal waste these are managed by two companies. ASM Rieti[42] spa manages municipal waste for portion of industrial area that is situated in municipality of Rieti. This company gives waste separate collection to sites authorized for recovery identifying them among those closest (see Figure 5.4).

[42] ASM Rieti is settled in the industrial area of Rieti-Cittaducale.

Figure 5.4. Waste management facilities to which ASM Rieti gives waste



Source: ASM Rieti, 2016

In accordance with the regional waste management plan, the mixed waste are transported to the landfill of Casale Bussi in Viterbo (ASM Rieti, 2016); Rieco spa manages municipal waste for portion of industrial area that is situated in municipality of Cittaducale. Four waste treatment facilities are located in industrial area three treatment plants for non-hazardous waste and an car demolition /scrappers. Recovery operations carried out in industrial area are R3, R4, R12 and R13. These facilities are owned by three companies of the industrial area. Regarding the Information and communication technology. There are 5 optic fiber rings with 200 fiber cables owned by Consortium managed by a company that is settled in the industrial area. Consortium has its own web site (www.consorzioindustriale.com). As regards the mobility about 90% of the roads within the industrial area are owned by Consortium and are managed by AeA. Industrial area is accessible via cars and buses from Rieti and Cittaducale. Within this area all roads are two-way traffic. There is also an old and non-continuous pedestrian and cycle track which is not currently active. Concerning green infrastructure in the industrial area, public green space are managed by consortium through AeA, a part of the future agricultural-naturalistic park planned in regulatory plan is owned by the consortium, other part is a private property.

Tab. 5.2. Companies active in industrial area of Rieti-Cittaducale broken down by industry and location of the production site (April 2015)

Sect.	Description	Firms	%	Rieti	Cittaducale
A	Agriculture, forestry and fishing	1	0,4	0	1
B	Mining and quarrying	0	0,0	0	0
C	Manufacturing	112	42,1	63	49
D	Electricity, gas,steam and air conditioning supply	5	1,9	3	2
E	Water supply; sewerage, waste management and remediation activities	3	1,1	1	2
F	Construction	6	2,3	2	4
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	81	30,5	42	39
H	Transportation and storage	16	6,0	12	4
I	Accommodation and food service activities	3	1,1	2	1
J	Information and communication	4	1,5	2	2
K	Financial and insurance activities	1	0,4	0	1
L	Real estate activities	17	6,4	9	8
M	Professional, scientific and technical activities	4	1,5	1	3
N	Administrative and support service activities	2	0,8	1	1
O	Public administration and defence; compulsory social security	3	1,1	3	0
P	Education	2	0,8	2	0
Q	Human health and social work activities	3	1,1	0	3
R	Arts, entertainment and recreation	1	0,4	0	1
S	Other service activities	2	0,8	1	1
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0	0,0	0	0
U	Activities of extra territorial organisations and bodies	0	0,0	0	0
Tot.		266	100,0	144	122

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

As regards the productive system of the industrial area in 2015, 293 companies had settled in the industrial area. 266 were instead companies active (see Table 5.2).It is interesting to note that most of these firms carry on an economic activity in the manufacturing (42.1%) and wholesale and retail trade, repair of motor vehicles and motorcycles (30,5%) industries.

Tab. 5.3. Companies active in industrial area of Rieti-Cittaducale broken down by location of the registered office (April 2015)

Registered Office	Firms	%	Registered Office	Firms	%
Rieti	95	35,71	Rieti-Cittaducale	165	62,0
Cittaducale (RI)	70	26,32	Other municipalities in province of Rieti	11	4,1
Roma	41	15,41	Province of Rieti	176	66,2
Milano	7	2,63	Province of Rome	44	16,5
Cantalice (RI)	3	1,13	Province of Viterbo	2	0,8
Contigliano (RI)	3	1,13	Province of Frosinone	1	0,4
Terni	3	1,13	Province of Latina	1	0,4
Concerviano (RI)	2	0,75	Lazio	224	84,2
Aprilia (LT)	1	0,38	Lombardia	9	3,4
Arcole (VR)	1	0,38	Abruzzo	5	1,9
Avezzano (AQ)	1	0,38	Umbria	5	1,9
Campo San Martino (PD)	1	0,38	Emilia Romagna	4	1,5
Casterlvetro (MO)	1	0,38	Veneto	3	1,1
Corciano (PG)	1	0,38	Campania	2	0,8
Corropoli (TE)	1	0,38	Sicily	1	0,4
Faenza (RA)	1	0,38	Not available	13	4,9
Fisciano (SA)	1	0,38			
Gricignano di Aversa (CE)	1	0,38			
L'Aquila	1	0,38			
Messina	1	0,38			
Monterotondo (Roma)	1	0,38			
Nazzano (Roma)	1	0,38			
Padova	1	0,38			
Paganica (AQ)	1	0,38			
Perugia	1	0,38			
Poggio Bustione (RI)	1	0,38			
Poggio Mirteto (RI)	1	0,38			
Reggio Emilia	1	0,38			
Rignano Flaminio (Roma)	1	0,38			
Rocca Sinibalda (RI)	1	0,38			
San Giovanni Teatino (CH)	1	0,38			
SanMartino in Rio (RE)	1	0,38			
Seriate (BG)	1	0,38			
Supino (FR)	1	0,38			
Vignanello (VT)	1	0,38			
Vimercate (MB)	1	0,38			
Viterbo	1	0,38			
Not available	13	4,89			
Total	266	100,00			

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

There is also a significant number of companies in the real estate activities (6,4%) transportation and storage (6,0%) sectors. There are no companies in the mining and quarrying industry. The majority of companies is located in the municipality of Rieti (54%). Two-thirds of the companies active in the industrial area have their registered office in the province of Rieti (see Table 5.3) and in particular in the municipalities of Rieti and Cittaducale (62%).

Tab. 5.4. Companies active in industrial area of Rieti-Cittaducale broken down by legal form (April 2015)

Legal Form					
Typology	**Companies**	**%**	**Typology**	**Companies**	**%**
Capital companies	*195*	*73,3*	**S.p.a**	*31*	*11,7*
			S.r.l.	*145*	*54,5*
			Soc. coop	*19*	*7,1*
Unincorporated partnerships	*39*	*14,7*	**S.a.s.**	*13*	*4,9*
			S.n.c.	*26*	*9,8*
Sole proprietorship	*23*	*8,6*	**Ditta individuale**	*23*	*8,6*
Other legal forms	*1*	*0,4*	**Associazione**	*1*	*0,4*
Not available	*8*	*3,0*	**Not available**	*8*	*3,0*
Total	*266*	*100,0*	**Total**	*266*	*100,0*

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

Companies having their registered office in the Lazio region are 84%, thanks to the significant presence of 41 companies registered in the municipalities of Rome (15,4%). In the industrial area of Rieti-Cittaducale most of the firms are capital companies (72,9%), in particular, more than half of the companies (54,5%) are S.r.l. (see Table 5.4). It’s interesting to note that more than 50% of enterprises in the industrial area of Rieti-Cittaducale have total assets under 10 million euro (see Table 5.5).

Tab. 5.5. Companies active in industrial area of Rieti-Cittaducale broken down by total asset (April 2015)

Total assets	Companies	%
< 2 millions	*95*	*35,7*
2 millions - 10 millions	*46*	*17,3*
10 millions - 43 millions	*13*	*4,9*
> 43 millions	*21*	*7,9*
Not available	*91*	*34,2*
Total	*266*	*100,0*

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti and AIDA, 2015

Tab. 5.6. Manufacturing companies active in industrial area of Rieti-Cittaducale broken down by Nace rev 2 division (April 2015)

	Division	Companies	%
10	**Food products**	*7*	*6,3*
11	**Beverages**	*1*	*0,9*
12	**Tobacco products**	*0*	*0,0*
13	**Textiles**	*1*	*0,9*
14	**Wearing apparel**	*0*	*0,0*
15	**Leather and related products**	*0*	*0,0*
16	**Wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials**	*7*	*6,3*
17	**Paper and paper products**	*1*	*0,9*
18	**Printing and reproduction of recorded media**	*5*	*4,5*
19	**Coke and refined petroleum products**	*1*	*0,9*
20	**Chemicals and chemical products**	*4*	*3,6*
21	**Basic pharmaceutical products and pharmaceutical preparations**	*1*	*0,9*
22	**Rubber and plastic products**	*3*	*2,7*
23	**Other non-metallic mineral products**	*11*	*9,8*
24	**Basic metals**	*5*	*4,5*
25	**Fabricated metal products, except machinery and equipment**	*19*	*17,0*
26	**Computer, electronic and optical products**	*15*	*13,4*
27	**Electrical equipment**	*4*	*3,6*
28	**Machinery and equipment n.e.c.**	*11*	*9,8*
29	**Motor vehicles, trailers and semi-trailers**	*1*	*0,9*
30	**Other transport equipment**	*1*	*0,9*
31	**Furniture**	*3*	*2,7*
32	**Other manufacturing**	*2*	*1,8*
33	**Repair and installation of machinery and equipment**	*9*	*8,0*
	Total	*112*	*100,0*

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

As for the manufacturing industry of industrial area (see Table 5.6), the largest number of companies carry out activities in the production in metal products (Nace rev 2 divisions 25 and 28) with 30 companies (30%), electrical and electronic products and equipment (Nace rev 2 divisions 26 and 27) with 19 companies (17%), and wood and of products of wood and cork and manufacture of articles of straw and plaiting materials (Nace rev 2 divisions 16 and 31) with 10 companies (9%). Based on a ISTAT classification most of the industrial area companies (42,9%) have a medium –low technology intensity (see Table 5.7). Finally, according to ISTAT classification with regard to companies working in the service sector, almost 90% of companies provide services (see Table 5.8). In 2012 the number of employed in the companies of the industrial site accounted to 4.606 employees (see Table 5.9).

Tab. 5.7. Manufacturing companies broken down by technological intensity

Technological intensity	Companies	%
High technology	*16*	*14,3*
Medium-high technology	*21*	*18,8*
Medium-low technology	*48*	*42,9*
Low technology	*27*	*24,1*
Total	*112*	*100,0*

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

Tab.5.8. Companies of services sectors broken down by degree of knowledge used

Knowledge-intensive	Companies	%	Typologies	Companies
High knowledge-intensive services	*18*	*13,0*	**High-tech services**	*4*
			Financial services	*1*
			Other market services	*4*
			Non-market services	*9*
Low knowledge-intensity services	*120*	*87,0*	**Market services**	*120*
			Non-market services	*0*
Total	*138*	*100,0*		

Source: Own elaboration of data from Consorzio per lo Sviluppo Industriale della Provincia di Rieti

Table 5.9. Time series of number of employees in industrial area of Rieti-Cittaducale

Year	Employees
1984	*3833*
1990	*4519*
1992	*4075*
1998	*3922*
2003	*4227*
2005	*4345*
2006	*4878*
2009	*4646*
2012	*4606*

Source: Consorzio per lo Sviluppo Industriale della Provincia di Rieti

5.2 Symbiotic scenario in the industrial area of Rieti-Cittaducale

Overall 168 companies were invited to work meetings with companies that have been organized in the conference hall of the headquarters of the Consorzio per lo Sviluppo industriale della Provincia di Rieti (see Table 5.10).

Figure 5.10. Companies active in the industrial area which were invited, booked, present and participating in the meetings

Section NACE rev.2	Invited		Booked		Present		Participating	
	Companies	%	Companies	%	Companies	%	Companies	%
A	1	0,6	1	2,0	0	0,0	0	0,0
B	0	0,0	0	0,0	0	0,0	0	0,0
C	110	65,5	34	66,7	20	74,1	18	78,3
D	5	3,0	2	3,9	1	3,7	1	4,3
E	3	1,8	2	3,9	0	0,0	0	0,0
F	4	2,4	3	5,9	1	3,7	1	4,3
G	39	23,2	6	11,8	2	7,4	2	8,7
H	3	1,8	0	0,0	0	0,0	0	0,0
I	1	0,6	1	2,0	0	0,0	0	0,0
J	0	0,0	0	0,0	0	0,0	0	0,0
K	0	0,0	0	0,0	0	0,0	0	0,0
L	0	0,0	0	0,0	0	0,0	0	0,0
M	0	0,0	0	0,0	0	0,0	0	0,0
N	1	0,6	1	2,0	1	3,7	0	0,0
O	0	0,0	0	0,0	0	0,0	0	0,0
P	1	0,6	1	2,0	1	3,7	1	4,3
Q	0	0,0	0	0,0	0	0,0	0	0,0
R	0	0,0	0	0,0	0	0,0	0	0,0
S	0	0,0	0	0,0	0	0,0	0	0,0
T	0	0,0	0	0,0	0	0,0	0	0,0
U	0	0,0	0	0,0	0	0,0	0	0,0
UC	0	0,0	0	0,0	1	3,7	0	0,0
Total	**168**	**100,0**	**51**	**100,0**	**27**	**100,0**	**23**	**100,0**

It is important to emphasize that 164 companies of Rieti industrial area were invited to both meetings. these companies are roughly 62% compared to companies active in the industrial site.

Four companies were invited only at the second meeting. This is because for this event in agreement with the Consortium, it was decided to invite three companies localized in Borgorose and in Passo Corese and a company located in the industrial area that was active again. Of these, only the company located in Rieti was booked for the second meeting, but later it was not present.

The large majority (almost 89%) of the invited companies was working in the manufacturing (65,5%) and wholesale (23,2%) sectors.

51 companies were booked for at least one of the meetings, with respect to the 168 companies invited. Most of the companies were from manufacturing sector (66,7%). It is important to note that there was a difficulty in contacting the wholesale companies located in the industrial area.

This is because for this type of companies, the decision is not taken by the managers of the operational site, but by managers from the registered office. It is also important to note that nine companies, which were booked for the first meeting but did not actually participate, they were also booked for the second meeting.So, concerning the 60 bookings made for the two meetings, 28 booking were for the first meeting and 32 for the second one (see Figure 5.14).

5.14. First results of the two meetings

Meeting	Booked Firms	Present Firms	Delegates	Participating Firms	Resources	Input	Output	Match	Matching Firm
Rieti 25.06.15	*28*	*18*	*20*	*15*	*85*	*29*	*56*	*45*	*14*
Rieti 11.09.15	*32*	*9*	*9*	*8*	*61*	*10*	*51*	*0*	*0*
Total	*60*	*27*	*29*	*23*	*146*	*39*	*107*	*45*	*14*

27 companies with 29 delegates were present at the two meeting compared to 60 bookings made:18 companies with 20 delegates were present at the first round table; 9 companies with 20 delegates were present at the second one.

It’s interesting to note that at the first meeting there was a company which was located outside the industrial area (Z101.030). The delegate was informed on this meeting and came to the headquarters of the consortium, although it could not participate to the round tables because of commitments.

The main difficulties for the presence of the companies were linked to the period when the meetings were organized (during the summer) and the number of workers available, in particular for the SMEs.

Fig.5.15. All companies involved during different stages (Part one)

Company Code	Legal Form	Registered Office	Production Site	Section	Class	Description	Total Assets (millions)	Employees in Production site
C10.014	S.p.a.	Castelvetro (MO)	Rieti	C	10.11	Processing and preserving of meat	> 43	182
C10.018		Rieti	Rieti	C	10.11	Processing and preserving of meat		
C11.037	Ditta individuale	Rieti	Cittaducale	C	11.01	Distilling, rectifying and blending of spirits		
C13.039	S.r.l. a socio unico	Cittaducale (RI)	Cittaducale	C	13.92	Manufacture of made-up textile articles, except apparel	2 - 10	12
C16.023	S.r.l.	Roma	Cittaducale	C	16.10	Sawmilling and planing of wood	< 2	10
C18.045	Soc. Coop.	Cittaducale (RI)	Cittaducale	C	18.12	Other printing		9
C20.016	S.r.l.	Roma	Rieti	C	20.42	Manufacture of perfumes and toilet preparations	< 2	
C20.032	S.r.l.	Roma	Rieti	C	20.59	Manufacture of other chemical products n.e.c.	2-10	24
C21.004	S.p.A.	Roma	Cittaducale	C	21.20	Manufacture of pharmaceutical preparations	> 43	342
C22.031	S.p.a.	San Martino in Rio (RE)	Rieti	C	22.29	Manufacture of other plastic products	10 - 43	
C22.025	S.r.l.	Cittaducale (RI)	Cittaducale	C	22.29	Manufacture of other plastic products	< 2	
C23.029	S.r.l.	Roma	Rieti	C	23.12	Shaping and processing of flat glass	< 2	9
C23.011	S.r.l.	Rieti	Rieti	C	24.20	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	10 - 43	28
C24.013	S.r.l.	Rieti	Rieti	C	24.33	Cold forming or folding	2 - 10	

Fig.5.15. All companies involved during different stages (Part two)

Company Code	Legal Form	Registered Office	Production Site	Section	Class	Description	Total Assets (millions)	Employees in Production site
C25.008	S.p.a.	Rieti	Rieti	C	25.62	Machining		80
C25.003	S.r.l. a socio unico	Cittaducale (RI)	Cittaducale	C	25.73	Manufacture of loaded electronic boards	< 2	
C26.026	S.r.l.	Rieti	Rieti	C	26.20	Manufacture of computers and peripheral equipment	10 - 43	
C28.017	S.r.l. a socio unico	Reggio Emilia	Rieti	C	28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	> 43	160
C28.019	S.r.l.	Rieti	Rieti	C	28.29	Manufacture of other general-purpose machinery n.e.c.	2 -10	45
C32.015	S.r.l.	Roma	Rieti	C	32.40	Manufacture of games and toys	2 - 10	
D35.009	S.r.l. a socio unico	Roma	Cittaducale	D	35.11	Production of electricity	2 - 10	4
E38.054	S.r.l.	Vimercate (MB)	Cittaducale	E	38.32	Recovery of sorted materials	2 - 10	
F42.010	S.r.l. a socio unico	Roma	Cittaducale	F	42.11	Construction of roads and motorways	< 2	7
G46.046	S.p.a.	Vignanello (VT)	Rieti	G	46.73	Wholesale of wood, construction materials and sanitaryequipment	> 43	
G46.001	S.a.s.	Cittaducale (RI)	Cittaducale	G	46.75	Wholesale of chemical products		
N82.005	S.p.a.	Roma	Cittaducale	N	82.99	Other business support service activities n.e.c	10 - 43	
P85.020	Società consortile per azioni	Rieti	Rieti	P	85.42	Tertiary education	2 -10	15
Z.101.030			Rieti					

One firm (E36.054) which was not booked and present to the two meetings, was subsequently involved during the scenario analysis.

About all companies involved during different stages we note that (see Figure 5.15):

- almost all companies are capital company (86%), of these companies, the most represented legal form was S.r.l. (57%);
- most of the companies has its registered office in Rome (32%) and Rieti (29%). There are some companies who don't have their registered office in Lazio. In particular they have their registered office in Emilia Romagna (3 companies);
- 57% of companies have their own production site in the municipality of Rieti; 43% in the municipality of Cittaducale;
- the largest number of companies is in the manufacturing (71%). There are also companies in the sectors of the wholesale (G); electricity supply (D); construction (F); support service activities (N); education (P);
- the majority of companies are small and medium enterprises, in particular with total asset between the majority of businesses are small and medium enterprises, in particular with total asset between 2 and 10 million euro (25%);
- the company with the lowest number occupied has 4 employees in its production site, the largest has 342 workers.

23 companies of the 27 companies present in the business meetings have participated in round tables.

4 companies have not participated because their company delegate also had other work commitments during the morning.

A total of 146 resources have been put into sharing among enterprises (see Figure 5.14): 39 input and 107 output.

In particular 85 resources (29 input and 56 output) were put into sharing in the first meeting and 61 resources (10 input and 51 output) in the second meeting (see Figures 5.16 and 5.17).

A total of 45 matches were found during the two meetings (see Figure 5.14). All matches were identified during the first meeting.

This was probably caused by the fact that during the second meeting there was only one round table with eight companies, so that few inputs were put into sharing as well (see Figures 5.16 and 5.17).

Fig.5.16. First results of the first meeting (25/06/2015)

Companies	Delegates	Participating	Resources	Input	Output	Match	Matching
G46.001	*1*	*Yes*	*5*	*1*	*4*	*1*	*Yes*
C25.003	*1*	*Yes*	*4*	*1*	*3*	*1*	*Yes*
C21.004	*1*	*Yes*	*7*	*4*	*3*	*3*	*Yes*
N82.005	*1*	*No*	*0*	*0*	*0*	*0*	*No*
C25.008	*1*	*Yes*	*5*	*3*	*2*	*4*	*Yes*
D35.009	*1*	*Yes*	*6*	*2*	*4*	*18*	*Yes*
C23.011	*1*	*Yes*	*2*	*1*	*1*	*0*	*Yes*
C24.013	*1*	*Yes*	*3*	*0*	*3*	*0*	*Yes*
C10.014	*1*	*Yes*	*22*	*10*	*12*	*7*	*Yes*
C32.015	*1*	*Yes*	*6*	*2*	*4*	*3*	*Yes*
C20.016	*2*	*Yes*	*2*	*1*	*1*	*3*	*Yes*
Z.101.030	*1*	*No*	*0*	*0*	*0*	*0*	*No*
C28.017	*2*	*Yes*	*12*	*3*	*9*	*2*	*Yes*
C10.018	*1*	*No*	*0*	*0*	*0*	*0*	*No*
C28.019	*1*	*Yes*	*4*	*1*	*3*	*0*	*Yes*
C16.023	*1*	*Yes*	*2*	*0*	*2*	*1*	*Yes*
C22.025	*1*	*Yes*	*4*	*0*	*4*	*2*	*Yes*
C23.029	*1*	*Yes*	*1*	*0*	*1*	*0*	*NO*
Total	**20**	**15**	**85**	**29**	**56**	**45**	**14**

Fig.5.17. First results of the second meeting (11/09/2015)

Companies	Delegates	Participating	Resources	Input	Output	Match	Matching
C22.031	*1*	*No*	*0*	*0*	*0*	*0*	*No*
C20.032	*1*	*Yes*	*12*	*3*	*9*	*0*	*No*
C11.037	*1*	*Yes*	*2*	*0*	*2*	*0*	*No*
F42.010	*1*	*Yes*	*2*	*0*	*2*	*0*	*No*
C13.039	*1*	*Yes*	*4*	*2*	*2*	*0*	*No*
C18.045	*1*	*Yes*	*8*	*4*	*4*	*0*	*No*
G46.046	*1*	*Yes*	*8*	*1*	*7*	*0*	*No*
P85.020	*1*	*Yes*	*12*	*0*	*12*	*0*	*No*
C26.026	*1*	*Yes*	*13*	*0*	*13*	*0*	*No*
Total	***9***	***8***	***61***	***10***	***51***	***0***	***0***

14 companies have matched during the two meetings (see Figure 5.14). All these companies were on the first meeting (see Figures 5.16 and 5.17).

During the post-event matching 65 matches were identified and 6 companies were involved in more (see Figure 5.18 and 5.19).

Fig.5.18. Number of matches and companies involved in the round tables and in the post-event broken down by resources put into sharing

Resources	Matches			Companies involved		
	Round Tables	Post-Event	Total	Round Tables	Post-Event	Total
Pallet	*7*	*14*	*21*	*7*	*2*	*9*
Cardboard packaging	*4*	*27*	*31*	*5*	*7*	*12*
Plastic packaging	*1*	*2*	*3*	*2*	*2*	*4*
Wood packaging	*4*	*5*	*9*	*5*	*0*	*5*
Metal packaging	*0*	*1*	*1*	*0*	*2*	*2*
Woody biomass	*5*	*4*	*9*	*4*	*3*	*7*
Fine and coarse salt	*2*	*0*	*2*	*3*	*0*	*3*
Distilled water	*1*	*0*	*1*	*2*	*0*	*2*
Thermal energy for district heating– Hot Water	*6*	*0*	*6*	*7*	*0*	*7*
Cooling energy - Cold water	*8*	*0*	*8*	*9*	*0*	*9*
Production space and office	*2*	*7*	*9*	*3*	*4*	*7*
Electric energy	*1*	*4*	*5*	*2*	*4*	*6*
Chemicals	*1*	*0*	*1*	*2*	*0*	*2*
Cleaners / sanitizers	*1*	*0*	*1*	*2*	*0*	*2*
Carpentry	*1*	*0*	*1*	*2*	*0*	*2*
Polyethylene sheets	*1*	*1*	*2*	*2*	*1*	*3*
Total	***45***	***65***	***110***			

Fig.5.19. Resources put into the sharing and companies involved during input/output matching

	Round Tables	Post-Event	Total
Resources	***45***	***65***	***110***
Matter	*28*	*54*	*82*
Energy	*15*	*4*	*19*
Services	*2*	*7*	*9*
Companies involved	***14***	***6***	***20***

It is important to highlight that the six companies in addition are all companies participating in the second round table.

Is also worth noting, overall that:

- 110 are the resources put into sharing: 89 regarding materials (81%), 19 concern energy (17%) and 9 concern the service (8%);
- the highest number of matches identified concern cardboard packaging (28%) and pallets (19%);

- 20 are companies involved in the matches: 14 companies matching during the working groups (70%), 6 companies involved during the post-event matching (30%);
- the largest number of companies involved in putting into sharing resource for the cardboard packaging with 12 companies involved, and pallets and cooling energy - cold water with 9 companies involved.

After a more careful study and analysis and evaluation of resources and matches we have reached the following final results.

Fig.5.20. Main factors that impede the implementation of the matches broken down by resources

Resources	Factors		
	Technical	Business	Other
Salt		X	
Electric energy			X
Cardboard packaging	X		
Sugar		X	
Metal packaging	X		
Plastic packaging	X		
Chemicals			X
Cleaners / sanitizers			X
Carpentry	X		
Polyethylene sheets			X
Distilled water			X
Production space and office			X

There are some factors preventing the implementation of matches (see Figure 5.20). In particular regarding:

- for cardboard packaging (with exclusion of the cardboard boxes unbranded), metal packaging, plastic packaging, carpentry, some technical issues arose, such as a mismatching between the demand and supply of the resource: a company wanted a resource that was not technically the same resource of what another company had, and/or vice versa;
- as for salt and sugar, there were some business issues: as it regards the salt the output company preferred to continue to re-use the excess of salt for internal

use to the company (e.g. as anti-freezing within their facilities); about sugar[43] the company output the company had managed to sell itself this resource;

- electric energy, chemicals, carpentry, polyethylene sheets they were all products relating to the core business of the output companies;
- as for cleaners/sanitizers, the input company entered a corporate crisis after the meetings;
- as for distilled water, the company produced it for own production and thus it should increase the quantity to give it to other companies;
- production space and office is not exactly a resource. The input company wants a warehouse of 1000 square meters for its production and the output company has this productive space.

Some peculiarities of the potential synergies should be highlighted (see Figure 5.21). Regarding thermal energy for district heating– hot water and cooling energy - the output company had a business idea for building up a facility that provides these services through the combustion of woody biomass.

The output company submitted an application for permission to the Province of Rieti for this project and it is waiting for response.

Fig.5.21. Matches that could become synergies

Resources	**Matches**	**Companies**
Thermal energy for district heating– Hot Water	*4*	*5*
Cooling energy - Cold water	*5*	*6*

Therefore, we can identify five industrial symbiosis pathways for the industrial area of Rieti-Cittaducale (see Figure 5.22).

In particular, four pathways are implemented through synergies regarding Pallet – EPAL, pallets of other sizes, unbranded cardboard boxes and wooden crates for the reuse of these resources; and one path is implemented through improving the management of waste in the industrial area.

[43] It is important to highlight that this resource was not put in sharing during the round tables. A participating company subsequently requested to put this one in sharing.

Fig.5.22. Possible pathways in the industrial area of Rieti-Cittaducale

Synergies

Resources	Quantity	Market value	Matches	Companies	Scenario
Cardboard boxes - Unbranded	*5000 unit*	*5.000 €*	*2*	*3*	*Re-use*
Wooden crates	*50 unit*	*15.000 €*	*1*	*2*	*Re-use*
Pallet - EPAL	*9490 unit*	*123.370 €*	*12*	*7*	*Re-use*
Pallet - Others	*300 unit*	*5.200 €*	*10*	*7*	*Re-use*

Efficiency

Resources	Quantity	Market value	Matches	Companies	Scenario
Woody biomass	*300 tons*	*34.000 €*	*8*	*9*	*Recycling*

In the next chapter it will be explained in greater detail an industrial symbiosis pathway through synergies regarding the wooden crates and the industrial symbiosis pathway through more efficient waste management in the industrial area of Rieti-Cittaducale.

Chapter 6

Possible Pathways of Industrial Symbiosis in the Industrial Area of Rieti-Cittaducale

In this chapter some of the possible pathway of industrial symbiosis to implement in the industrial area of Rieti-Cittaducale are examined. Two different types of paths are analyzed particularly: one related to the implementation of synergies relating wooden crates; and another one relating to an increased efficiency in waste management within the production site. Finally a possible draft of circular economy pathway to close the wood loop is shown.

6.1 Industrial symbiosis pathway: wooden crates

The companies involved in the industrial symbiosis pathway concerning the synergies of wooden crates are as follows (see Table 6.1).

The input company C28.019 is a *S.r.l.* with registered office in Rieti. Its production site is in the industrial area falling in the municipality of Rieti where it has a number of employees equal to 45 units. The C28.019 is a manufacturing company working in the manufacture of general-purpose machinery (ISTAT, 2016). This small-medium enterprise has an total assets between 2 and 10 million (AIDA, 2015) and it has the following certification: EN-ISO 9001-2008, EN-ISO 1090-1.

The output company is a C28.017 is *S.r.l. a socio unico* with registered office in Reggio Emilia. Its production site is in the industrial area falling in the municipality of Rieti where it has a number of employees amounted to 160 units. The C28.017 is a manufacturing company working in manufacture of engines and turbines, except aircraft, vehicle and cycle engines (ISTAT, 2016). This large company has total assets exceeding 43 million euro (AIDA, 2015) and has the following certifications: UNI EN ISO 9001:2000 VISION, ISO TS 16949:2002.

Tab.6.1. Companies involved in the synergy concerning the wooden crates

Company Code	Legal Form	Registered Office	Production Site	Section	Class	Description	Total Assets (millions)	Employees in Production site
C28.017	S.r.l. a socio unico	Reggio Emilia	Rieti	C	28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	> 43	160
C28.019	S.r.l.	Rieti	Rieti	C	28.29	Manufacture of other general-purpose machinery n.e.c.	2 -10	45

.

Business as usual. The input company C28.019 estimates an annual requirement of wooden crates around 50 units. To purchase this resource the company annually spends 15.000 euro inclusive of transportation costs. The company has two suppliers of crates, one is located in Terni roughly 46 km and the other one is in Aprilia (LT) about 145 km. It's important to highlight that the annual demand for wooden crates enterprise is linked to the performance of orders relating to its core business products.

The output company C28.017 has wooden crates that are former containers for cast iron machinery from non-EU suppliers. The crates have variable sizes but the most common, accounting for almost 70%, have 120x80x63H measure and weigh approximately 70 kg each (see Figure 6.1).

Fig.6.1. Wooden crates of the output company C28.017

Source: Company delegate of the output company C28.017

Based on the latest information the company has about 400 wooden crates having 120x80x63H size per year and 150 wooden crates having different dimensions. This resource currently is disposed with EWC code 150103 concerning wood packaging and transferred to another company in the industrial area of Rieti-Cittaducale to be recycled. It has an annual cost estimated to approximately 5.000 euro (inclusive of transport costs) for the total amount of wood packaging recycled approximately 40 tonnes per year. It is noteworthy that at the moment this enterprise would be also willing to lease to other companies the reusable wooden crates for free.

Synergy description. The synergy was identified through round tables organized in the headquarters of the Consorzio per lo Sviluppo Industriale della Provincia di Rieti. The synergy concerns two companies: one output company, C28.017, and input company, C28.019. Both companies work in the same division of economic activity: Manufacture of machinery and equipment n.e.c..

Based on this synergy, the input company C28.019 reuses the wooden crates transfered by the company C28.017. These two companies are distant from each other by the road approximately 700 meters (see Figures 6.2 and 6.3).

Fig. 6.2 Flowchart of the wooden crates

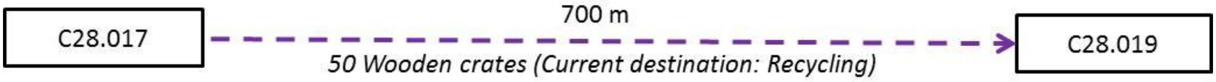


Fig. 6.3. Geo-referencing of the companies potentially involved in synergy of the wooden crates

Source: Own elaboration through QGIS software (QGIS, 2016)

The flow of the resource is batch. It is possible the meeting between the demand for wooden crates by the input company (about 50 units per year) and the offer by the output company (400 wooden crates having 120x80x63h size and 150 wooden crates with other dimensions).

Economic assessment. As regards the economic assessment on this synergy we suppose that:

- the output company C28.017 has 40 tons of wood packaging equal to 400 wooden crates; each wooden box weighs 70 kg; the cost to recycle a wooden crate is 12,5 euro; the total cost for the recycling of wooden crates is 5.000 euro per year (see Table 6.2);

- the input company C28.019 buys 50 wooden crates from two suppliers, located in Terni and Aprilia (LT); each wooden crate costs 300 euro; the input company spends annually on buying wooden crates roughly 15.000 euro (see Table 6.3).

Tab. 6.2. Economic assessment on the wooden crates' synergy for the output company C28.017

BAU			Symbiotic Scenario				
Unit	Unit price	Total	Unit	Unit price	Total	Δ€	Δ%
400	*12,5 €*	*5.000 €*	*350*	*12,5 €*	*4.375 €*	*-625 €*	*-12,5%*

Tab. 6.3. Economic assessment on the wooden crates' synergy for the input company C28.019

BAU			Symbiotic Scenario				
Unit	Unit price	Total	Unit	Unit price	Total	Δ€	Δ%.
50	*300 €*	*15.000 €*	*50*	*0*	*0*	*-15.000 €*	*-100%*

Based on these assumptions in the BAU scenario, the companies involved in the synergies have a total cost of approximately € 20.000 per year and as a whole the industrial area has a cost of 15.000 euro. This last result is due to the fact that the output company C28.017 manages its waste through another industrial area company[44], while the input company C28.019 has suppliers for the wooden crates that are out of the industrial area.

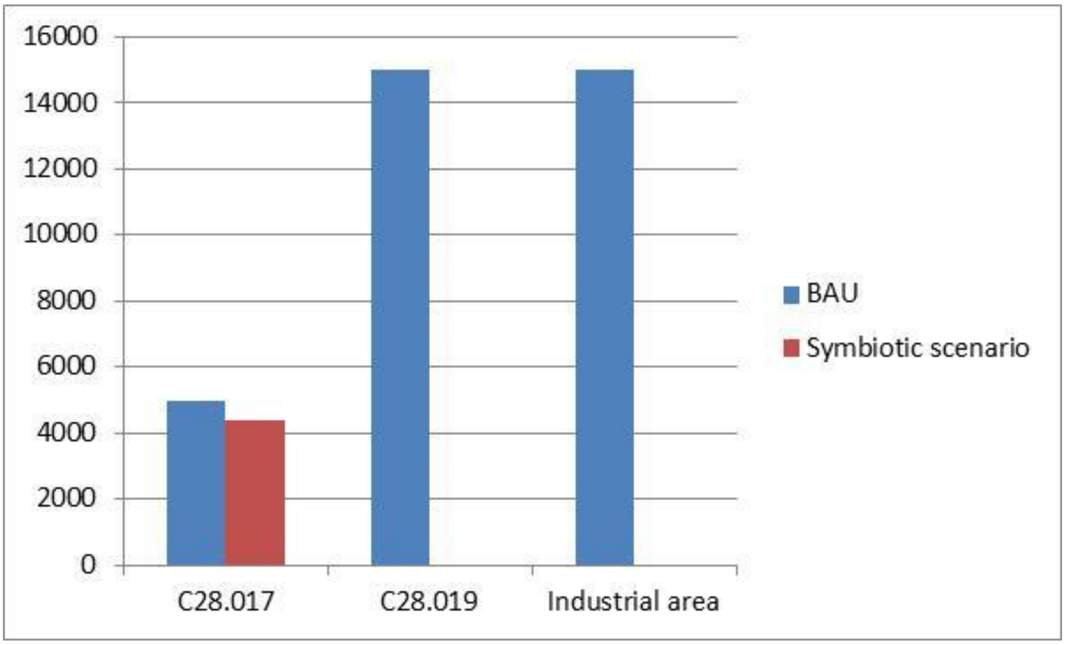
By activating the synergy, the companies involved would have potential lower costs and / or new revenues to approximately 15.625 euro per year (excluding the impact of transport costs). The company C28.017 would have lower costs for the treatment of wooden crates for 625 euro. The company C28.019 would have lower costs for 15.000 euro.

It is interesting to note that if in 2014 the output company C28.019 had transferred its wooden crates to the input company C28.017 for free, this company would have had lower production costs for raw materials, consumables and goods for € 15.000. According to balance sheet data of this enterprise in 2014 (AIDA, 2016) this lowest cost would have improved its operating income of approximately +11% and earnings before taxes of around +54%.

As for the industrial area this synergy could lead to lower overall costs or higher revenues for approximately 15.000 euro (see Figure 6.4).

[44] Is worth noting that to have a more accurate cost estimate concerning the industrial area we would need more information on the economic and operational management of the wood packing by the environmental manager who currently provides the service to the company C28.017.

Fig. 6.4. Changes in costs related to the synergy of wooden crates for the companies C28.017, C28.019 and industrial area



Environmental assessment. At the environmental level, as regards the waste management 40 tons of wooden packaging are recycled currently by output company C28.017.

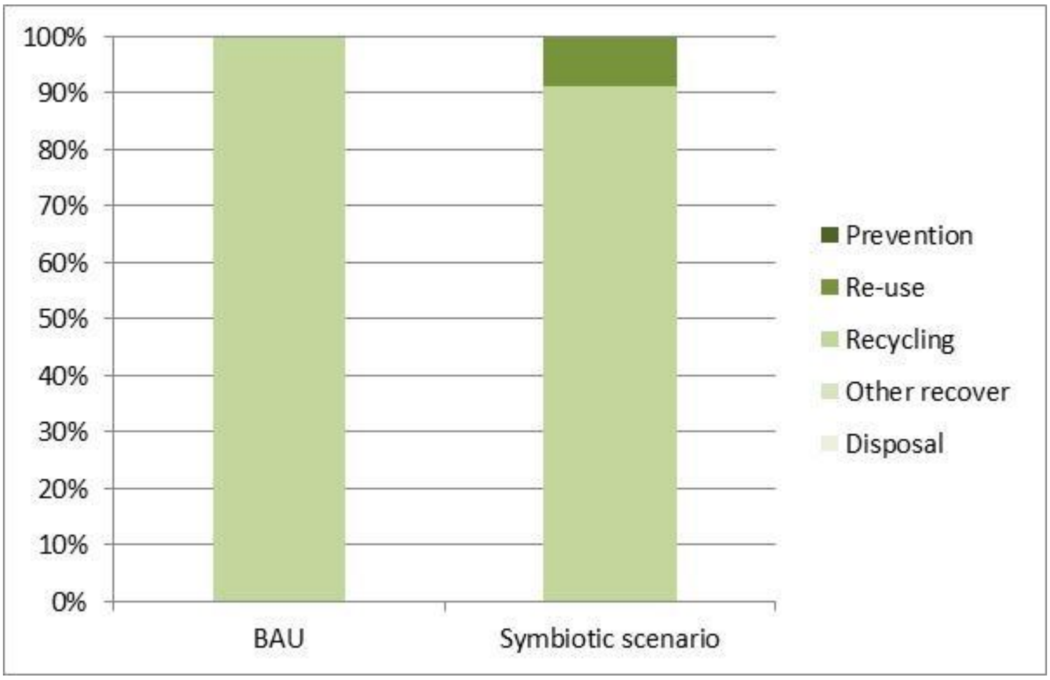
According to the European Union waste hierarchy, by synergy of activation we would have a better waste management (see Table 6.4 and Figure 6.5). This is because about 3,5 tons per year of wood packaging would be reused instead of being recycled.

It's important to highlights that this result is very important from a perspective of a circular economy because it lengthens the life cycle of these products.

Tab. 6.4.Environmental assessment on the synergy of wooden crates based on the EU hierarchy of waste

EU Waste Hierarchy	BAU	Symbiotic Scenario		
Priority order	Tons	Tons	Δ	Δ%
Prevention	*0,0*	*0,0*	*0,0*	
Re-use	*0,0*	*3,5*	*+3,5*	
Recycling	*40,0*	*36,5*	*-3,5*	*-8,8%*
Other recover	*0,0*	*0,0*	*0,0*	
Disposal	*0,0*	*0,0*	*0,0*	

Fig. 6.5. Changes in waste management relating to the synergy of wooden crates



It's interesting to note that through the activation of this synergy the input company C28.019 wouldn't buy more wooden crates from its two suppliers located in Terni and Aprilia (LT). This would lead to less traffic of goods by road for 191 km in total. So we suppose that in the BAU scenario:

- the company C28.019 has a unique supplier of wooden crates;
- the sole supplier is located at an average distance of 95 km;
- the company C28.019 purchases monthly wooden crates (then about 4 wooden crates that are heavy roughly 0.3 tons).

The lack of transport of the wooden crates in the symbiotic scenario would lead to a reduction in energy consumption equal to 360 Megajoules per year and lower greenhouse gas emissions by approximately 0,03 tons of CO_2 equivalent[45] (EcoTransIT World, 2016).

Is important to note that with regard to the emission of greenhouse gases as well as the energy consumption, we should also take into consideration the benefits of the non-production of 50 new wooden crates and the non-recycling of 3.5 tons of wood. With regard

[45] Detailed description of the calculated transport services: Truck (26-40 t,EURO 5,LF: 60.0%,ETF: 20%), 95.12 km. (EcoTransIT World, 2016).

to the lower greenhouse gas emissions related to the non-recycling of 3.5 tons of wood, we can estimate to be equal to 1,8 tons CO_2 equivalent[46] (see Table 6.5).

Tab.6.5. Climate change and energy consumption relating to synergy of wooden crates

	BAU	Symbiotic scenario
Climate change GHG emissions as CO2e	*1,83 tonnes*	*0*
Energy consumption Energy resource consumption	*360 Megajoule*	*0*

Considerations. I spoke by telephone business delegates. they have proved interested in the possibility of implementing the synergy regarding the wooden crates. In particular, the input company C28.019 has also seen some pictures of wooden crates of output company C28.017. That could have a positive effect on transaction costs. It is important to note that to date, primarily for data confidentiality reasons, the companies involved in this synergy does not know who is the other company involved. However, based on some information collected during the first meeting we know that the two companies already have other types of economic relations. This could have a potentially positive impact on transaction costs.

At the regulatory level, the main reference legislation for reuse of industrial packaging is art. 218 Legislative Decree 152/2006 (Repubblica Italiana, 2006b; Rilegno, 2014).

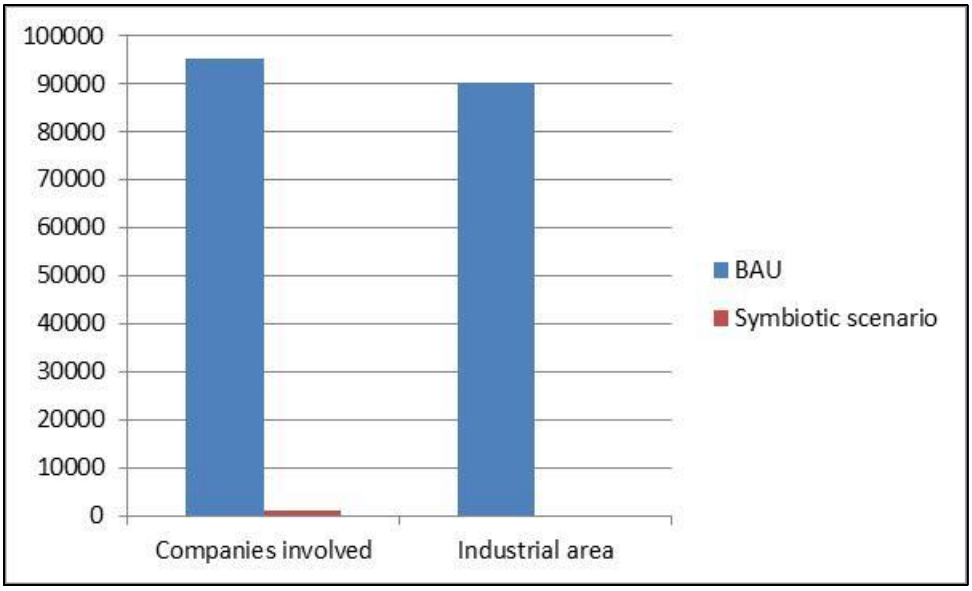
In terms of logistics, at moment the main barriers are no-continuous and no-programmability of resource flow over time. This may result in higher transaction costs for this synergy.

It's noteworthy that in the industrial area of Rieti-Cittaducale, there are six other companies working in the same category of economic activity where input company works. Five of these companies have a total activity in the same class of input company that is between 2 and 10 million euro. Therefore, we could estimate an overall demand for wooden crates for the industrial area of approximately 300 units per year.

These demand could be totally met only by output company C28.017. If this should occur (see Figure 6.6), potential industrial area economic effects could be roughly equal to 93.750 euro (excluding transportation costs).

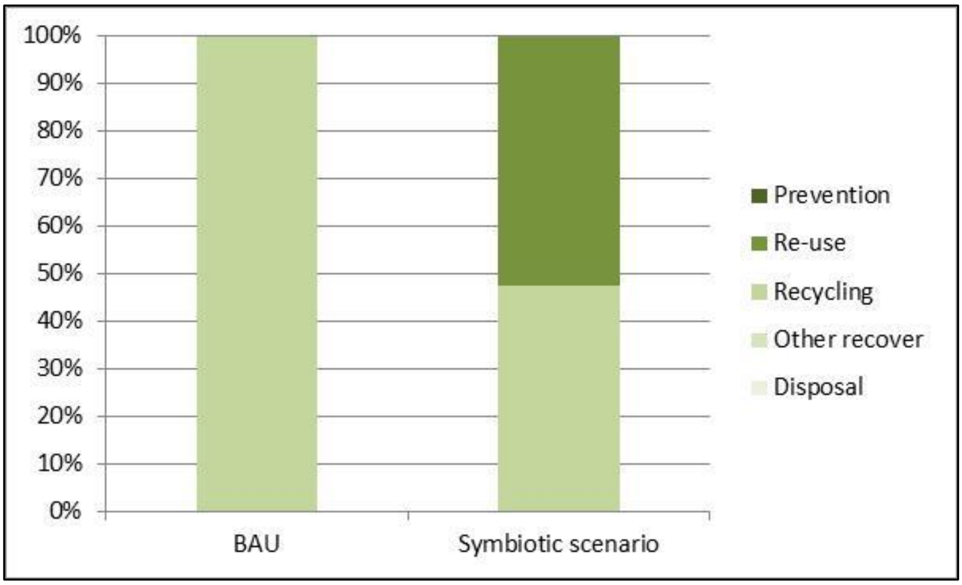
[46] On the basis of CO_2 emissions for the production of pallets (Dotelli, 2011), we suppose the following conservative assumptions: a) the wooden pallet is equal to the wooden crates (the latter might be most precious); b) the production process of pallet is equal to the production process of wooden crates (the latter might be more complex).

Fig. 6.6. Overall change in costs related to synergies on wooden crates for all companies potentially involved and for the industrial area



This one would also lead to an improved management of waste equal to 21 tons of wood packaging that would be reused instead of being recycled, with positive effects for the environment (see Table 6.7).

Fig. 6.7. Changes in waste management relating to all potenzial synergies of wooden crates in the industrial area



We note also that in the industrial area the economic activity division which includes the input and output companies (manufacture of machinery and equipment n.e.c.) represents compressively 11 companies of the industrial area (the third field of manufacturing specialization of the industrial area). This means that this type of synergy can be particularly interesting for the production site because it could potentially involve roughly 9.8% of manufacturing companies of the industrial area.

Finally, it is interesting to note that through the synergies of this type, the entire local economy can have positive effects because there would be more competition between local businesses and greater competitiveness of the production system as a whole. The potential effects of the synergies of this type would be therefore in line with remarks made by Italian Competition Authority to the Lazio Region (Autorità Garante per la Concorenza e del Mercato, 2009) on possible solutions to adopt in Lazio for waste management through the role played by market (Regione Lazio, 2012).

It is also important to point out the possible social implications obtained from this synergy. Based on the company's annual cost of one workman in the manufacturing sector, which in Italy roughly equals to 34.000 euro (Jobpricing, 2016), the economic value of the synergy on wooden crates (50 units) is of almost half of this cost and, however, it covers almost all the tax wedge paid for one workman. Thus the economic value of all possible synergies on the wooden crates (300 units) in the industrial area is equal to nearly the average annual cost of three workmen for a manufacturing company.

6.2 Industrial symbiosis pathway: efficiency improvement of the woody biomass management

The companies involved in the industrial symbiosis pathway through the efficiency improvement of wood biomass management are as follows (see Table 6.6). The output company are as follows.

The company C10.014 is a *S.p.a.* with registered office in Castelvetro (MO). Its production site is in the industrial area falling in the municipality of Rieti where it has a number of employees amounted to 182 units. C10.014 is a manufacturing company working in processing and preserving of meat (ISTAT, 2016). This large company has a total assets exceeding 43 million euro (AIDA, 2015) and has the following certifications: ISO 9001, ISO 14001; IFS, OHSAS 18001.

The company C16.023 is a *S.r.l.* with registered office in Roma. Its production site is in the industrial area falling in the municipality of Cittaducale (RI) where it has a number of employees amounted to 10 units. C16.023 is a manufacturing company working in sawmilling and planing of wood (ISTAT, 2016). This small medium enterprise has total assets of less than € 2 million (AIDA, 2015) and has the following certifications: ISO 9001 - EC - 100% Made in Italy.

The company C20.032 is a *S.p.a.* with registered office in Rome. Its production site is in the industrial area falling in the municipality of Rieti where it has a number of employees equal to 24 units. C20.032 is a manufacturing company working in the manufacture of chemical products (ISTAT, 2016). This small medium enterprise has a total activity between 2 and 10 million euro (AIDA, 2015) and has the following certification: ISO 9000.

The company C25.008 is a *S.p.a.* with registered office in Rieti. Its production site is in the industrial area falling in the municipality of Rieti where a number of employees amounted to 80 units. C25.008 is a manufacturing company working in machining (ISTAT, 2016). This small and medium enterprises has the following certifications: ISO 9001 and 14001.

The company C26.026 is a *S.r.l.* with registered office in Rieti. Its production site is in the industrial area falling in the municipality of Rieti. C26.026 is a manufacturing company working in the manufacture of computers and peripheral equipment (ISTAT, 2016). This small medium enterprise has a total asset of between 10 and 43 million euro (AIDA, 2015) and has the following certification: ISO 9001.

Tab.6.6. Companies involved in the efficiency improvement of the woody biomass management

Company Code	Legal Form	Registered Office	Production Site	Section	Class	Description	Total Assets (millions)	Employees in Production site
C10.014	S.p.a.	Castelvetro (MO)	Rieti	C	10.11	Processing and preserving of meat	> 43	182
C16.023	S.r.l.	Roma	Cittaducale	C	16.10	Sawmilling and planing of wood	< 2	10
C20.032	S.r.l.	Roma	Rieti	C	20.59	Manufacture of other chemical products n.e.c.	2-10	24
C25.008	S.p.a.	Rieti	Rieti	C	25.62	Machining		80
C26.026	S.r.l.	Rieti	Rieti	C	26.20	Manufacture of computers and peripheral equipment	10 - 43	
C28.017	S.r.l. a socio unico	Reggio Emilia	Rieti	C	28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	> 43	160
C28.019	S.r.l.	Rieti	Rieti	C	28.29	Manufacture of other general-purpose machinery n.e.c.	2 -10	45
D35.009	S.r.l. a socio unico	Roma	Cittaducale	D	35.11	Production of electricity	2 - 10	4
E38.054	S.r.l.	Vimercate (MB)	Cittaducale	E	38.32	Recovery of sorted materials	2 - 10	
G46.046	S.p.a.	Vignanello (VT)	Rieti	G	46.73	Wholesale of wood, construction materials and sanitaryequipment	> 43	

The Company C28.017 is a *S.r.l. a socio unico* with registered office in Regio Emilia. Its production site is in the industrial area falling in the municipality of Rieti in which he has a number of employees amounted to 160 units. C28.017 is the manufacturing company in the manufacture of engines and turbines, except aircraft, vehicle and cycle engines (ISTAT, 2016). This large company has total assets exceeding € 43 million (AIDA, 2015) and has the following certifications: UNI EN ISO 9001: VISION 2000, ISO TS 16949: 2002.

The company G46.046 is a *S.p.a.* with registered office in Vignanello (VT). Its production site is in the industrial area falling in the municipality of Rieti. G46.046 is a company that provides services working in wholesale of wood, construction materials and sanitary equipment (ISTAT, 2016). This large company has total assets exceeding 43 million euro (AIDA, 2015).

The input company is D35.009 which is a *S.r.l. a socio unico* with registered office in Rome. Its production site is in the industrial area falling in the municipality of Cittaducale (RI) which has a number of employees equal to 4 units. D35.009 is a company which produces electricity through a biomass power plant. This small-medium enterprise has total assets between 2 and 10 million euro (AIDA, 2015).

In this possible industrial symbiosis pathway there is also an environmental manager, E38.054, which acts as intermediary enterprise (input-output). This company is a *S.r.l.* with registered office in Vimercate (MB). Its productive site is in the industrial area falling in the municipality of Cittaducale (RI) which has a number of employees equal to 2. E38.054 is a company working in the recovery of sorted materials (ISTAT, 2016). This small-medium enterprise has a to total assets between 2 and 10 million euro (AIDA, 2015). It is interesting to note that this company didn't participate in the two meeting organized in the industrial area. This was due to the fact that at that time E38.054 didn't have a specific area manager (appointed in early 2016). It was possible to involve this company later thanks to some information given by the company D35.009. In the later period, I informed the heads of this company on industrial symbiosis activities in the area up to that moment and the company has given its consent to be involved.

Business as usual. The company C10.014 has 28,18 tons per year of wood packaging that are disposed with EWC 150103 through a company that recycles them. This company is not located in the industrial area. Wood packaging are predominantly EPAL pallet not reusable (C10.014 reuse the reusable EPAL pallets). There is a certain amount of pallets with different sizes that are intact and reusable but that it does not use for its business. The annual expenditure for the disposal of wood packaging is about 3.100 euro per year.

The company C16.023 has shavings, sawdust and virgin wood to approximately 200 tons per year. This resource is classified as a by-product with PRODCOM code 16211449 concerning fibreboard of wood or other ligneous materials (excluding medium density fibreboard [MDF]), whether or not bonded with resins or other organic substances, of a density not exceeding 0,5 g/cm³. Sometimes the company has a problem to classify this resource as a by-product or waste (eventually it is classified as waste with EWC code 030105 concerning sawdust, shavings, cuttings, wood, particle board and veneer). For a correct interpretation of the law, the company asks a chemical certifying expert in the special waste field as well as the support of some associations. Currently this resource is used within the company as fuel for self-produce hot water for heating and drying. In this way the company saves on the methane and heating costs and has no cost for the disposal of this resource. The storage operation cost of this resource in the company is the only cost that this enterprise could have. This cost is mainly caused by excessive amounts of this resource produced. For this reason the company is also considering to reduce its economic activity. The company could also give freely the amount of resource that exceeds its corporate needs. By the support of another company of industrial area, C16.023 is also considering the possibility of developing its own plant to produce cooling purposes from its boiler.

The company C20.032 has pruning and pallets but not large amounts. The company has however a cost of disposal. Pruning is currently disposed of in landfills.

The company C25.008 has pruning for a quantity of 10 tons per year. Pruning takes place every six months. This enterprise has costs for the disposal of 50 euro per ton around that the company pay to a company which is not located in the industrial area.

The company C26.026 has pruning for an amount of 2 tons per year. Currently this resource is disposed of in landfills. It is estimated a total cost for pruning and disposal of 560 euro that the company pay to a company which is not located in the industrial area.

The company C28.017 has 40 tons per year of wooden packaging (cratesand pallets) which are disposed with EWC code 150103 through an industrial company in the industrial area that recycles them. As noted in the previous section the crates could be reused. The pallets are partly reusable (these one are pallet different from EPAL pallets that are not used by the company) and in part are broken and not reusable. The company has a cost for the disposal of wood packaging of about 5.000 euro a year approximately. The company would also give free pallets and reusable wooden crates to other companies.

The company G46.046 has 20 tons per year of pallets and wooden panels that are disposed of in landfills with EWC 170201 relating to wood. The disposal is carried out by a company located in the province of Viterbo. It is estimated that the G46.046 has a disposal cost of approximately 1720 euro.

The company E38.054 is an environmental manager having a facility where it carries out the following activities:

- to recover cellulosic biomass from wood cuttings and prunings or from untreated wood and forestry which are classified as non-hazardous waste;
- to take advantage the wood biomass from agricultural and forestry, which are not waste but products;
- to put in reserve and start to recover in an external system the treated wood from recycling.

The plant has three production lines:

- Line 1 for compost which can be fed by 3.000 tons for year of plant-tissue waste (EWC 020103), wastes from forestry (EWC 020107), waste bark and cork (EWC 030101), sawdust, shavings, cuttings, wood, particle board and veneer (EWC 030105), wooden packaging (EWC 150103), biodegradable waste (EWC 200201);
- Line 2 for putting in reserve of wood waste that can be fed by 10.000 tons for year of waste bark and cork (EWC 030101), wooden packaging (EWC 150103), wood (EWC 170201, 191207 and 200138);
- Line 3 for the production woody biomass. it has no limit.

As for the price that this company does charge to other companies to provide its services (mainly the cost per ton for inserting and the transport cost per each trip) these vary according to the type of customer and treated quantities.

As regards the revenues that gets from the sale of resources obtained from recovery operations:

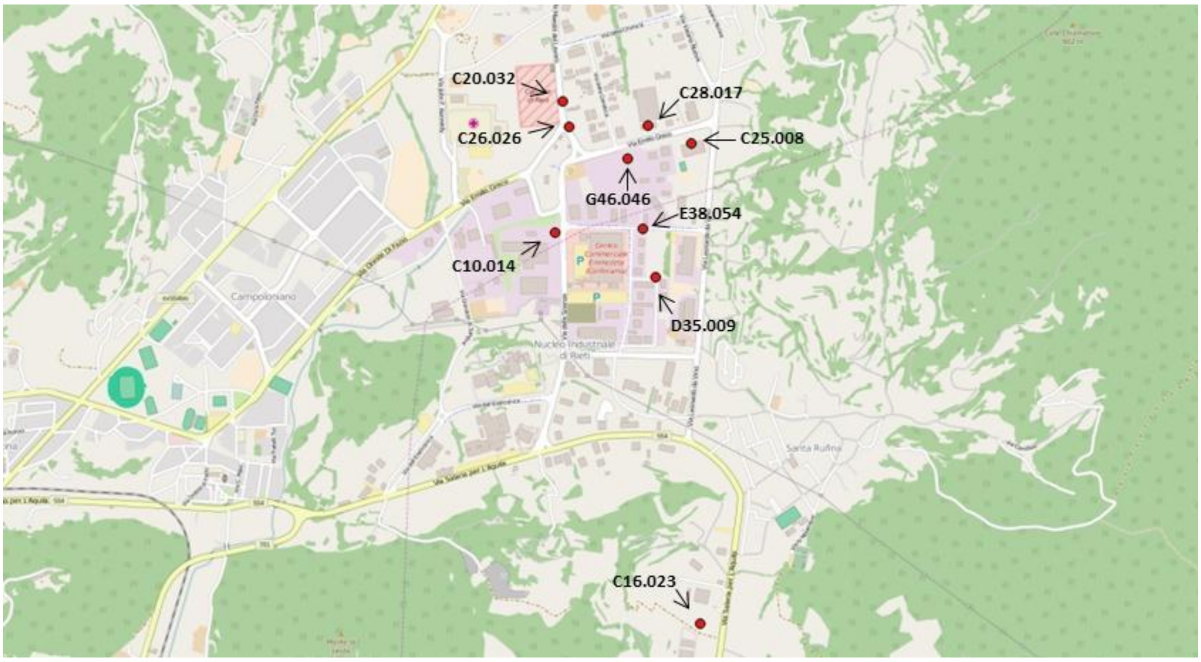
- the sale price for the compost is about 25-30 euro per ton (excluding transport and VAT);
- the selling price of biomass for use as fuel varies from 30 to 60 euro per tonne (the price varies a lot in relation to the amount of biomass that power plants already have);
- the selling price of biomass to the chain of chipboard panels depends on the type of wood sold.

The company D35.009 has a plant for the production of electricity from wood biomass of a 1 MW electric. This plant is mainly fed by 50 tons per day from pruning and 15 tons day from tree trunks. The biomass collection is mainly carried out by the Company E38.054.

It's important to note that the output companies do not have economic relations with E38.054. It is likely that this is partly due to the fact that the company has settled in the industrial area in 2011 and Province of Rieti has issued permission to carry out the business in December 2012. He was also appointed a specific charge of only at the beginning of 2016. In addition a specific area manager was appointed only at the beginning of 2016. The companies 38.054 and D35.009 have economic relations between them. D35.009 has settled in 2011 in the industrial area as well and it carries out its business from 2013.

Efficiency improvement description. Efficiency improvement of the woody biomass management was identified and developed later than the round tables. This pathway concerns nine companies of the industrial area of Rieti-Cittaducale (see Figure 6.8): seven output companies (C10.014, C16.023, C20.032, C25.008, C26.026, C28.017, G46.046); one input company (D35.009); and an input-output company that acts as an intermediary (E38.054).

Fig. 6.8. Geo-referencing of the companies potentially involved in the pathways of industrial symbiosis concerning efficiency improvement of the woody biomass management.

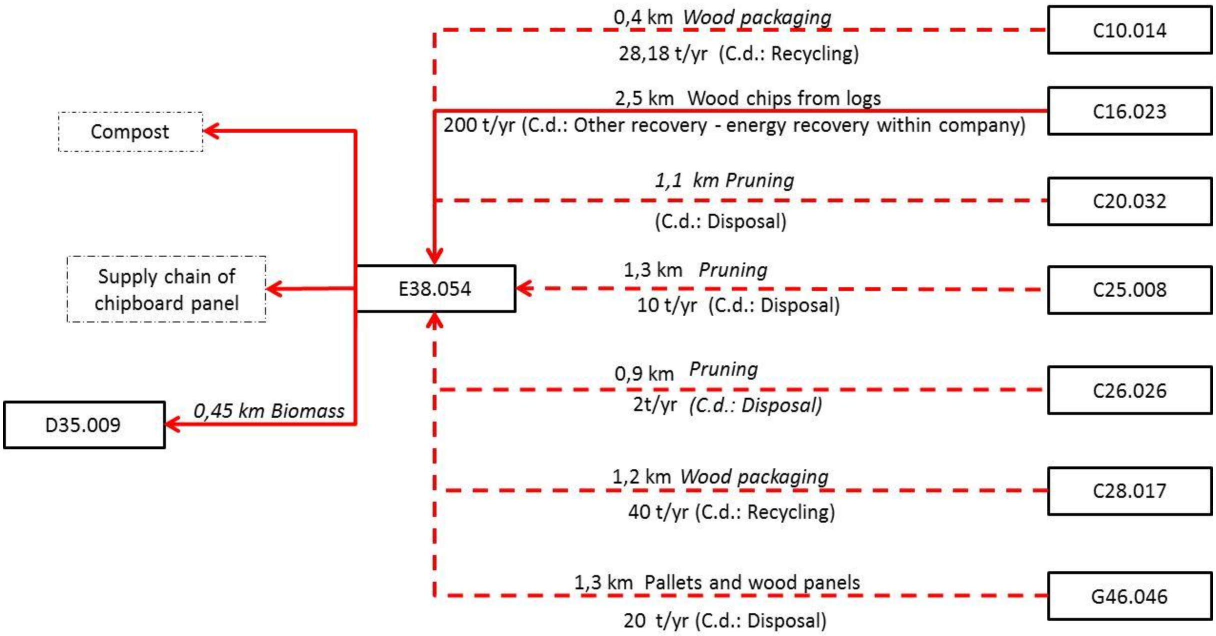


Source: Own elaboration through QGIS software (QGIS, 2016)

Six of these companies carry out economic activity in the manufacturing industry; a company carries out economic activity in the production of electricity; a company carries out economic activity in the industry of waste management; and finally another one carries out activities in wholesale.

The possible industrial symbiosis path implies that the seven output companies can give their biomass to E38.054. Thus, this company can use this resource to produce compost, to insert it into the chipboard panel supply chain or to produce wood biomass as fuel for the company D35.009 (see Figures 6.9).

Fig. 6.9. Flowchart of the woody biomass



The seven output companies are distant compared to E38.054 by road between a maximum of 2,5 kilometers and a minimum of 400 meters. The distance between E38.054 and input company D35.009 is around 450 meters, although the two companies are geographically contiguous. With the exception of the flow coming from C16.023, the resource flows from the other output companies are batches. The offer of the waste management service by E36.054 can meet the demand of the output and input companies.

In particular as regards the demand of the output companies a service is estimated regarding the treatment of the following aggregate quantities: i) wood packaging as EWC 150103 for approximately 68,18 tons per year; ii) wood obtained from construction operations as EWC 170201 roughly for 20 tonnes per year; iii) biodegradable wastes obtained from gardens and parks as EWC 200201 roughly for 12 tonnes per year; iv) fibreboard of wood or other ligneous materials as PRODCOM 16211449 approximately 200 tons per year.

Tab. 6.7. Economic assessment on the efficiency improvement of the woody biomass management for the output companies

Output Companies	Waste and By-products	BAU			Symbiotic Scenario				
		Unit (ton)	Unit price (€/ton)	Total (€)	Unit (ton)	Unit price (€/ton)	Total (€)	Δ€	Δ%
C10.014	*EWC 150103*	*28,2*	*110*	*3.100*	*28,2*	*110*	*3.100*	*0*	
C16.023	*PODCOM 16211449*	*200,0*	*0*	*0*	*200,2*	*0*	*0*	*0*	
C25.008	*EWC 200201*	*10*	*50*	*500*	*10,0*	*50*	*500*	*0*	
C26.026	*EWC 200201*	*2,0*	*50*	*100*	*2,0*	*50*	*100*	*0*	
C28.017	*EWC 150103*	*40,0*	*125*	*5.000*	*40,0*	*110*	*4.400*	-600	-12
G46.046	*EWC 170201*	*20,0*	*86*	*1.720*	*20,0*	*86*	*1.720*	0	
Overall costs				***10.420***			***9.820***	**-600**	**-6**

Tab. 6.8. Economic assessment on the efficiency improvement of the woody biomass management for the input company

Input Company	Goods and Services	BAU			Symbiotic scenario				
		Unit	Unit price (€)	Total (€)	Unit	Unit price (€)	Total (€)	Δ€	Δ%
E36.054	*Waste management service*			*0*			*9.820*	*+9.820*	
Overall revenues				***0***			***9.820***	***+9.820***	

Economic assessment. Based on the data available to date and considering only the side of the industrial symbiosis pathways concerning E36.054 and output companies[47] (See Figure 6.9).

At the economic level, the current economic value of this industrial symbiosis pathway is approximately 10.420 euro (see Tables 6.7 and 6.8).

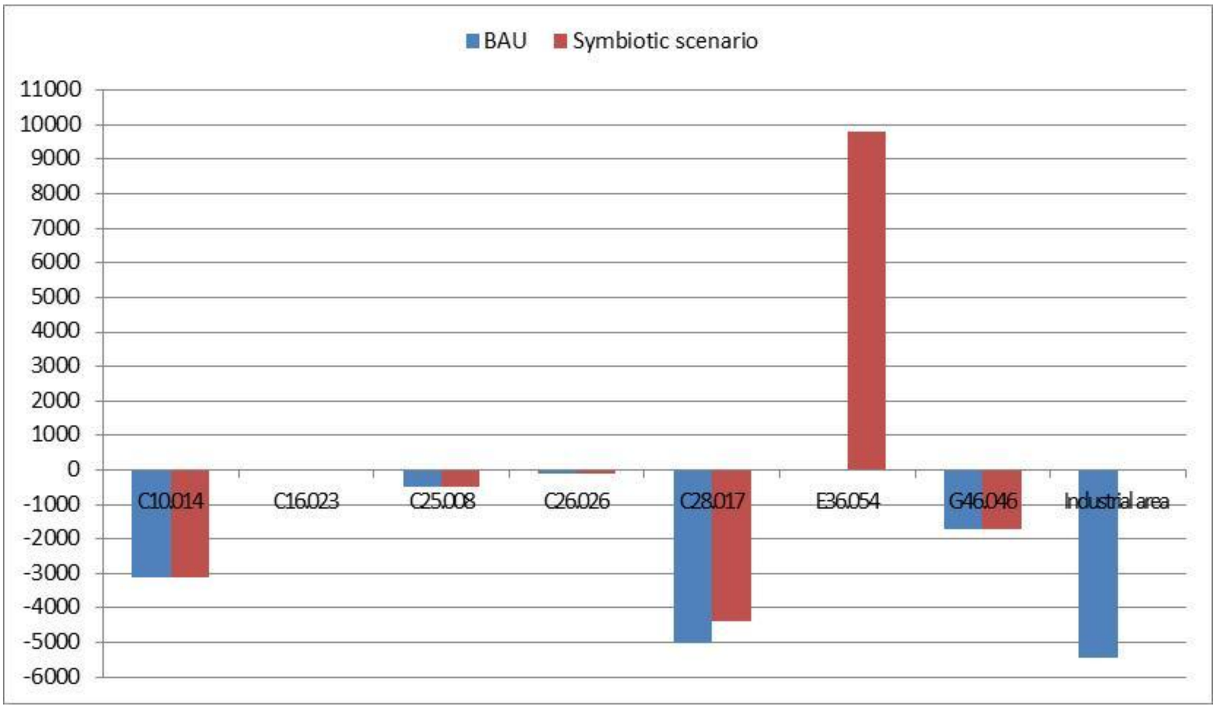
Based on the BAU scenario the companies involved have a total cost to dispose of and treat their waste equal to 10.420 euro.

If we consider the industrial area as a whole the current scenario determines costs equal to 5.420 euro. This is due to the fact that only the company C28.017 manages its waste through one of others companies of the industrial area.

To begin the process of industrial symbiosis, we assume that:

- the company E38.054 fixes a price approximately equal to the price that the output companies pay to dispose and treat their waste in the BAU scenario;
- the unit cost of waste management is for each waste equal to the lowest price paid in the BAU scenario and the same for each company.

Fig. 6.10. Profitability changes related to the efficiency improvement of the woody biomass management for the output and input companies and the industrial area



[47] We exclude company C20.032 because we have not enough data available.

On the basis of these assumptions, in a symbiotic scenario we note that (see Figure 6.10):

- the company E38.054 increases revenues for about 9.820 euro;
- the total cost paid by all firms amounts to 9.820 euro which is less than the BAU scenario for about 600 euro (the lower costs are only for company C26.017);
- as a whole the industrial area has lower costs or higher revenues for about 5.420 euro.

Environmental assessment. At the environmental level (see Table 6.9 and Figure 6.11), based on BAU scenario, 68,18 tons of wood packaging are recycled; 200 tons of wood processing by-products are used as fuel for heating and drying within the company that produces them; and 32 tons of biodegradable and demolition waste are disposed of in landfills.

In a symbiotic scenario, we have a better waste management because 32 tons of biodegradable and construction waste would not be disposed of in landfills but recycled.

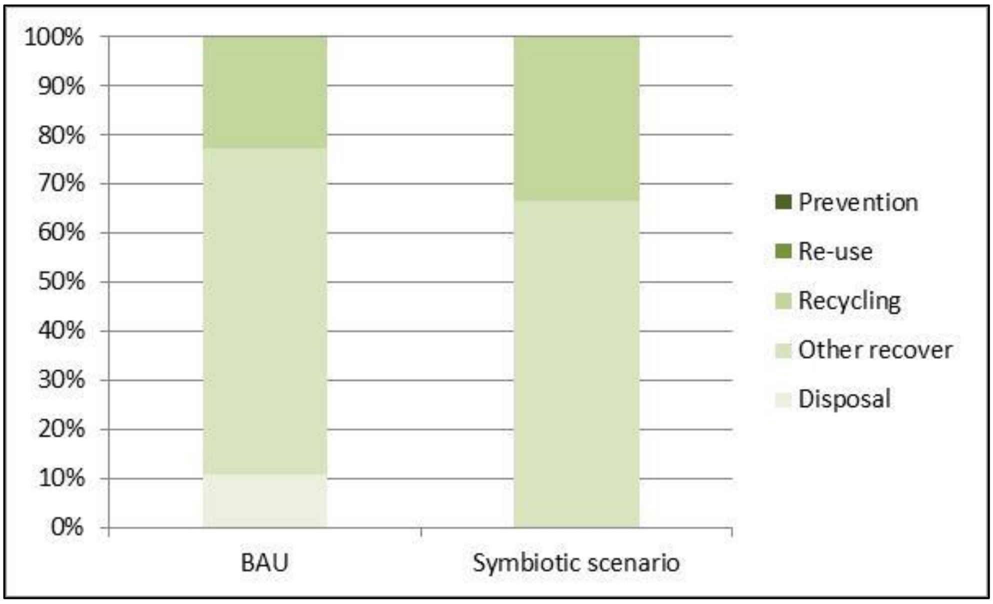
As for the C16.023 enterprise, it would continue to use its by-product as fuel within the company. It is interesting to note, however, that at a price equal to zero a part of by-products could be recycled because the company has a storage cost for excessive amount of by-products generated.

According to the european waste hierarchy, this would lead to an improvement in the management of this quantity because it would not be used for energy recovery but to be recycled.

Tab. 6.9. Environmental assessment on the efficiency improvement in the woody biomass management based on the EU hierarchy of waste

EU Waste Hierarchy	BAU	Symbiotic scenario		
Priority order	*Tons*	*Tons*	*Δ*	*Δ%*
Prevention	***0,0***	***0,0***	***0,0***	
Re-use	***0,0***	***0,0***	***0,0***	
Recycling	***68,2***	***100,2***	***+32,0***	***+46,9%***
Other recover	***200,0***	***200,0***	***0,0***	***0,0%***
Disposal	***32,0***	***0,0***	***-32,0***	***-100,0%***

Fig. 6.11. Changes in waste management relating to the efficiency improvement in the woody biomass management



Considerations. When I spoke by phone with company delegates they were interested in the possible paths that can lead to a better management of waste generated by them. This is also true for companies with low amounts of available biomass.

To date, primarily for data confidentiality reasons, the companies involved in this path does not know who is the other company involved.

At the regulatory level the main reference legislation is the Legislative Decree 152/2006. This industrial symbiosis path is based on activities already carried out by the E38.054 within the industrial area. This company has all the necessary permissions to implement this industrial symbiotic pathway.

In terms of logistics, at moment the main barriers are non-continuous and non-programmability of resource flow over time. This may result in higher transaction costs.

Finally it is important to highlight that the economic and environmental assessment on this process of industrial symbiosis focused only on the relationship between E38.054 and output company. At the time, it did not take into account the other side of the path, that is, the relationship between the E38.054 and D35.009. It is necessary to pay attention also to the transaction costs of the output companies involved by moving from their current suppliers to E38.054.

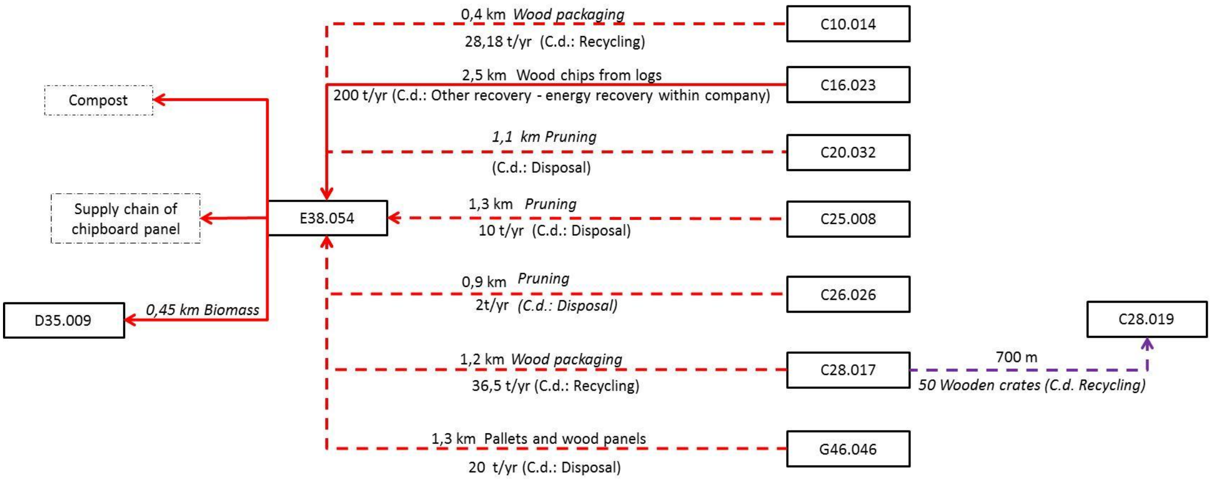
6.3 From a possible industrial symbiosis pathway to a possible circular economy one

Based on the data available, it is important to note that with regard to waste classified as wood packing or as wood from construction there are pallets and crates intact and reusable. As shown previously this can potentially lead to further synergies regarding these resources.

Fig.6.12. Geo-referencing of the companies potentially involved in the new industrial symbiosis pathway

Source: Own elaboration through QGIS software (QGIS, 2016)

Fig. 6.13. Resource flow chart in the new industrial symbiosis pathway



As for the pallets it is necessary to make a distinction between EPAL and not EPAL.

The EPAL pallets are the most used for the store and move goods. Based on the data obtained from the companies in the industrial area of Rieti-Cittaducale there is a demand for this resource equal to 9490 units for a market value estimated at for 123.370 euro. Through the potential synergies identified only a very small part of the demand would be met by other companies.

As for pallets of different dimensions by EPAL, the question is approximately 300 units per year. It is estimated a market value equal approximately 5.200 euro.It is important to note that this need could be met by other companies of the industrial area of Rieti-Cittaducale through industrial symbiosis pathway (currently over 700 pallets no EPAL have been identified).

This would also lead to better environmental management of these resources that would be reused instead of recycled or disposed of in landfills. In terms of logistics it is always highlight that these resources are no-continuous and no-programmability. In terms of logistics it is always to highlight the need for further information on the quantities relating to the different sizes of pallets that are asked or offered by companies.

We suppose to integrate the results obtained from previous industrial symbiosis pathway relative to the wooden crates and woody biomasses.

We can note that in this new industrial symbiosis path would be involved 10 companies (see Figure 6.12).

It is interesting to note that the company C28.017 is involved in both types of symbiosis (see Figure 6.13).

Based on the assumptions made in the previous paragraphs, this new industrial symbiosis path can lead to the following economic and environmental results.

Economic assessment. At the economic level (see Tables 6.10 and 6.11 and Figure 6.14), the current economic value of this new industrial symbiosis pathway is approximately 25.420 euro.

According to the BAU scenario, the companies involved have total costs for the waste management approximately for 25.420 euro. Industrial area has total costs for approximately 20.420 euro. The companies involved in the new industrial symbiosis pathway have lower costs for 15.985 euro and higher revenues for about 9,435 euro. The industrial area as a whole would have lower costs and higher revenues for 20.420 euro.

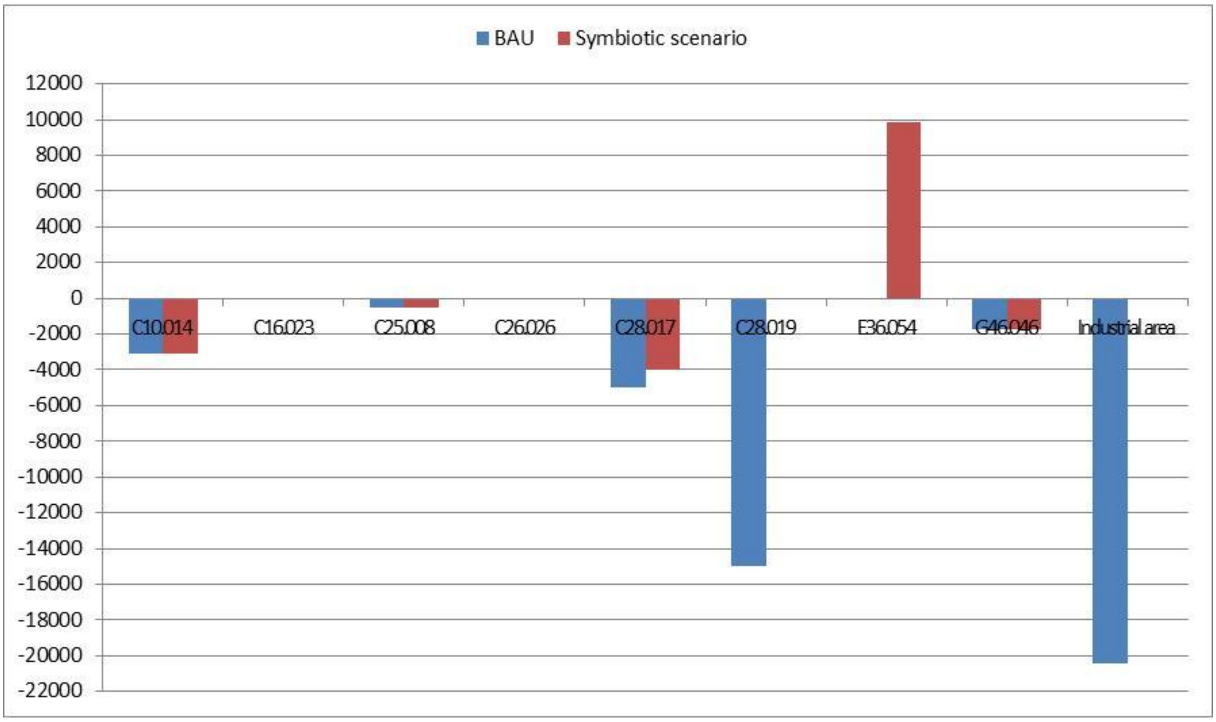
Tab. 6.10. Economic assessment on the new industrial symbiosis pathway for the output companies

Output Companies	Waste and By-products	BAU			Symbiotic Scenario				
		Unit (ton)	Unit price (€/ton)	Total (€)	Unit (ton)	Unit price (€/ton)	Total (€)	Δ€	Δ%
C10.014	*EWC 150103*	*28,2*	*110*	*3.100*	*28,2*	*110*	*3.100*	*0*	
C16.023	*PODCOM 16211449*	*200,0*	*0*	*0*	*200,0*	*0*	*0*	*0*	
C25.008	*EWC 200201*	*10,0*	*50*	*500*	*10,0*	*50*	*500*	*0*	
C26.026	*EWC 200201*	*2,0*	*50*	*100*	*2,0*	*50*	*100*	*0*	
C28.017	*EWC 150103*	*40,0*	*125*	*5.000*	*36,5*	*110*	*4.015*	-985	-19,7%
G46.046	*EWC 170201*	*20,0*	*86*	*1.720*	*20,0*	*86*	*1.720*	0	
Overall costs				***10.420***			***9.435***	**-985**	**-9,5%**

Tab. 6.11. Economic assessment on the new industrial symbiosis pathway for the input companies

Input Company	Goods and Services	BAU			Symbiotic Scenario				
		Unit	Unit price (€)	Total (€)	Unit	Unit price (€)	Total (€)	Δ€	Δ%
C28.019	*Wooden crates*	*50*	*300*	*-15.000*	*50*	*0*	*0*	*+15.000*	*-100,0%*
E36.054	*Waste management service*			*0*			*9.435*	*+9.435*	
Overall revenues				***0***			***9.435***	***+ 24.435***	

Fig.6.14. Profitability changes related to the new industrial symbiosis pathway for the output and input companies and the industrial area



Environmental assessment. At the environmental level (see Table 6.12), in a Business as Usual there are approximately:

- 64,18 tons of waste that are recycled;
- 200 tons of by.product from wood processing that are used as fuel for energy recovery;
- 32 tons of waste sent for landfill.

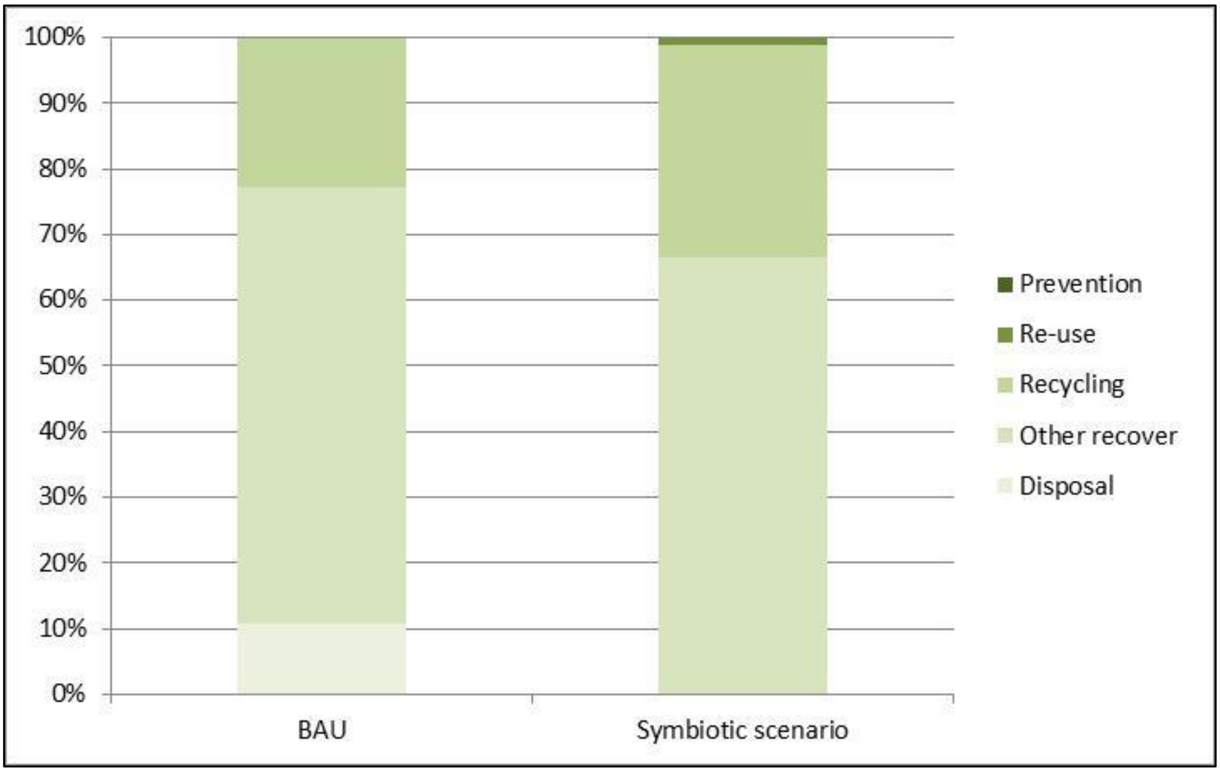
Tab. 6.12. Environmental assessment on the new industrial symbiosis pathway based on the EU hierarchy of waste

EU Waste Hierarchy	BAU	Symbiotic Scenario		
Priority order	tons	tons	Δ	Δ%
Prevention	*0,0*	*0,0*	*0,0*	
Re-use	*0,0*	*3,50*	*+3,5*	
Recycling	*68,2*	*96,7*	*+28,5*	*+41,8%*
Other recover	*200,0*	*200,0*	*0,0*	*0,0%*
Disposal	*32,0*	*0,0*	*-32,0*	*-100,0%*

In a symbiotic scenario if we assume the simultaneous activation of both the two pathways of industrial symbiosis we note an improvement in the management of waste (see Figure 6.15) due to:

- a reduction of 32 tonnes of biodegradable and construction waste disposed of in landfill;
- recycling of a part of the wood byproducts which are currently used for energy recovery;
- reuse of about 50 wooden crates equal to 3,5 tonnes of wooden packaging which would not be recycled.

Fig. 6.15. Changes in waste management relating to the new industrial symbiosis pathway



In conclusion it is important to make the following considerations.

The company 35.009 has submitted an application to the Province of Rieti for permission regarding a project of tele-heating and tele-cooling of which six of the businesses participating in the first round table showed interest (including the company C16.023).

In the industrial area there are: a total of 10 companies carrying out economic activities in the wood industries including furniture production; one company that carries out activities in logging; three companies working in the recovery of sorted materials and treatment and disposal of non-hazardous waste; 90 companies working in the same category of economic activity of other companies potentially involved in the industrial symbiosis pathway relating to biomass, pallets and wood crates.

In the industrial area the company operating in the municipal waste management for the municipality of Rieti is also settled. There is also an university pole where the main degree programs are related to forestry sciences and technologies and building engineering for sustainability.

The chipboard panel can be used in the production of wooden crates and pallets, as well as for furniture and fixtures or used in green building (Rilegno, 2014).

In the regulatory plan concerning the industrial area the creation of a naturalistic-agricultural park is planned.

The compost can be used for agriculture and forestry. The production site is located in the Apennines where there are also several protected area. Agriculture and forestry have an key importance in the local economy of the province of Rieti.

Thus, the integration and development ecosystem of these and other tangible and intangible assets in the province of Rieti could form an important basis for implementation of a circular economy pathway aimed at the closing the wood loop and in which the industrial area of Rieti-Cittaducale can playing a leading role

Conclusions

In the coming decades one of the main challenges for the world economy will be that of a decoupling between economic growth, environmental impact and natural resource consumption. To achieve this objective, it will be necessary to adopt strategies and industrial policies that promote a more efficient use of resources, avoiding excessive human pressure on biodiversity, ecosystems and the services they provide; thus focusing on the natural capital, which is a key concept of the green economy. With regards to this objective, it is important to note that the extent of human impact on environment depends on three factors: the population; the consumption (i.e. lifestyle); the efficiency with which natural resources are converted into goods and services that depends mainly on the technology used. Coherently with this direction, at the international level, we are gradually moving from a linear economy to a circular economy that, through new lifestyles and a more efficient use of resources, aims to reduce the pressures on biodiversity and the marine and terrestrial ecosystem services. Repeating constantly the pattern *take-make-dispose*, the linear economy is a system in which the life cycle of a product ends when it is consumed, becoming a waste. On the contrary, in the circular economy all the activities are organized in such a way that the waste of somebody becomes resources for someone else, starting from the extraction, the design and the production. In this way, the traditional concept of waste ideally disappears because the goods exchanged are never, in any time of their lives, considered as waste, but always as economic goods.

So in order to answer the first research question we have explained the importance in moving from a linear economy to a circular economy through industrial symbiosis. To move towards a circular economy the industrial symbiosis is one of the most powerful tools that "*engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity*" (Chertow, 2000, p. 313). We may consider the industrial symbiosis as the most explicit implementation of industrial ecology in a territorial perspective. Industrial symbiosis differs from the more traditional *greening* industrial initiatives because it is realized through the cooperation among companies not focusing on actions at individual company level. In this field, indeed, companies are viewed as nodal points within an ecosystem network.

Within this framework, in order to answer the second research question we have identified some of economic concepts that can be used to explain the industrial symbiosis at the regional level. In this regard it was important to highlight the contribution that spatial economics provides to the implementation of possible pathways of industrial symbiosis. Methodologies related to this branch of the economy in fact give a considerable contribution to a better assessment and maximization of the different impacts the symbiosis determines at the company level and at the regional level. More specifically, we emphasized the importance of the economies that arise from spatial proximity and that result in a significant reduction of production costs (i.e. the transportation costs of activities operating in closely concentrated supply chains) and transaction costs (i.e. the costs of market transactions due to information gathering) made possible by the powerful synergy effects that such proximity can generate. These are key concepts that are at the basis of industrial symbiosis. It was so crucial to review the different approaches used for the spatial interpretation of economic phenomena (physical-metric space; uniform-abstract space; diversified-relational space, diversified-stylized space) and the main economic theories that are at the basis of spatial analysis (location theory, and regional growth - and development - theory). We focused particularly on the theories of regional economics describing more effectively the role played by industrial organizations working at territorial level: the industrial location theory and the theory of local development. As to the first theory, we highlighted above all the two great economic forces that influence the industrial organization in the space: agglomeration economies and transport costs. As for the second theory, we especially focused on the role played by some main factors in fostering a greater local development: infrastructure and new communication technologies as exogenous factors; and static and dynamic efficiency as endogenous factors.

It was interesting to notice that, despite obvious relevance for the regional science, industrial symbiosis has generated little interest among economists and geographers with a few exceptions. This situation is paradoxical because since the middle of the nineteenth century, several economists and geographers discussed in some depth both the processes described in the industrial symbiosis literature, as well as the theoretical concept. It is important to note that although advantages of co-locating businesses is nothing new to economic geographers and regional development specialists, "*the concept of industrial symbiosis enhances the concept of agglomeration economies by expanding its scope to* *include environmental benefits, thus lessening the impact of negative agglomeration externalities while increasing production efficiency*" (Chertow et al., 2008, p.1303).

In order to answer the third research question we have shown the most interesting initiatives of circular economy and industrial symbiosis at different territorial scales. In the last few years circular economy and industrial symbiosis have increasingly become an important part of the international, national, regional and urban institutions' agendas. According to the United Nations the industrial symbiosis supports a number of Sustainable Development Goals, in particular the target 12, which is about sustainable consumption and production patterns. In June 2015, the G7 Leaders, under the German presidency, established a G7 Alliance on Resource Efficiency. As follow-up of this initiative a series of workshops about the best practices have been organized. The first of these events was, indeed, an industrial symbiosis workshop held in Birmingham in October 2015. Also China has focused much on the concept of circular economy. As confirmation of this, in 2008 China has adopted the *Circular Economy Promotion Law*, the first law of its kind in the world. According to the European Union the transition to a circular economy is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. In order to achieve these objectives and to stimulate Europe's transition, in December 2015, the European Commission adopted an ambitious new Circular Economy Package called "Closing the loop".

Among the most important successful cases regarding the industrial symbiosis implemented at the local level, there are certainly the model of industrial symbiosis realized in the eco-industrial park at Kalundborg in Denmark representing the first concrete realization of an industrial ecosystems; and the Guigang Group, a state-owned sugar company based in southern China, that has become the first national pilot eco-industrial park in this country.At the regional level, successful cases are the NISP in United Kingdom, the world's first national industrial symbiosis programme in order to facilitate symbiotic exchange over a given geographic area; and ENEA experiences of industrial symbiosis in Italy where in Sicily and Emilia Romagna two projects of industrial symbiosis have been developed and implemented through a network approach. In particular ENEA has created the first regional platform of industrial symbiosis in Italy, which in 2014 has been cited as a good practice by the Eco-Innovation Observatory.

In order to answer the fourth and the fifth research questions, we relied mainly on Enea's industrial symbiosis experiences (based on a regional prospective) and on some tools indicated by Marian Chertow in her works. We have adapted and applied this methodology on a specific industrial area. It's important to highlight that to verify if there were some possible pathways of industrial symbiosis to be implemented in the industrial area of Rieti-Cittaducale (the case study) it was crucial the collaboration agreement among the Consorzio di Sviluppo Industriale della Provincia di Rieti, the University of Tuscia and ENEA.

The methodology used in industrial area of Rieti-Cittaducale was based on three main steps: i) carrying out a stakeholder process; ii) representing a state-of-the-art of the territory; iii) identifying some possible symbiotic scenarios in the industrial area. Thus, first of all, we have aimed at promoting awareness and active participation of the Consortium, the managing institution of the industrial area, and the 266 companies actives located in the productive site. Then we described the territorial context where the industrial area is situated and we drew up an industrial inventories in this productive site. Finally, after two meetings with companies from different industries (electronics, pharmaceuticals, mechanics, wood, energy, food, chemical, plastic, wholesale, construction, waste management, education, etc.), we identified, analyzed and assessed the possible industrial symbiosis pathways to implement in the industrial area.

Five possible industrial symbiosis pathways could be implemented in industrial area of Rieti-Cittaducale. Four of these paths concern the re-use of the resources (pallet EPAL; pallet having other dimensions; wooden crates; cardboard boxes). One possible industrial symbiosis path, having as symbiotic scenario a more efficient waste management within the industrial area, concerns the woody biomass.

It is important to highlight that due mainly to the limited time and the data available, it was not really possible to implement the industrial symbiosis pathways identified, and they are not fully estimated the economic and environmental effects that these pathways can have at the local level. However, to begin to assess the potential impact that these paths can have, some simple analyzes have been made aimed at evaluating the possible economic and environmental impacts of two possible industrial symbiosis pathways identified and that they could be activated realistically in the short term: wooden crates and woody biomass.

Based on the data available, the implementation of these two industrial symbiosis pathways would lead to interesting economic advantages for companies, in terms of lower costs or higher revenues, and environmental benefits for the industrial area, in terms of more efficient use of resources. These effects could be greater if they were projected at the level of entire industrial area so as to justify probably a public intervention.

On this point, it is interesting to note that in November 2015 the CUEIM (*Consorzio Universitario di Economia Industriale e Manageriale*) submitted an industrial symbiosis project for the industrial area of Rieti-Cittaducale to a Call for Proposal of the Lazio Region (*"Sostegno al riposizionamento competitivo dei sistemi imprenditoriali territoriali"*). Based on the data collected through this research at that date, this project estimated the following overall economic effects: possible industrial symbiosis among companies of the industrial area for approximately a thousand; investments for roughly 2.5 million €, 20% of which come from external capital; investments for each synergy activated equal to € 2000-3000; a reduction in supply costs of raw materials and energy, equal to approximately 20% of the investment needed to activate synergies.

This research has certainly the following critical points. Although we worked with the willing, not all companies active in the industrial area have participated in meetings. We have not analyzed in detail the production processes of companies, going into their production sites. The lack of resources and logistics needed to carry out more accurate research activities by working on the territory. The limited time had in order to obtain other data from companies, to analyze in depth the obtained data, and in particular to implement some of the industrial symbiosis paths already identified. Lack of data to better clarify the economic and environmental potential of the identified industrial symbiosis pathway and to identify further synergies. In particular on the economic side: there is the need to further deepen the costs of transport and logistics required for the realization of symbiosis paths; although this research has reduced certain some research costs of companies in for the identification of possible symbiotic partners, there is the need to further analyze the transaction costs in moving from supply chain as usual to symbiotic supply chain with other firms working in traditionally separate industries. Closer examination on regulatory and logistical issues related to the identified synergies. The current negative economic phase having a negative impact on the participation of the companies (above all SMEs) in these types of research projects because of the limited number of available staff for other activities.

In conclusion, as regards the possible next developments it's crucial the implementation of the synergies identified in order to monitor the results. To achieve this goals it is considered appropriate to organize a round tables with companies involved in industrial symbiosis paths and with the Consortium where they can also highlight critical issues or any shortcomings, and make suggestions or other observations they consider useful. In particular to facilitate the implementation of some types of synergies identified by this research, that are typified mainly by the no-continuity and no-programmability, an enabling condition can be the creation of a *community warehouse* in the industrial area of Rieti-Cittaducale. In an EEIA's perspective, the creation of a structure used in common by all enterprises where enterprises can deposit and share reusable resources (such as wooden crates, pallet, cardboard boxes, ect.) can lead to a greater resource efficiency and, through an ITC platform, to a sharing economy that can reduce, in addition, the warehouse management cost of the individual company.

In order to provide a better support to development policies in the area, another next key step it is certainly a more accurate economic and environmental assessment of the impacts of industrial symbiosis paths both at company level and at territory level, also based on life cycle thinking approach such as life-cycle assessment and life-cycle costing.

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