Potential for Implementing an Industrial Symbiosis Network
in Rural Portugal

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Muito obrigado
Potential for implementing an Industrial Symbiosis network in rural Portugal
Abstract

Industrial Symbiosis (IS) is a tool that may facilitate coordination of the factors necessary to improve resource use efficiency at regional levels. This thesis studies the potential of developing an IS network in rural Portugal, that could support the competitiveness of the local companies, whilst also improving their own and the regions environmental profile.

The research is based on a hybrid of action research and case study research. It analyses the special case of the municipality of Reguengos de Monsaraz and the factors crucial for the development of a IS network at the regional level. These factors are linked to domains such as technical, informational, economic, political/organisational and institutional. The research identified and worked with eleven organisations in the region: five private, three public/private joint ventures, two government bodies and one non-governmental organization

The following crucial factors for the implementation of an IS network were shown to exists in Reguengos de Monsaraz: Engagement of the various stakeholders, identification of their own inter-organisational connections, the willingness of the local administration in taking part or supporting such a project, the availability of economic gains for stakeholders, the available economic aid from national or European funds and the degree of awareness various companies had regarding the resources available, their quantities and the needs of each other. With all these factors identified, the research concentrated on setting the foundation that can support further developments leading to the emergence of an IS network. Rather than direct exchanges between companies, the research is focused on the creation of central infrastructures for the revalorisation of waste streams into valuable products. The research project also provides partial analysis related to certain technologies that could enable synergistic inter-organizational relations.

Keywords: Industrial symbiosis, network, sustainable region
Potential for implementing an Industrial Symbiosis network in rural Portugal
Executive Summary

Industrial Symbiosis (IS) is a tool that may facilitate coordination of the factors necessary to improve resource use efficiency at the regional levels, and thus contribute to more sustainable growth in rural areas. This thesis focused on studying the potential of a particular area of Portugal to develop a network based on the IS concept and harvest benefits that could support the competitiveness of the local companies, whilst also improving their own and the regions environmental profiles. In order to achieve this, two main research questions were posed:

1. What is the potential of Industrial Symbiosis to contribute to the sustainability in Reguengos de Monsaraz?

2. How could this potential be realised?

In answering these questions, an extensive literature review was first conducted to establish a conceptual framework that encompassed several related themes such as Regional Sustainable Development, Industrial Ecology and Industrial Symbiosis. Second, a brief overview of the present situation of the research area (a rural Portuguese region) was gained. This research consisted of a hybrid of action research and case study research, due to the fact that it focused on a particular area and that it was conducted in a way that allowed active contribution from the author, working together with the participants.

As IS is a tool that could enable replacement of virgin materials with by-products or waste, through the identification of synergies and consequently the creation of linkages, it could increase efficiency and reduce resource use, thereby contributing to sustainability. There are, however, several factors crucial for the development of a IS network at the regional level. These are rooted in different domains such as technical, informational, economic, political/organisational and institutional. IS is a tool that should always be striving for improvement in efficiency and in the identification of new potential synergetic collaborations. Thus, raw materials availability, waste management, logistics or infrastructures that may enable the identification of new synergies should be constantly reviewed. The right institutional setting must also be in place, or conditions for its creation should be arranged, so that inter-organisational business partnerships may be created and go further than any single resource input/output exchange. In this way, an entire network of utilities, jobs and in some cases even new products or services, can be created.

To answer the first question, it was necessary to identify the industries in Reguengos de Monsaraz that might have a chance for economic profit through process improvements and collaborations, whilst at the same time enhancing their environmental profile. The identification of other main actors, such as political decision makers or regional development agencies was also required. Eleven organisations were identified within the geographic boundaries of the Reguengos de Monsaraz municipality. Each of these organisations were approached and attracted to the project. Information about different needs and capacities of these organisations were collected through interviews, questionnaires and observations.

From the analysis, performed on the potential for creating exchanges for some of the by-products and wastes currently produced and discharged, a number of potentials to convert currently wasted biomass, sludge and organic waste streams into valuable products were identified. A simple analysis was performed on the synergies that might be generated amongst the companies and some potential economic considerations where undertaken. The research
uncovered, amongst others, a sizable potential to generate electricity with the currently available biomass. This potential was estimated to be approximately two times more than the energy currently consumed annually by all the companies engaged in the research project. Taking into account the available quantities of biomass, its energetic qualities, and the necessities expressed by each of the companies, a scenario for the production of electricity, heat and cold from this wasted biomass was suggested and analysed. Guidance regarding the use of technologies (such as cogeneration plants and biogas digesters) that have been implemented in other countries under similar input/output situations, as well as some economic data related with the project’s economic feasibility, was also given. Some limitations to the analysis and suggestions for further research were also made.

Additionally, some risks related with the implementation of IS were identified, such as the potential decline in commitment from the organisations recruited into the network, or the risk that certain companies with more power might try to monopolise the network.

For this research project, a simplified sustainable development assessment tool was presented, giving more strength to the conclusions relating to the potential sustainability contribution of the alternatives considered during the research project. Nevertheless, results concerning both the economic and social aspects of this assessment are associated with significant uncertainties at this stage and are presented more for the purposes of demonstration. This may serve as a starting point for further assessments that would need to be undertaken in greater detail if the network were to be progressed beyond this thesis. To this end, a number of recommendations are also made for the future development of the project.

If implemented, the proposed IS network may bring advantages related with regional sustainable development. These advantages include:

- Reducing the regions dependency on fossil fuels by using a local biomass feedstock for the production of energy;
- Energy recovery by turning what was considered up until now to be a waste, into a main raw material for a cogeneration plant and a biogas digester;
- Improvements in regional environmental performance from the new destiny given to the biomass (that was open burning until now) to a new treatment process for the organic wastes (avoidance of discharge to waters); and
- Potential for job creation resulting from all of the above.

The latter may be achieved if the willingness from stakeholders is fully achieved, as well as the availability of waste and by-product, the potential for synergies, existing technology, and the possibility of available funds (i.e. from stakeholders or external sources such as the Portuguese government, or the EU).

This research project was not based in the classical direct exchanges between companies normally associated with an IS network. Instead, the potential for the creation of synergies between companies, enabled by central infrastructures that process the wastes and by-products into energy, was established. This model, despite its clear reference to classical examples of IS networks, creates a new paradigm in synergies between companies, enabling cooperative work in a way that generates major benefits, not only for the companies
themselves, but also helps to boost local and regional development. It does so by bringing state-of-the-art technology, based on environmentally friendly processes, into the area.

A unique aspect of this research is linked to the fact that the IS concept, which is traditionally considered for heavy industries, is applied to a rural area. This research brings a new factor of versatility to the profile of IS, as it shows that the elements existing in the classic industrial world that allow the implementation of such networks, may also be found in smaller rural settings.

The implementation of an IS network in this region may initiate a new paradigm for the spread of this conceptual tool in other regions of the country, not to say the world, that have conditions to enable implementation of a network based on the same types of premises.
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1 Introduction

“There are regions where potentials to gain environmental and economic benefits through inter-organisational collaboration among regional activities do exist, or can be created, but these potentials remain unexploited.”

(Mirata and Backman, 2004)

It has long been recognised that the approach of wasting resources, which is inherent within the traditional paradigm of industrial development around the world, is no longer acceptable. There is a growing concern amongst the developed world, and even developing nations, that the way in which we use and waste our precious natural resources is unsustainable. The effects of our continuous abuse of the earth and the gradual decline in the quality of our water, air and soil are becoming more visible by the day. Political and industrial spheres are also beginning to become aware of this issue, as the sustainability of human life on earth becomes more prominent within the media. As issues relating with the cost and availability of natural resources gain more importance and attention, many concepts and tools have been developed to assist industry and political decision-makers in their strive towards more sustainable development. Of these tools, the concept of Industrial Symbiosis (a branch of Industrial Ecology) is proving to be one way in which industrial growth may be achieved through the creation of inter-organisational cooperation by creating efficiency gains in terms of raw materials, water and energy consumption and waste re-use.

1.1 Background

Mankind, as all other living organisms, has always depended on its natural surroundings for survival, using nature also to bring economic benefits. Since its origins, mankind has been using so-called “ecosystem services” at its will, consuming for its own benefit the natural capital that supports all life on earth and that is essential to the quality of all human life and to the functioning of the world’s economies (Miller, 2006). As a consequence of the awareness that our finite resources will be exhausted if we endure our continuous strive towards economic growth, the concept of sustainable development was born (Ehrenfeld, 2005).

Amongst the many challenges that modern societies face today, the capability to achieve development in a sustainable way is one of the greatest. If sustainability is to be achieved, it will need efforts from all spheres of society, from global to regional and local perspectives. Ekins and Newby (1998) state that as environmental impacts are mostly felt at a local level, it is logical that there should be an added interest and investment on local and community economic development, through investments in the triple bottom line concept1 (local environment, local economy and local people) and local institutions.

In the pursuit of sustainable development at local and regional level, societies everywhere face several challenges such as a shift in mentalities, attitudes and habits. The need for such change assign new responsibilities to governments, the scientific community, industry, individuals and other societal stakeholders. It is a complicated process comprising a wide range of different interactions such as physical, institutional, financial, cultural, political, etc. (Roberts, 2006). To

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1 The triple bottom line principle focuses corporations not just on the economic value that they add, but also on the environmental and social value that they add – or destroy (Elkington, 2004)
be successful a combined consideration of environmental and economic aspects in decision making, aided by technology and alternative/innovative policy measures will be necessary (Gouldson and Murphy, 1996). It is also necessary to build a system-based approach that can analyse complex relationships and that at the same time integrate science, economy, technology and the environment (Brand and de Bruijn, 1999). These kinds of systems may be based on conceptual tools such as Industrial Ecology and more particularly Industrial Symbiosis (IS), whose principle seek to identify a number of industries in a given area and how exchange relationships between them can be created. These exchange relations are based on the principle of ones waste can be another's raw material. Normally these exchanges centre on their wastes, by-products, water or energy allowing for economic and environmental benefits.

Portugal is a country where development asymmetries are a clear problem, with more and more people relocating from the interior and settling in littoral areas in search for better conditions, due to issues such as lack of investment in technology or job creation. Different stages of development can be found in Portuguese regions, leading to significant differences in the wellbeing, density, efficiency of the economic tissue and capacity for employment. Amongst these development problems in Portugal, the regional asymmetries or weaknesses in the agricultural system, is a very specific and sensitive issue (Gabinete de Planeamento e Politica Alimentar, 2004). Despite having most of the country covered by agro-forestry, in the past years hardly any prioritisation has been given to issues related with rural areas. There has been a clear abandonment of policies to revitalize development of the country's interior regions. Also, very few technological investments were done in these regions that enabled performance development of local industries. The most depressed areas in Portugal are found where agriculture was, and still is, the main economic activity and to which hardly any development incentives have been provided by governments in the past 30 years. In line with that is the lack of capacity to improve the efficiency of the use of natural resources that compose the base of the economy of most rural areas of the country. Industries in rural areas have not been showed until now how to increase their gains through maximization of the resources they have available.

Novel ways to help change this situation are required. IS is a tool that may facilitate coordination of the necessary factors required to assist the improvement in resource use efficiency in rural regions in Portugal. By doing so it is not certain that a considerable rural development will be achieved, nevertheless conditions will be improved in the pursuit for a more sustainable growth. To do so, it is necessary to research a particular region, and assess if the right number of factors are in place that could allow for the implementation of this tool. Thus, the focus area of this thesis is set in the region of Alentejo, particularly in the municipality of Reguengos de Monsaraz. The problems affecting this region are representative of the rural Portuguese landscape: low employment levels, lack of technology development, energy dependence, aging population, and desertification. Despite this, the region is considered to have conditions suitable for more sustainable development (Gabinete de Planeamento e Politica Agro-Alimentar, 2004).

The research conducted in this particular region is intimately related with existing challenges concerning sustainability of rural areas, such as investment in technology, resource use, or job generation. In order to assess if there are conditions to move towards more sustainable rural development, it is necessary to engage multiple sectors in the rural economy involving local and regional coordination and several local actors. In this work the potential of IS concept to contribute to the sustainability challenges in Reguengos de Monsaraz is explored, by being
attentive to social and environmental sustainability without neglecting expected economical growth.

### 1.2 Objectives and Research Questions

The objective of this research is to assess the potentials and barriers to the development of a regional inter-organisational network using the IS concept, which through a process of collaborative actions may enable a continuous improvement in business and environmental performances, thus contributing to regional sustainable development.

In order to achieve these, the following research questions were used:

- What is the potential of Industrial Symbiosis to contribute to the sustainability in Reguengos de Monsaraz?
- How could this potential be realized?

Another sub-question that will help guide the research and establish the logic for answering the main research questions is:

- What are the drivers and barriers for implementation of an IS project within the region of Reguengos de Monsaraz?

### 1.3 Methodology

#### 1.3.1 Research methods

This research was conducted in the following way:

- **Literature review:** An extensive literature review was conducted to establish a conceptual framework encompassing several related themes such as Regional Sustainable Development, Industrial Ecology and Industrial Symbiosis. A brief update on the present situation of the analysed Portuguese region was given. Others cases of IS were studied in order to assess the already existent organizational structures and networks.

This research was focused on studying the potential of a particular area with specific conditions and characteristics to adopt the IS conceptual tool. At the same time it was conducted in a way that allowed active contribution from the author, working together with the participants. Because of this it consisted of a hybrid of action research and case study research.

O’Leary (2005) defines action research as:

“Research strategies that tackle real-world problems in participatory and collaborative ways in order to produce action and knowledge in an integrated fashion through a cyclical process. In action research, process, outcome and application are inextricably linked.”

Dick (2002) adds that action research is a process of acting then reviewing results, searching for continuous methodological improvement by seeking change and understanding. The
researcher is not solving a problem for practitioners, but with them. In this way, empowerment of participants, collaboration through participation, acquisition of knowledge, and social change is achieved. As shown in Figure 1-1, these four basic themes are accomplished through the establishment of a spiral of cycles constituted by: planning, acting, observing and reflecting (Master, 1995). Action research identifies a practical problem, helps to understand it and attempts to implement solutions in the given context (O’Leary, 2005).

To some extent, this approach was considered suitable for this thesis research since it was done mainly on-site and based on interactions with the practitioners. In this context, some problems are clearly identified and ways to deal with them were proposed. This was mainly achieved through data collection, engagement and participation from the practitioners to seek changes in various ways (processes, habits, collaborations).

Figure 1-1 represents the various cycles present in action research.

![Figure 1-1 Cycles in action research](source: Adapted from O’Leary, 2005)

Case study research is characterised by the collection of data from fieldwork, archival records, verbal reports, observations or any combinations of these (Kogg, 2007). This characterisation comes from the fact that this research was mostly done on-site in the Herdade do Esporão.
and in other identified potential players of the network around the municipality of Reguengos de Monsaraz.

The data upon which this research is based was conducted in the following way:

- **Direct field observations:** Visits to the facilities of the companies were performed, in order to amongst others understand their processes and identify potential intervention areas. From this, an initial review was undertaken so that the entire context of the identified potential IS network (material flows, waste flows, energy and water consumption, and local economic activities) could be properly understood. This required a proper document analysis from any pertinent potential stakeholder, besides the development of a data collection form adapted from work developed by IIIEE researchers in IS programs both in the UK and Sweden. This data collection form was adjusted to the Portuguese context and provided to every company. Also, semi-structured interviews and meetings were conducted allowing the establishment of contacts with relevant parties and understanding how the hypothetical symbiotic relations within the IS network could be reached. This was useful in giving a much more realistic view of the willingness of the potential stakeholders to get involved in such a project, while at the same time assessing the potential drivers and barriers for them to do so. These interviews were also used to try to raise awareness about the benefits of such IS networks. Research was gathered in various formats, such as first-hand observation, diary notes, oral and written correspondence. Finally, the realisation of a workshop provided further information related with the actual willingness of the stakeholders to participate in the materialisation of the IS network.

- **Group interactions/workshops:** Following the previous steps, it was desirable that at least one workshop would be conducted involving as many stakeholders as possible. The major purpose in organising such an event was to bring the stakeholders together in one room and start building trust by making them interact in a brainstorm session. In the first part of the workshop, the research project was described and its main conclusions highlighted, particularly the analysis conducted on the available by-products/ wastes, potential uses and the research project IS network development. In the second part, a small brainstorm session was held, where the participants tried to identify further drivers and challenges/ barriers to the fulfilment of this research project in the future.

- **Data analysis:** As a final stage of the research, a thorough analysis of the gathered data was made in order to identify potential synergies between parties, opportunities for savings, and an overall view of the drivers and barriers for the implementation of the project. As the main input requirements of the companies and the available wastes and by-products were identified, the author began to envisage a hypothetical IS network. All of the results and conclusions were presented in the workshop held. Also, a simplified tool was created for the assessment of the sustainability of the research project based on the triple bottom line (TBL) concept. In this way, 3 main evaluation aspects are discerned (People, Planet, Profit). For each aspect, 4 key criteria are defined, each criteria can be scored 1 (situation improvement), 0 (equal) or –1 (worse). Finally the scores are totalled per sustainability aspect (hence a maximum of 4 points can be obtained per aspect). Therefore, a score of 4 points has the greatest potential for a sustainable profile.
In summary, Figure 1-2 shows a schematic vision of how this thesis methodology was conducted.

1.3.2 Data collection and analysis

The different organisations (stakeholders) present in the region that have a profile suitable for involvement in the project, were identified, along with their specific needs and capacities. This was conducted before informing each of them about various aspects of IS networks and of potential collaboration areas.
The majority of the research findings were obtained through direct interactions with the stakeholders trying to show the potentials and benefits of Industrial Symbiosis and trying to secure their engagement. Semi-structured interviews allowed for the identification of the stakeholders’ necessities, as well as their willingness to engage in a project of this nature. Also, it helped collect a useful amount of information mostly related with behavioural aspects of the stakeholder’s attitude towards the research project or other participants. First hand observations from field trips also helped to collect data. Much information concerning relevant enabling aspects of the potential network was obtained through exchange of oral and written information.

Meetings were also conducted allowing the establishment of contacts with relevant parties that could help secure legitimacy and to provide institutional support for the hypothetical Industrial Symbiosis network. Meetings with experts were also held in order to obtain relevant data concerning technology options.

A workshop was conducted providing further information related with the willingness of the stakeholders to participate in the materialisation and formalization of the IS network.

In all of the meetings that the author held with the aforementioned stakeholders, the other companies’ names, local administrators or regulatory bodies already engaged in the research would always be mentioned. This information was provided as an incentive for the new companies as a means of attesting to the seriousness of the research project and as a way of showing the companies that other economic actors of the region had already shown interest and had agreed to participate. The companies would also be asked if they had previous contact, relations or synergies of any sort with another company in the network. The author always mentioned the intention to perform a workshop around the end of the research project with all of the engaged stakeholders.

1.4 Scope and limitations

This research focused on the assessment of potentials and barriers to the development of an IS network within the geographical boundary of the Municipality of Reguengos de Monsaraz. It focused on the main problem of wasted energy, water and biomass utilisation potential. Issues relating to pollution prevention or cleaner production were considered to be outside of the scope of this research project, since the research related more with resource use maximization and waste recovery, than with the reduction of waste production or the focus on improving efficiency through the companies’ own processes.

Several possibilities for synergies were identified in this research, nevertheless the focus was given to biomass and organic waste, mostly concentrating on energy production. In this case the opportunity to revalue a waste was recognised as having considerable potential to create synergies. However, there might be other synergetic routes for these companies that do not focus on revaluing the waste for energy creation purposes.

The term “eco-industrial parks” is often cited within literature; however, Harper and Graedel (2004) stress that relations of symbiotic nature between industries don’t necessarily have to exist within the physical boundaries of an “industrial park”. Thus, a taxonomy of five different scenarios for eco-industrial parks where proposed by Chertow (2000):

- Type 1: Through waste exchanges;
- Type 2: Within a facility, firm, or organisation;
Type 3: Among firms co-located in a defined eco-industrial park;
Type 4: Among local firms that are not co-located; and
Type 5: Among firms organized “virtually” across a broader region.

For the present research the author has chosen to follow the model classified as type 5:

Type 5: Across a Broader Region

Despite the engagement of key actors for the research project (i.e. economic actors, political decision makers and non governmental organisations), the coverage of social issues that might influence the development of an IS network in Reguengos de Monsaraz was left out of the scope. This way, issues related to the willingness of the local population for the implementation of certain infrastructures or the impact that it might have, job creation, wealth distribution, quality of life or education were not covered. This is due to the fact that social conditions are not the prime objective of this research but are nevertheless touched upon. The potential obstacles identified as related with the region are mostly of social nature. Also, a simplified tool for the assessment of the sustainable profile of this research was used to exemplify on some of the potential fields of analysis. However, results related with social and economical issues are too incomplete to be considered reliable enough for decision making.

The research was also limited to some extent by the fact that there were difficulties with reliable and accurate data. Despite several requests to the companies to deliver it in a more accurate form, all the time the answer would be that it was the only available data and that there was no other way to present it. Since it was not possible for the author to standardise some units, assumptions were made in order to proceed with the conduction of the research. Also, some of the data gathered was not accurate, meaning that the values provided were sometimes quite conservative.

The findings of this research could be valuable for other regions that have the same kind of strong rural profile in Portugal, or even other countries. However, this will always be determined by the site specific conditions encountered in each region, meaning that the findings of this research can be best suited for required arrangements in institutional, informational and/or organisational purposes, rather than for the actual synergies it identified. This research project cannot therefore be used as a blueprint for similar IS projects in other regions but instead be seen as model for cooperation between the various stakeholders. Yet, the findings of this research project may serve as a valid example for this and other rural areas of Portugal, showing that synergies can be created between companies and that what was once considered a waste can then be considered a resource with economic value.

Nevertheless, there is always a risk as to what extent the practitioners consider the research project to be truly valid or feasible. It is necessary to clearly show the new business development opportunities that might arise from the identified synergies, hypothetical savings and economic gains of the IS network. Obviously, there is also the risk that the proposed technology or other better suited and available technologies may simply be too expensive to make this research project economically beneficial. Also, even though some technology options have been proposed for the viability of the IS network, as well as some economic data concerning dimensioning of proposed facilities, a thorough analysis of all of the available technologies that could be applied in the Reguengos de Monsaraz context was not made, neither was a proper economic viability study of all of the available technologies undertaken, such as a study on the return on investments. This is due to the fact that it was not an
objective of this research project to propose technology, but rather assess the potential benefits that could be achieved through the establishment of an IS network. Limited analyses are conducted with selected technologies for the purposes of demonstration. Still, having accurate information is indispensable, thus in the future there is a necessity for more refinement of the economic issues.
2 Industrial Symbiosis and regional development

In order to better understand how the Industrial Symbiosis tool can be applied and used in a regional context, it is first necessary to understand how it developed and what its academic and practical origins are.

In this chapter, the author will describe the Industrial Symbiosis conceptual tool in order to better understand the theoretical framework used in this research. Section 2.1 gives a short review of the conditions that will be required for a paradigm shift in environmental management (from the classic industrial approach of pollution control towards one of pollution prevention and resource recovery) to occur. It also indicates the conditions that lead to the rise in awareness that this change is required. Section 2.2 describes the Industrial Ecology concept, how it developed, how it is divided into different categories, and which of these are more suitable for the case of this research. In Section 2.3, the Industrial Symbiosis concept is explained in detail, including the added value that it brings, the factors by which it is guided, how it is helping to change the way industry approaches classic environmental issues (e.g. energy consumption or waste production) and also highlights some practical examples. Finally, in Section 2.4 some light is cast over the importance that Industrial Symbiosis can have in aiding sustainable development at the regional level. This section also highlights the particular characteristics of Industrial Symbiosis that make it a tool that, if well implemented with the right set of elements and opportunities, can be a true stimulus for sustainable development at a regional level.

2.1 Sustainability concerns

Due to a number of reasons, such as the rapid development and growth during the industrial revolution, industry did not consider the proportionally rapid increase in waste generation and the problems associated with its consequent disposal. Nor were there any concerns regarding minimising the production of waste, reusing it or even exchanging any of it with other industries to be used as a resource. Things evolved slowly, and by the late 19th century, signs of concern regarding waste disposal and resource depletion began to show. These concerns were mirrored in certain industry initiatives, such as cooperation and exchange of wastes and/or by-products that mostly related to strong competitive pressures and with the rise of new technologies. However, in most cases these synergies were isolated, did not have continuity and were abandoned (Desrochers, 2000). It seems that a progressive decline in the environment over the next 100 years was almost necessary for this new paradigm of resource recovery and waste reuse to re-arise in practice.

Goodland (1995) recognised that human economy is characterised by the use of environmental resources (e.g. raw materials, energy, water, etc) and their subsequent return to the environment as potentially harmful wastes. Aware of these sort of facts, environmentalists such as Robért (2001), governments such as the ones comprising the European Union (1992), members of the scientific community such as Brundtland (1987), NGO’s such as WWF (2007) and even industries like BP (2006), all agree that if we continue at this rate of environmental consumption and degradation, we will soon get to a point where the threshold of environmental capacities is reached resulting in a “profound effect upon the ability of all peoples to sustain human progress for generations to come” (WCED, 1987). Given the significant role the industry plays in exploiting world’s natural resources, it is logical that these resources are viewed as the limiting factor for industrial development. The uncontrolled use of non-renewable resources has resulted in severe problems related with potential resource depletion, water, air and land contamination (UNEP, 1996) and the emergence of certain
types of wastes to which nature simply cannot adapt (Korhonen, 2001). To achieve a sustainable relationship between the product demands of society, economic benefits from industry and the environmental carrying capacity, Lovins and Lovins (2001) propose what they refer to as the four principles of ‘Natural Capitalism’. The concept of Natural Capitalism is based upon the ideal that natural resources have an economic value that should not be wasted and can be summarised by the following requirements:

- A radical increase in resource efficiency;
- Elimination of the concept of waste by redesigning the economy along more biological lines that close the loops of materials flows;
- Rewarding resource productivity; and
- Reversing the planetary destruction that is now underway with programs of restoration that invests in natural capital.

The cornerstone of the Natural Capitalism ideology is resource efficiency, with total elimination of the concept of waste as the ultimate goal. This can only be achieved when the totality of output flows from industry generate products with market value instead of waste disposal costs, as well as a progressively reduction of waste from consumption. This ideology is complementary to the Sustainable Development (SD) concept.

A wide variety of definitions to describe the concept of SD can be found in literature. From an overall perspective, SD refers to the assumption that humanity cannot maintain its current rate of economic growth without compromising its finite resources (Ehrenfeld, 2005). SD cannot be set apart from environmental protection, nor is it a “fixed state of harmony” as described by Brundtland (1987). It is instead a process of change, with implications on a plethora of factors such as the exploitation of natural resources, direction of investments, technological developments, etc, which depend on the needs of both future and present generations (WCED, 1987) This change may be rooted in different domains, such as an overall reduction in resource use from both industry (reduction on the quantity of resources spent by unit of product) and the consumers (opting for more environmentally friendly products). The expansion and increase use of renewable sources of energy such as solar and wind, or the development of less hazardous technology. Ehrenfeld (2007) views the concept of sustainability as dynamic because development can only be defined by a group of characteristics that are common to the world at large and are therefore in constant change. It is understandable that while economic sustainability focuses on the physical inputs into production processes provided by natural resources, both renewable and exhaustible, the environmental aspect of SD emphasises the life support systems (e.g. the earth’s atmosphere, water and soil) that enable the existence of both production and humanity. Logically, the social part of sustainability is heavily dependent upon the good maintenance of the previously mentioned life support systems of the earth.

2.2 Industrial Ecology

2.2.1 The conceptual innovation

Due to the growing awareness of the role that industry plays in the well being of society, Frosh and Gallopoulos (1989) in their seminal article for Scientific American titled Strategies for Manufacturing, recognised that the classic industrial production model where raw
materials are used to manufacture products to be sold and the resulting waste disposed of to the environment, should be enhanced into a new paradigm where waste is not created in the first place. Further, within this same paper, they developed and presented the concept of Industrial Ecology (IE). IE is based on optimising the consumption of materials and energy, where the effluent of one process might become the raw material for another. In the words of Frosh and Gallopoulos (1989) it is “a better system for the coordination of technology, industrial processes, and consumer behaviour”. This is due to the strive for processes optimisation, the necessity of engaging industry to reduce their material needs, the use of better technologies that are aligned with pollution prevention and economic savings, the achievement of environmental improvements through dematerialization, use of best available technology and sensitising the consumer to more environmental friendly product choices. This approach is based on the awareness that industrial systems are not independent pieces of ecosystems. Industry as a whole, due to its major role in influencing the natural function of ecosystems needs to realize how this is changing the dynamics of the biosphere. Once this is understood, then it is possible to design a way to restructure the entire production process so that it more closely resembles the function of a natural ecosystem (Erkman, 1997).

This method of process optimisation may lead to benefits at several levels, such as reducing virgin material consumption and consequent emission output, economic gains from raw materials savings or reduction in energy and water costs, and even improvement in the environmental image of the company (Burström and Korhonen, 2001).

The concept of Industrial Ecology is very well established within the engineering field. Although there have been many disparate attempts to define the concept, there are three main, generally agreed upon characteristics:

1. IE is a systemic, comprehensive, integrated view of all the components of the industrial economy and its relation with the biosphere;

2. IE emphasises the biophysical substratum of human activities, i.e. the complex patterns of material flows within and outside the industrial system, in contrast with current approaches which mostly consider the economy in terms of abstract monetary units, or alternatively energy flows; and

3. IE considers technological dynamics, i.e. the long-term evolution (technological trajectories) of clusters of key technologies as a crucial (but not exclusive) element for the transition from the actual unsustainable industrial system to a viable industrial ecosystem. (Erkman, 1997)

Putting it simply, IE attempts to conciliate several different industrial activities within an area with the interactions of the surrounding environment in a sustainable way. This leads to a continuous strive for economic profits and technological development with minimal adverse environmental impacts.

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2 The main goal of ‘dematerialisation’ is to achieve an absolute reduction of the aggregated volume of resource throughput through changes in the ‘metabolic efficiency’ of firms, sectors or regions, a more efficient management of resources as well as changes in consumer behaviour (Giljum et al., 2005).
With an approach that considers economic profit and technological development, with a minimal adverse environmental impact, industry places itself in the forefront of innovation and leadership, thus at the same time becoming qualified to better anticipate risks and to identify opportunities for environmental improvement (Tibbs, 1993). IE goes one step further than the classic industrial approach, for instead of focusing on reducing material inputs or waste at the firm level, it strives for a general systematic approach, engaging companies to be part of a change, moving from the ruling paradigm of “end-of-pipe” solutions to one focused on prevention and on planning environmentally sound industrial development (Tibbs, 1992; O’Rourke, et al., 1996).

To do so, it is fundamental that a transformation from traditional linear to more cyclic material flows occurs (Figure 2-1).

\begin{center}
\textbf{Linear Material Flow}
\end{center}

\begin{center}
\begin{tikzpicture}
    \node (raw) at (0,0) {Virgin Raw Material};
    \node (prod) at (0,-1) {Production};
    \node (prodwaste) at (0,-2) {Product \quad Waste};
    \node (waste) at (0,-3) {Waste};
    \draw[->] (raw) -- (prod);
    \draw[->] (prod) -- (prodwaste);
    \draw[->] (prod) -- (waste);
\end{tikzpicture}
\end{center}

\begin{center}
\textbf{Cyclic Material flow based on ecological principles}
\end{center}

\begin{center}
\begin{tikzpicture}
    \node (raw) at (0,0) {Raw Material};
    \node (pro) at (0,-1) {Production};
    \node (byprod) at (0,-2) {By-product \quad Re-generation \quad Product};
    \draw[->] (raw) -- (pro);
    \draw[->] (pro) -- (byprod);
\end{tikzpicture}
\end{center}

\textit{Figure 2-1 Schematic presentation of the transition from traditional material flow to a cyclic flow based on ecological principles (Adapted from Andersen, 1997)}

The adoption of a cyclic approach by industry enhances the value of waste and/ or by-products. It allows potential generation of savings and eventual profits without added pressure on natural resources.
On an operational basis, the concepts with which IE development is most closely related are Life Cycle Assessment (LCA), Design for the Environment (DfE) and Extended Producers Responsibility (EPR), which are all concerned mostly with products and with the processes used to manufacture products (Harper and Graedel, 2004). On the other hand, when IE is viewed on a systemic basis, instead of purely through the individual actors, we see that it is closely aligned with the concepts of Industrial Symbiosis, Material Flow Analysis and Urban Ecology.

IE takes a more holistic approach to managing the pollution caused by a group of companies within a particular region or that are involved in the value chain of a particular product. In this way, the IE approach enables companies to exchange knowledge as well as allowing for a greater range of flexibility when adapting to continuous technological developments, and also to constantly changing political and regulatory requirements (Boons and Berends, 2001; Graedel and Allenby, 1995).

With a focus on continuous improvement, secured by the commitment of companies in the project, identification of opportunities for improvement becomes easier, such as conditions for sharing production processes, by-products, recycling of materials and energy consumption. Identifying these factors within a group of companies is not enough condition for the creation of local industrial systems or networks, but can be a step towards that. Identification of cooperation possibilities is amongst the required factors for this sort of networks to emerge. If these synergies are achieved in an initial stage, having collective and individual benefits, confidence for long term collaboration can be achieved with time (Korhonen, 2001; Gibbs, et al., 2005).

This new approach in industry operations could be due to their growing awareness of the economic costs related with waste production/disposal and inefficient industrial processes, and with the potential economic savings that might arise from innovation in those areas. Examples have already arisen where different industries have already achieved such innovation in their processes through (amongst others) synergies relating to output exchanges, namely with energy, wastes and by-products. These examples show clear benefits to the environment from the approach towards output maximisation (such as waste reuse or energy recovery) and waste reductions and will be discussed in more detail in Section 2.3.1. The success of such examples can lead to more and more industries, political decision makers and society as a whole gaining a heightened awareness for the need to strive for a more sustainable existence. Industrial innovation at the regional/local level, made particularly through IE or related conceptual tools, has the potential to generate benefits not only for the economy of industries themselves, but also to the local communities through job creation and improvements in the environmental conditions. Although they are few, the available cases are fair examples on how this can actually be achieved if the right conditions (e.g. resource availability, exchange potential, willingness from industries to engage in such systems, etc) are in place.

The engagement process required for successful implementation of the IE concept needs to be done at different levels and with several different actors. The companies can be engaged by setting the focus at an inter-organisational level, namely internal operations and synergetic connections that may lead to environmental improvements and economic benefits. Business-to-business approaches also help to secure trust between companies through organised activities such as thematic group meetings or company visits (e.g. that may help showing the present and future benefits of such relations). The way to engage the local community passes firstly and above all, through public-private communication and collaboration. This collaboration may lead to the involvement of regional and national public body
representatives, in this way creating the necessary trust for the involvement of local communities and for the strengthening of that trust.

Given the nature of this thesis, a more emphasis will now be given to the concept of Industrial Symbiosis.

2.3 Industrial Symbiosis

2.3.1 The concept

As stated previously, Industrial Symbiosis (IS) is one of the tools available in the field of IE. IS can be described as a process of identifying and engaging different industries within an area or region into a collective process of exchanges of materials, water, wastes, by-products and energy. IS as been defined by Chertow (2000) in the following way:

*Industrial Symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of materials and energy through local and regional economies. 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.*

Besides identifying conditions for these physical exchanges, IS also attempts to engage regional parties into other types of collaborations and exchanges – for example as suggested by Mirata and Emtairah (2004) those involving the exchange of knowledge, human or technical resources.

Above all, when addressing IS networks there is a necessity for linkages between companies. As IS is a tool designed to increase efficiency and reduce resource use, by the identification of synergies and consequently the creation of linkages, companies may optimise their processes to replace virgin materials with by-products or waste. This is reflected in the work by Ehrenfeld and Gertler (1997) who stress the importance of creating links that serve to enhance efficiency via the entire cluster of industrial processes through material and energy flows.

The classic example of IS documented in literature is the one of Kalundborg in Denmark. Since the early 70’s several different companies started cooperation with significant improvements in efficiency, both in environmental and economical terms. In Kalundborg, the industries share land, wastewater, steam and electricity, whilst also exchanging a variety of other residues that become feedstock in other processes (Chertow, 2000). It is interesting to analyse that this project was initially motivated by pure economics, and it was not until decades later that the companies realised the environmental benefits of these networks. While pursing the rational business interests of their companies, the business leaders of Kalundborg also helped to reduce the adverse environmental impact of their operations (Ehrenfeld and Gertler, 1997).

Interestingly, it was actually the ex-manager from one of the key companies in the IS network at Kalundborg, Valdemar Christensen, who first coined the term IS as “a cooperation between different industries by which the presence of each... increases the viability of the other(s), and by which the demands [of society for resource savings and environmental protection are considered” (Valdemar Christensen as cited by Chertow, 2000).
Case Study: Industrial Symbiosis in Kalundborg (Denmark)

The quintessential example of industrial symbiosis developed organically over a period of 25 years. At the heart of the network of exchanges is Asnaes power station which supplies power and district heating to the city of Kalundborg and process steam to Statoil refinery and Novo Nordisk. Fly-ash from Asnaes is used for cement making, and nickel and vanadium are recovered from the ash, whilst gypsum from the desulphurisation of the flue gas is supplied to Gyproc for construction material. Statoil sends wastewater to Asnaes for reuse, some of which is returned as steam. Novo Nordisk supplies by-product yeast slurry from insulin production for pig fodder, and Novozymes provide by-product biomass by pipeline to farmers as replacement fertiliser. The system of exchanges developed because of the openness, close cooperation and mutual trust that existed in the relatively tight knit business community.

Annual resource savings through interchanges

Water savings: Statoil - 1.2 million m$^3$ from Asnaes (Novo Nordisk is now producing 900 000 m$^3$ of treated water that is available to replace fresh supplies, but is being discarded at present.).

Fuel savings: Asnaes – 30 000 tonnes of coal (about 2% of throughput) by using Statoil fuel gas; about 19 000 tonnes of oil by using fuel gas from Statoil in Novo Nordisk’s boilers and Gyproc; Community heating via steam from Asnaes.

Input chemicals: Fertilizer equivalent to Novo Nordisk sludge (about 800 tonnes nitrogen and 400 tonnes phosphorous); 2 800 tonnes sulphur; 80 000 tonnes of gypsum; dryer fuel.

Wastes avoided through interchanges: 200 000 tonnes fly ash and clinker from Asnaes (landfill); 80 000 tonnes scrubber sludge from Asnaes (landfill); 2 800 tonnes sulfur as hydrogen sulfide in flue gas from Statoil (air); 1 million m$^3$ of water treatment sludge from Novo Nordisk (landfill or sea); 1 500 - 2 500 tonnes of sulfur dioxide avoided by substituting coal and oil (air); 130 000 tonnes carbon dioxide avoided by substituting coal and oil (air).

Source: Ehrenfeld and Gertler, 1996 and Jacobsen, 2006

2.3.2 The development

The concept of IS has grown and has been successfully applied within industrial regions that seemed to have the right characteristics and conditions. This has resulted in increased process efficiency, decreased resource consumption and economic benefits from changes in attitudes and in processes. Today there are successful cases of IS implementation, such as the Research Triangle Park in North Carolina, the Brownsville case in Texas, the By-Product Synergy in Tampico, Mexico (Chertow, 2000) and the Landskrona Industrial Symbiosis Project in Sweden (Mirata and Backman, 2004), just to mention a few that give hope for future projects. Despite the common bond between all these projects, there are clear differences ranging from location and cultural differences, resource uses, wastes, by-product availability, management structures or regulatory climate. This may influence the behaviour and the attitude of the companies towards these kinds of projects, or the way they deal with any particular aspect of the network. Mirata (2005) emphasises this by stating that differences in individual projects can range from the types of technological transformations experienced, the social settings that enabled implementation, and other individual operational characteristics.
It is obvious that in earlier stages of IS implementation, the verification of sufficient incentives to assure that its implementation will be successful, is required. These incentives may sometimes fall under certain fields that can be considered to deal with more “intangible” aspects that might influence these types of networks namely technical, political, informational, economic, organizational and institutional issues (Mirata, 2005). These issues can be reflected in governmental policies, people’s behavioural aspects, organisational constraints, trust, financing, marketing, etc.

The factors identified by Mirata (2005) as being crucial for the development of a IS network at the regional level are rooted in different domains as follows:

**Technical**: Companies in a same area are required to have compatible and complementary resources needed and possessed.

**Informational**: Technical factors that are in place for every company should be made available to others in the network. All companies should be informed of each others technical factors. Companies should also be aware amongst others about market prices, subsidies or funding mechanisms.

**Economic**: The synergetic relations will be dependent on direct investments and transaction costs required for its functioning, and also to the savings and/or revenues they provide.

**Political**: Laws and regulations may provide certain incentives to companies, such as financial benefits or privileges, in order to promote the change to alternative practices with better environmental and eventual economical performances. Nevertheless, law and regulations can also compromise or delay the development of synergistic relations.

**Organisational and Institutional**: There should be an alignment between the main objectives guiding companies and those of IS, trust and openness between companies, general awareness of sustainability concerns, learning and innovation capabilities.

It is also important to not just mention the technical aspects such as materials and energy, but also other important aspects of IS philosophy such as the human and social dimension, which must be addressed when evaluating the capacity to implement such a network. As demonstrated by Côté and Cohen-Rosenthal (1998), issues like networking in transportation (car pooling), personnel training, communication and dissemination of information are other factors that influence the success or failure of the IS networks.

When assessing the conditions for implementation of an IS network, it is of utmost importance to identify if these factors are all in place, or if at least there are conditions for its development. If one or more of the aforementioned factors are not in place nor are there the conditions to develop it, there is a risk in compromising the entire network or at least to make it weak.

Besides these factors, the available literature identifies several other components that may determine whether the implementation of IS on a regional and local level will be able to evolve. Amongst these are mechanisms that may help to identify the matching input/outputs of different companies in a way that easily identifies potential synergies. Likewise, it is useful for companies to acknowledge what the available quantities of these same input/ output flows are. Chertow (1999, 2000) calls this “material budgeting”. It is also necessary to assess the nature of the reasons that entice companies to embark on such projects, as this might indicate
more or less commitment to the project. These reasons can range from potential business benefits derived from wasted resources, energy necessities, or due to problems associated with waste generation and/or disposal. Another factor that influences the network’s development is the availability of infrastructure that may facilitate the exchange of resources between companies. Also, the capacity of the existing infrastructure should be assessed along with the potential for increasing capacity if required. The importance of this is also emphasised by Chertow (2000) who says that existing infrastructures are crucial for the planning of IS networks.

Besides all of the aforementioned factors, in order to develop an IS network on a regional level it is necessary to identify the partners that might play key roles. The roles played by these partners are related with gathering the right set of conditions, such as being a powerful economic player in the region, having the capacity to engage other companies by showing awareness towards synergetic opportunities and their potential economical profits and/or environmental benefits. These synergies between companies create potential for new organisational arrangements based on technological and cooperative elements (Mirata and Emtairah, 2005). The key partners can also have the capacity to influence and engage both the municipality and other levels of governance such as regional development agencies. Mirata (2004) summarises this by suggesting that key partners within a region must be identified and the local community should be involved. These factors will set the boundaries for symbiotic relations.

From all of the settings for the 5 factors required for the development of IS networks mentioned until now, the identification of a group of actors in a region with potential to engage into an IS network, input/output balance, identification of synergetic opportunities, or decision makers engagement, should be all coordinated by one entity. This entity is known in the literature as the “coordination body”. The coordination body should assess if all of the previously mentioned factors are in place, the extent to which they can be implemented and whether or not changes are required and how to conduct them. In the words of Mirata (2004), the coordination body should “take the role of coordination and organisation, acting as an impetus for healthy development of the network”.

2.3.3 Benefits and success factors
The criteria of success in IS exchanges is greatly dependent on both the context and the perspective in which the relations between the companies is viewed (Jacobsen, 2006). Several other experts in the field of IE (Ehrenfeld and Gertler, 1997; Korhonen, et al., 1999; Boons and Baas, 1997; Schwarz and Steininger, 1997; Mirata, 2004; Jacobsen, 2006) mention some of the benefits of IS networks, such as:

- Environmental benefits due to the increased efficiency of resource use and the reduction of pollutant emissions;

- Economic benefits due to the cost reduction associated with decreased resource inputs, better waste management, additional financial input from the added value given to by-products/waste streams and estimated payback times when projects of different exchange programs are starting. Greater potential for the generation of employment, improvement in the quality of existing jobs, and enhancement in the quality of working conditions; and
• Business benefits arising from external relationships with other partners, improvement of environmental image, and the creation of new products and markets.

The concepts that guide the triple bottom line are expressed in the latter. If these are achieved, or if the conditions to its achievement are gathered, then a step towards sustainable development is achieved. IS was not conceived to be the answer to all of the problems haunting contemporary societies, nevertheless it has a number of characteristics that enables it to be considered a sustainable development tool at least on a regional or local level.

However, for successful implementation, IS faces quite a wide and variable range of challenges that van Berkel (2006) narrowed to the three following “enabling mechanisms”:

• **Facilitating structures** that encourage collaboration among industries and/or other sectors operating in the same industrial area;

• **Operational and contractual arrangements** that enable commitment of the necessary resources for implementation of IS projects; and

• **Evaluation methods** that can track and quantify the environmental, social and economic benefits (triple bottom line) of IS projects.

These enabling mechanisms and their relation with the regional synergy development are depicted in Figure 2-2.

![Figure 2-2: Synergy Development Process](image-url)
Figure 2-2 Contributions of enabling mechanisms to the process for development, evaluation and implementation of IS

Source: Adapted from van Berkel, 2006

Figure 2-2 shows, in a schematic way, the various mechanisms that must be followed and the several elements that must be in place for a regional IS network to be built. When starting the identification of companies for a potential IS network, an assessment of conditions should be made in order to determine if the minimum requirements are in place (i.e. resource input/output, exchange opportunity, synergy creation, etc). IS is a cycle that should always be striving for improvement in efficiency and in the identification of new potential synergetic collaborations. Thus, raw materials availability, wastes management, logistics or infrastructures that may enable the identification of new synergies should be constantly reviewed. The right institutional setting must also be in place, or conditions for its creation should be arranged, so that inter-organisational business partnerships may be created and go further than any single resource input/output exchange, creating instead an entire network of utilities, jobs and in some cases even services. A methodology for evaluating the sustainability of these projects should also be created, taking into account the related economic, environmental and social factors, and what improvements in each of these areas arises out of the implementation of IS.

Clearly, every economy related with IS exchanges will vary in scale and scope due to its specific production-related context. Some companies may have a bigger commitment than others in the creation and efficient functioning of a network, simply because they will profit more with the created synergy. Therefore, Jacobsen (2006) states that every exchange project has to include a justified individual economic and environmental related argument.

The establishment of IS can promote a natural evolution in business operations, as companies progressively become aware of the availability of resources which were previously viewed as something to discard or treat (Côté, 2003). This in turn, will create a positive environmental balance, which is related above all with reduction in resource consumption, while at the same time creating potential for economic profits derived from the new IS approach from industry. The economic growth derived from IS implementation may directly promote job creation due to new business opportunities that might arise from the resources previously considered wastes. Jacobsen (2006) argues that IS networks are well positioned to enable better inter-industrial collaboration with a positive net effect for the environment.

2.4 Industrial Symbiosis contribution to regional sustainable development

2.4.1 A tool for regions

Due to the characteristics upon which it is based, IS is rooted in the general approach of SD. Where SD can be facilitated if approached through small sustainable regions, IS is a practical tool that if applied at a local/regional level and if aligned with the right conditions can also assist in regional sustainable development. The synergies born from an IS network are related with resource use efficiency, waste reduction and by-product reuse, economic growth, job creation, as well as other environmental and social improvements. In this way, as long as regions present certain requirements such as business alignment and collective approaches, IS may be used in certain situations to help boost local sustainable development. (Wallner and Narodoslawsky, 1995; Chertow, 2000). In order for a sustainable operational framework to be set in a realistic way, it is necessary to take the ecological, social, economic and cultural aspects
of the region into consideration. Along with this, some criteria for measuring and enhancing sustainability should also be set in order to better identify problematic areas at the regional level (Buëhler-Natour and Herzog, 1999).

One of the purposes of IS is that it be used as a tool to achieve sustained regional development by involving different stakeholders during the early stages of the process. This development should be in phases in order for it to be properly achieved. This phasing is characterised by the kind of participants engaged in every stage, the definition of responsibilities, the commitment dedicated to these kind of projects and the contributions for the development of the IS networks and the overall regional sustainable development scenario. As shown in Figure 2-3, three different stages have to evolve in order to achieve this.

**Figure 2-3 From regional efficiency to a sustainable industrial district (Adapted from Bass and Boons, 2004)**

In the first stage, regional development is characterised by the autonomous decision-making of firms and by coordination between local firms so as to achieve better process efficiency. Different actors such as local government authorities and/or any existing co-operative arrangements between entrepreneurs may arrange these activities. In the second stage, the goals of the partners in the symbiosis are broadened due to the recognition and trust achieved in the first stage, allowing the network to exchange knowledge and hence enhance the concept of sustainability in which they operate. It is a phase where other stakeholders such as the local community may be involved. The third stage is then achieved when the sustainable industrial district is completed by the existence of a strategically shared vision of development and industrial activity based on sustainability. It is however, not clear where the beginning of the third stage is set, as it cannot be estimated until a strong collective orientation of firms has arisen (Boons and Berends, 2001; Baas and Boons, 2004; Jacobsen, 2006).

### 2.4.2 Adapting to a region’s profile

Mirata and Emtairah (2004) define IS in a practical regional context as “a collection of long-term, symbiotic relationships between and among regional activities involving physical exchanges of materials and energy carriers as well as the exchange of knowledge, human or technical resources, concurrently providing environmental and competitive benefits”. Therefore, IS can be considered either as a local initiative that uses the special proximity of companies to act upon environmental concerns, facilitating this way the development of regions towards new approaches on sustainability. Or, IS may just take advantage of the region’s already existing ability to undertake collective action, in this way setting the path for a healthy industrial network to be built through the establishment of new linkages, based on clear sustainable goals (Storper and Scott, 1995; Ekins, 1999).

Due to the corresponding characteristics of IS and SD, it may happen that projects developed by several economic actors within a region, based in IS and with clear sustainable goals, may meet requirements already required by regional strategic policies. Regional governments that are willing to create the kind of competitive advantages supported by sustainable development policies, may be interested in supporting a project that includes such aspects as innovation, research and development, or alternative energies. Sustainable regional programs and projects may have the ability to engage all the parties into a certain level of cooperation. They can do
this on one hand by facilitating the change in institutional processes that might delay or endanger such initiatives (e.g. removing potential policy barriers and/or supporting fund applications either at regional, national, or international level). On the other hand, regional governments may also encourage or enhance the collective action of the intervenient and attract more actors in the region to such projects. This may in turn generate opportunities for the creation of jobs and economic growth under more sustainable programs, conducted in partnership between public and private sectors. Bridger and Luloff (1999) confirm this by saying that the main objective when developing sustainable regional projects is to create a balance between environmental concerns and development objectives, enhancing local social relationships.

Local development can also benefit greatly from regional industrial culture that IS builds, due to its socio cultural context, such as similarity in habits, attitudes or costumes. For instance, it is easier to achieve informational and organisational relations in small regions, due to the potential familiarity amongst the companies responsible and that it is due to economic forces that these networks come to be (Schwarz and Steininger, 1997). Nevertheless, the potential familiarity between companies might weaken the commitment in the collaboration process, inducing different action schedules to companies and to some extent also driving companies out of these networks, simply just by not keeping up with the pace set by majority in network.

One way to try to assess the success of IS implementation, might be through the identification of synergetic processes that have clear quantified results, be this in economic or environmental performance, as well as in other sustainability requirements. These will depend largely on what aspects are looked upon and how. Taking for example a potential project on regional synergies related with an energetic scheme based on renewable resources. Issues such as economic savings, generation and sell of energy will be accountable, as well as environmental or social benefits from this new energetic scheme (e.g. CO₂ emission reduction, improved regional air quality, etc). If a cost benefit analysis on the return period for investments proves medium-long term profits, then the creation of indicators for a positive evaluation to be made based on economic, environmental and social criteria may be produced. The latter is supported by the words of van Berkel (2006) who states that value creation from regional resource synergies is profound when it comes to economic and environmental outcomes.

The usefulness of applying IS in a regional/local context is mirrored by the possibility of assisting a region to concentrate more on the use available resources within and in the way they are managed. In this way, regions traditionally considered dependent on energy or other resources from outside of the region have the capability to become more self-sufficient or ‘energy secure’. It is not only the typically available natural resources that can be considered here (e.g. energy, water, fertilisers, etc), but also those products, by-products and/or wastes of industry, agriculture or other any economic activity that is predominant in the region and that generates several different outputs. With the generation of symbiotic relations between different industries, the conditions are in place for the creation of mutual benefits such as raw material, waste or energy reduction and even energy production. Thus, allowing reduction on external dependency and the self sustained growth of the region. There is no market limitation imposed through this approach, simply because it is related with the already existing resources within the region and not with the external relations that normally force a change of markets. Existing markets will continue to exchange as usual, there will however be the potential for new markets to be created from the resulting new synergies. At the most, a new commodity might enable for market expansion. An example of this could be where such a region makes the shift from energy receiver to energy supplier, in this way ending a certain type of market, but at the same time creating a new one.
The inherent versatility of IS allows for its adaptability to any existing conditions, as long as the required aspects for synergy creation are present in any given scenario. The needs and available exchange materials might change, but the synergies or the potential for creation of valuable new markets will always be available. This, in line with regional sustainable development implementation is something that has a different approach in every site-specific case. The conditions that are required for the implementation of IS and the differences that might be found in political, cultural or economical regional settings do not allow for one standardised approach. Nijkamp and Vreeker (2000) substantiate this by saying that there is no place for generalisation of sustainability indicators, as there are always particular site-specific issues that make each region individual.

As the odds for generating concrete SD situations increase by moving to the local level, it is of utter most importance that there is a constant strive towards continuous improvement from the members of IS networks. This includes an approach based on the network itself and the inter-organisational links that are generated in between members. At the same time, an analysis of how each single company faces sustainability issues and long-term environmental concerns must be conducted. Operations involving production and consumption systems cannot reach longer-term sustainability without first implementing better environmental solutions (Mirata and Pearce, 2006). The innovations achieved should be continuously reviewed, new technology assessed and the chance for more synergies analysed. This requires that the companies involved within the network have a role in setting their own environmental profile outside of the networks. If companies do not have in general an open approach towards sustainability issues, their participation in such networks might then be compromised. In addition, with time the tendency should be for this kind of sustainable framework to mature through natural improvements in efficiency, engagement of new stakeholders, and more suited regulations. The main capacity enablers, such as governance, industry and other stakeholders should proactively support this maturation process. van Berkel (2006) also mentions that by enabling synergy development processes, the potential for more sustainable regional development arises mainly through policy interventions (e.g. economic incentives, tax discounts and increased efficiency in the regulatory framework) and continuous learning (e.g. companies in the region sharing best practices).

### 2.5 Conclusion

The issues surrounding sustainable development have long been discussed and many tools have been developed in order to improve the chances of actually achieving it. IS is one of those tools. With the right set of conditions related with different areas of concern (political, technical, organizational, etc.) in place, a step towards a more sustainable system may be created. The boundaries of this system may be defined from an industrial area to a regional level. These systems or networks may have the flexibility to adapt to particular circumstances encountered in any region, trying to engage the necessary partners to give it credibility and always taking in consideration economic development side by side with the environment and society.

In the next chapter, a brief introduction to the Alentejo region and particularly Reguengos de Monsaraz, will be given. The research project based on the IS framework that has been described here will be introduced, as will its potential application to the Reguengos de Monsaraz region. Chapter 3 will also identify potential stakeholders and describe how their engagement into the research project network took place.
3 The Reguengos de Monsaraz Industrial Symbiosis Project (RMISP)

In this chapter the potential participants in an IS network in the region of Reguengos de Monsaraz, from companies to regional decision makers, will be characterised. A description of the process to engage them into this research project will also be given. Hence, Section 3.1 starts with a brief characterisation of the Portuguese region at study, Reguengos de Monsaraz, within the regional context in which it is placed. Following, the various stakeholders are identified in Section 3.2 and the way in which contacts were established and stakeholder engagement into the project was achieved will also be briefly described. Next, Section 3.3 gives a thorough description of each of the companies engaged in the research project as well as a detailed analysis of their resource flows, needs and capacities.

3.1 Reguengos de Monsaraz: Characterising a region

3.1.1 The Alentejo region

With an area of approximately 31 551 km², Alentejo is the largest of all five Portuguese regions, representing approximately 34% of the national territory (CCDRA, 2007), as seen in Figure 3-1.

![Figure 3-1 Alentejo territory within the context of Portugal national territory](Source: Câmara Municipal de Reguengos de Monsaraz, 2006)

Not that long ago (approximately 50 years), Alentejo was considered to be “Portugal’s barn” due to its high capacity for cereals production and other related agriculture activities such as vineyard or olive grove production. With the passage of years, Alentejo has witnessed continuous abandon, first from the main strategic policies of the ruling class and progressively from the local inhabitants that started leaving the region due to a continuous feeling of neglect and abandonment due to political decisions.

Until today, this region presents a relatively low standard of living for its inhabitants in comparison to the average national and European Union (EU) level. In the past years, the regions GDP is lower than the national average and has faced serious difficulties keeping up with the annual average GDP of the EU (CCDRA, 2005). These conditions make it even
more difficult for the region to improve its standard of living, thus serving to increase the disparity between indicators of wealth in comparison to the average standard of living for the rest of Portugal and the EU (such as wages, earning capacity, etc). As a result of all of these factors, Alentejo is the region of the country with the highest unemployment levels (CCDRA, 2007).

According to the analysis of the document Plano de Inovação Regional (CCDRA, 2005), the region presents an aging index that is considerably higher than the EU average and has the lowest population density index in Portugal. On the other hand, the Alentejo region presents high levels of productivity in primary activities such as agriculture and fisheries. In the region, productivity is associated with sectors that evolve around scale economies. Nevertheless, in the report Avaliação de Oportunidades de Desenvolvimento Regional do Alentejo (CEDRU/TIS, 2003), it is mentioned that although this region has structural development fragilities, it denotes a “trajectory of positive evolution”.

Alentejo has some competitive advantages that are related with a profile of productive specialization based around activities that exploit natural resources, several certified products and a set of institutions capable of promoting innovation, research and development. Improvement in the road network is projected because of new residential and tourism development projects related with the Alqueva Lake. On the other hand, the region also faces disadvantages that are related mainly with its geo-economic status, the lack of economic investments in the past, the individual characteristics of the territory (such as desertification, natural/environmental degradation), or an industry structure characterized by companies of micro-dimension, generally little inclined to innovation. This is reflected in the low competitive stability and low wages of the region that are directly related to the low levels of formal education amongst the majority of the labour force of the region (CCDRA, 2007).

Given that in the past years the Alentejo region has faced development problems related above all with lack of investment in the region, it is only natural that this less diversified economy, in comparison with the rest of the country, has a small capacity to generate jobs. This, coupled with a very high ageing index, which is related amongst others with the difficulties the region has in enticing young people to stay, places the region in an altogether fragile position to develop sustainably. (CCDRA, 2007).

Alentejo still faces problems of global impacts on its development potential, such as weak competitiveness in relation to several globalisation processes like flows of ideas, people, goods, services, capital or information, EU economic and monetary integration, lack of enterprises and entrepreneurs, problems related with regional logistics, not to mention the enormous restriction of water scarcity (CEDRU/TIS, 2003).

Alentejo, despite the fact that it represents one third of the national territory, has less that 5% of the total Portuguese population, approximately 4% of the active population, less than 1% of the enterprises and less than 4% of the wealth created on an annual basis in the country

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3 A ‘scale economy’ refers to the relationship between the size of a plant or industry and the lowest possible cost of a product. When a factory increases output, a reduction in the average cost of a product is usually obtained (Encyclopaedia Britannica, 2007).
Potencial for implementing an Industrial Symbiosis network in rural Portugal (CEDRU/TIS, 2003). This scenario shows the necessity for immediate actions in the region, leading to the increasing creation of improved localised economies, with a continuous aim towards more sustainable development.

This region faces high sustainability problems due to the fact that, if the political attention given to this area continues to be inadequate, people will continue this exodus and Alentejo will eventually become a totally deserted area. This has the knock-on effect of bringing littoral regions closer to their carrying capacity⁴, leaving both the littoral and interior regions of Portugal unsustainable living areas.

Therefore, it is necessary to create a new strategic approach to the Alentejo region. This approach should lead to the convergence of the region with the living conditions of rest of the country and ultimately with the premises of the EU. The existing natural resources must once more be considered a competitive advantage, and that, along with a bigger investment in the traditional industries of this region may boost economic and social growth. Nevertheless, there should be a permanent endeavour in achieving this without adding any unnecessary burden to the environment.

Many challenges to more sustainable rural development can be identified in Portugal, the most serious of these being related with the competitiveness and sustainable use of agriculture and forest, quality of life, environment, land management and the diversification of economic activities (European Commission, 2006).

### 3.1.2 Reguengos de Monsaraz

The municipality of Reguengos de Monsaraz, located in the south east part of Alentejo, belongs to the Évora district and has an area of approximately 369 km².

![Figure 3-2 Municipality of Reguengos de Monsaraz at a regional and national level](source: Câmara Municipal de Reguengos de Monsaraz, 2006)

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⁴ ‘Carrying capacity’ refers to the maximum number of individuals of a given species that can be sustained indefinitely in a given space (area or volume) (Miller, 2005).
Reguengos de Monsaraz has a population of 11,382 inhabitants (Instituto Nacional de Estatística, 2007) and a population density of approximately 19 inhabitants/km² ( Câmara Municipal de Reguengos de Monsaraz, 2007). The municipality is divided into 5 civil parishes: Reguengos de Monsaraz, Monsaraz, Corval, Campo and Campinho.

The municipality of Reguengos de Monsaraz has an economy of strongly traditional characteristics, with the main industries in the region related to the agriculture and manufacturing sectors. The municipality is a big wine growing centre, making it one of the most prosperous small towns in Alentejo. It is a region characterised by hot dry summers and short rainy winters (C.M. de Reguengos de Monsaraz, 2007), which makes it a region with perfect climate conditions to the development of certain economic activities based on agriculture.

The majority of the population works in the primary (e.g. agriculture) and tertiary (e.g. services) sectors, 39% and 33% respectively. These values are more than double the regional and the national averages for these sectors ( Câmara Municipal de Reguengos de Monsaraz, 2006). The unemployment rate in the municipality is approximately 10%, which is similar to the national average. Development of the region is characterised by a slow pace (Instituto Nacional de Estatística, 2007). Despite this, it does have stable growth, as some of the biggest actors of the Portuguese agro industry are located in the region. Also, the municipality has a clear interest in maintaining the natural resources offered by the region, as large areas have been zoned for agricultural use.

Concerning demography, during the period 1991 to 2001 (the time of the last census) the population did not change, placing it in a good position in comparison to the rest of the region and the country. Nevertheless, this situation does not spread to the entire municipality, but solely to the biggest civil parish (Reguengos) (Instituto Nacional de Estatística, 2001). The population in Reguengos de Monsaraz is also ageing due to the decrease in numbers of young people and an increase in the average age of the population, at a rate that is much higher than the regional and national tendency ( Câmara Municipal de Reguengos de Monsaraz, 2006).

The total area of the municipality, is divided by agriculture area (dry arable land and irrigated), agroforestry (which includes pasture for cattle), land at rest (i.e. arable land that is not being
cultivated) and some uncultivated land. All of the agricultural (primary) industries are essentially on dry arable lands. Viticulture and olive grove are the main transformation industries in the municipality, being the primary sector that has the biggest influence on the economy of the region (for instance, Reguengos holds 20% of the wine market in Portugal). In the last years the tertiary sector started to grow in the form of tourism mainly due to the strong historic, cultural and natural heritage of the region (Câmara Municipal de Reguengos de Monsaraz, 2007). Reguengos is the municipality in the Évora district with the largest number of industries in activity (Direcção Regional de Economia do Alentejo, 2007). Also, the construction of the Alqueva damn created the largest artificial lake in Europe. This construction enables, on one hand conditions for agriculture to grow and expand in the region due to the bigger availability of water, which is a scarce resource in the region. And on the other hand, it boosts even more the development of tourism in the region, with big projects such as the previously mentioned residential tourism development projects.

In despite of this, the region faces historic problems (e.g. desertification, and illiteracy), as well as new ones (e.g. changes in the economic and social structure, lack of formal educational qualifications, lack of urban planning, Common Agriculture Policy reforms, globalization, etc.) that influence its future as a region with historical self-identity in a very direct way (Congresso Alentejo XXI, 2003).

Considering that this municipality is in an intermediate development level, and that it faces difficulties for further development due to its integration in a less developed area, it can also be considered as having great potential for boosting the local economy and for developing in a much more sustainable way (Gabinete de Planeamento e Política Agro-Alimentar, 2004). Given the potential that this region has to adopt more sustainable policies, it is required that projects with a clear sustainable profile come to the region. Not only is a continuous sustainable growth from the traditional industry already set in the region necessary, but also new projects that might be supported by municipality policies are required.

Nevertheless, this municipality presents a fair level of development while maintaining strong rural characteristics (e.g. high economic, social and spatial weight along with low demographic density). This development occurs through quite a large social cohesion without demographic, sectorial and social pressures in the short term. Reguengos can act as an “island” of small-scale regional development, acting as a catalyst to neighbouring municipalities (Gabinete de Planeamento e Política Agro-Alimentar, 2004).

This region is classified according to the report Desenvolvimento e Ruralidade em Portugal—uma analise empirica (Gabinete de Política e Planeamento Agro-Alimentar, 2004) as “a pole of intermediate development in a fragile space”, meaning that it might have the conditions to boost development in its surroundings. By investing in sustainable policies and by supporting local economic actors, Reguengos de Monsaraz can act as an example and as a driving force towards the development of the entire surrounding area, and even of the Évora district as a whole. Given that most of the interior regions of Portugal have characteristics similar to the ones found in Reguengos, any policies that might come to have clear benefits for the economy and the society, without injuring the environment, have the potential to be used as an example elsewhere.

### 3.2 Identifying a potential Industrial Symbiosis network

The main objective of this research was to identify if there were the necessary set of conditions to implement an IS network in the Reguengos de Monsaraz area. This relates
amongst others, to the necessary identification of industries that might see a chance for economic profit through improvement and collaborations while at the same time enhancing their environmental profile. It is also required the identification of other main actors such as political decision makers or regional development agencies. The recognition and engagement of all these parties will necessary create the conditions to assess also the extent to which the factors identified by Mirata (2005) (as shown in Table 3-1) are influencing the development and the operational characteristics of an IS network within this case study.

Table 3-1 Factors influencing development and functioning of IS networks

<table>
<thead>
<tr>
<th>Domain</th>
<th>Elements constituting the factors</th>
<th>Potential areas of influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informational</td>
<td>Access to relevant information. Availability of timely and reliable information from a wide spectrum of areas to the right parties. Continued review info.</td>
<td>Possibilities to identify synergies. Possibilities to operationalize synergies Risk perception of companies</td>
</tr>
</tbody>
</table>

Source: Mirata, 2005

3.2.1 Building relationships

The author identified eleven organisations within the geographic boundaries of the Reguengos de Monsaraz municipality: Five private, three public/private joint ventures, two government bodies and one non-governmental organization. The names of these organisations and the sectors within which they operate are provided in Table 3-2.
The idea of exploring the possibilities for developing an IS network in the region of Reguengos de Monsaraz was first discussed with Finagra S.A. This company has supported the idea and agreed to act as a champion for its development. The fact that Finagra S.A. is one of the biggest economic actors of the region and the fact that it was supporting the research project made it the perfect incentive to entice other potential stakeholders to the network.

In the appointment held at CARMIM’s facilities, the representative was very interested in participating in the research project, having stated that he would give “all necessary support” within his range in order to assist in the progression of the research. In the meeting with the Maporal representative, besides engagement and commitment to the network, the existence of previous past contacts made with Finagra S.A. and CARMIM were brought to light. These contacts were initiated in order to create an exchange program for workers due to the seasonal activity all these companies have. Unfortunately, at the time this synergy did not prove to be feasible.

When EuroEste, S.A. was contacted, most of the stakeholders were already engaged in the project. Besides acknowledging the engagement of the municipality and of some of the most
important economic actors in the region in this research project, the representative showed a strong willingness and commitment to improving its image with the local population and in the region. From the early contacts with the AromaAlentejo company, it was established that given their line of activity their part in this research project would be purely as receivers, instead of the classic exchange approach.

As a result of the meeting with the municipality, institutional support for the project was gathered. Not only was the vice-president very receptive to the research project, but also provided a document sent to the secretary of state in the Ministry of Industry and Innovation (Secretário de Estado da Indústria e Inovação) dated 9 February 2007, which exposed the willingness of the municipality to install a project of renewable energy, namely a biomass power plant. According to the vice-president, plans for this implementation in the region have existed for some years now.

From the meeting held with ADRAL, information was provided relating to other institutions or people that might aid in the creation of synergies amongst the companies, or that might give inputs related to R&D issues that could arise from the research project. In the CCDRA, the meeting was conducted along the same lines as those already mentioned, with acknowledgment of how the agency could provide help in the future of the research. That is to say, the agency representatives indicated how they could act as an intermediate in the case of a candidature to EU funds from a hypothetical future project born from this research, namely to the next community support framework. The representatives of the agency also stated that they could be available to help identify possible barriers to further implementation of the IS network, particularly related with policy and institutional (bureaucratic) issues. In addition, they provided the name of a professor in Évora University who had undertaken some studies on the energetic content of some particular biomass by-products during the early 1990s. This detail will be further explored in Chapter 4.1

From the contacts made with the company managing the WWTP, it was understood that AdCA is a public/private partnership, where the Reguengos de Monsaraz municipality holds a share. This only helped to facilitate the engagement of the company (as the municipality was already engaged through the vice-president). As requested, the company provided data from the restructuring project of the WWTP, related with quantities of both sludge and effluent waters determined for when the WWTP is fully operational. Data concerning the quality of the sludges can only be obtained once the WWTP is operational. The company believes however, that the ultimate facility will produce high quality sludge. In the Reguengos de Monsaraz transfer station, the entire municipal solid wastes of the region are collected, plus that of two other municipalities in the region. The gathered wastes are then transferred by truck to the Évora landfill. As the company’s representative agreed to help as much as possible, data concerning the types and quantities of wastes that are delivered to the Reguengos de Monsaraz transfer station where requested.

Logically, it was agreed with the representative from ADIM, that this NGO’s role in the research project would be initially only of acknowledging the identified benefits this could bring to the region (the NGO was therefore invited to the workshop that followed the research period) and potentially later, to involve the local community in the development of the project.

### 3.3 Characterising stakeholders

A data collection form which uses the work developed by IIIEE researchers in IS programs both in the UK and Sweden, and which was adjusted to Portuguese context (the same format
of data collection was followed for each engaged stakeholder) was supplied to each of the potential stakeholders. These, along with interviews conducted by the author, allowed a suitable profile of each of the identified potential stakeholders in the RMISP to be created. This characterisation was based on the following primary areas:

- Material, energy and water in- and out-puts;
- Processing, utilities, logistics and waste management infrastructure capacities and needs; and
- Needs and capacities of human, knowledge, and managerial resources.

Based on the data collected, through different means, the key characteristics of the main stakeholders of RMISP are presented below:

### 3.3.1 Finagra S.A.

As previously mentioned, Finagra S.A. is a major agro industrial wine producing company. It is a private company located in the southwest part of Reguengos de Monsaraz. It is approximately 600 ha in area, making it the largest private wine producer in the country (holding a 7% share of the market). It has 243 workers and its major activities are focused on grape cultivation and consequent processing to produce and bottle several varieties of wines. It also participates in eno-tourism\(^5\) and belongs to a national network of eno-tourism facilities, which is an area with clear expansion potential for the company.

Highly efficient management practices are conducted at Finagra S.A. This includes high density, regular and controlled irrigation, along with monitoring for all the activities related with the grape growing and wine production. The soils are subjected to periods of rest where they are not cultivated, with the purpose of preserving the structure of the soil. Out of the total quantity of the grapes (raw materials for the production of wine), 60% are not produced on-site, but are delivered by truck from 8 other producers. Depending on whether the grapes are red or white, some of the processes may differ. Nevertheless, the general processes occur as follows. Once the grapes have been collected and separated from the stem, they are weighed and consequently pressed (depending on the stage of the wine and if it is red or white). All of the consequent wine production processes (i.e. fermentation, maturation, filtration, stabilization, filling and labelling of the bottles and finally the storage) are conducted on-site in the cellar of the company. When the time comes, the wines are distributed around Portugal and to a number of other countries by truck and boat. Table 3-3 was produced from the information supplied by the representative of Finagra S.A. as a result of the data collection form supplied to them. It details the annual raw material inputs, outputs, wastes produced and electricity and water consumed.

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\(^5\) Eno-tourism refers to all the tourist, leisure and spare time activities, dedicated to the discovery and to the cultural and enophile pleasure of the vine, wine and its soil (Deloitte, 2005).
### Table 3-3 Relevant Inputs and Outputs of Finagra S. A.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Quantities</th>
<th>Revenues / Costs (R/ C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw Materials</strong></td>
<td>Grapes produced on-site</td>
<td>4 000 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grapes imported from off-site</td>
<td>6 000 tonne/year</td>
<td></td>
</tr>
<tr>
<td><strong>Main Products</strong></td>
<td>Wine</td>
<td>8 000 000 l/year</td>
<td></td>
</tr>
<tr>
<td><strong>By-products</strong></td>
<td>Grounds</td>
<td>300 000 l/year</td>
<td>(R) 24 000 €/ year</td>
</tr>
<tr>
<td></td>
<td>Bagasse</td>
<td>1 200 tonne/year</td>
<td>(R) 42 000 €/ year</td>
</tr>
<tr>
<td><strong>Wastes</strong></td>
<td>Stem</td>
<td>720 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vine-shoot</td>
<td>2 000 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial waste</td>
<td>30 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sludge</td>
<td>24 m³/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shred</td>
<td>5 tonne/year</td>
<td></td>
</tr>
<tr>
<td><strong>Disposal</strong></td>
<td>Burn</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burn</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landfill</td>
<td></td>
<td>(C) 275 €/ tonne</td>
</tr>
<tr>
<td><strong>Total Energy</strong></td>
<td>Electric</td>
<td>1 330 749 kWh</td>
<td>(C) 114 444 €/ year</td>
</tr>
<tr>
<td></td>
<td>Thermal</td>
<td>29 975 kWh</td>
<td>45 500 €/ year</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>148 800 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>Potable</td>
<td>33 000 m³/year</td>
<td>(C) 3 234 €/ year</td>
</tr>
<tr>
<td></td>
<td>Hot (80’)</td>
<td>1.5 m³/hour</td>
<td>Included in total water cost</td>
</tr>
</tbody>
</table>

The wastes and by-products originate from several batches, the biggest waste of all being the vine shoot that is produced whilst still in the vineyard fields during pruning. The stem is generated during the separation process and the bagasse comes from the pressing. Finally, the grounds are the result of several distinct phases.

From the data presented in Table 3-3 it is clear that there is a large problem related to the volume of wastes generated by the company, namely the stem and the vine shoot. The stem, as mention previously, originates from the process of separation and preparation of the grapes for fermentation into wine. The vast amounts of vine shoot generated are a result of the vine maintenance that is performed every year in the vineyard, creating several hundreds of tonnes of wood, which consequently produce the biomass waste. This large quantity of biomass is currently burned out in the open, constituting a clear waste of resources. Instead, the company could reap the economic benefits of its calorific\(^6\) or lignocellulosic\(^7\) value for conversion into energy. Not to mention the unsustainability of the biomass burn which releases CO\(_2\) back into

---

\(^6\)Calorific value refers to the amount of heat released by the combustion of a mass of fuel (Calorific value, Encarta Encyclopedia Online, 2007)

\(^7\) Lignocellulose is a strengthening substance composed of lignan and cellulose found in the woody tissues of plants (Lignocellulose, Encarta Encyclopedia Online, 2007).
the atmosphere, causing detrimental effects upon the local air quality, to say the least. This is quite clearly one of the biggest environmental impacts of the company’s activities.

Added to this, is the fact that Portuguese legislation forbids the burning of any kind of material in open spaces. The only exceptions are related with agricultural activities during a certain period in the year (decree law no.78, 2004), but due to the unsustainable character of this activity there is no guarantee that this will not change some time in the future to be in line with the majority of other EU countries. The other value that immediately stands out is the energy that the company consumes per year (approximately 1.3 million kWh corresponding to 114 thousand €/year). This value is determined from the electricity used to operate machinery (i.e. automated bottle filling, labelling and packing of the wine) and to produce cold (e.g. fermentation processes, decanting and storage of the wine, and air conditioning). Lighting is another electricity requirement for the offices of the company as well as in the eno-tourism facilities, which include a restaurant.

Finagra S.A. also requires heat in order to warm water to 80ºC for machine cleansing processes. This is done with the help of a boiler that runs on liquid fuel (i.e. diesel) (this value is described in Table 3-3 has thermal energy consumption). Of course, the company also uses a large amount of water for irrigation and other purposes (e.g. drinking, cooking, cleaning, etc). However, the water consumed is from an internal source (on-site dam) and does not contribute to any potential for synergies with other network partners. The company owns a Waste Water Treatment Plant (WWTP) for the effluent from its processes. This WWTP produces sludge, which is taken to landfill for disposal at the present time.

3.3.2 CARMIM – Cooperativa Agrícola de Reguengos de Monsaraz

CARMIM is the biggest wine cooperative in the country, having 912 associated, of which 500 are grape growers (most of these associates are also olive growers) contributing to a total vineyard area of approximately of 3 600 ha. This cooperative is situated in the northeast of Reguengos de Monsaraz, with its associated grape growers scattered throughout the entire municipality. Besides producing wine it also produces olive oil, receiving also cereals and wool. It has approximately 85 employees and an annual turnover of 3 086 750 €. Contrary to the efficient cultivation processes of Finagra S.A. and due to the fact that it is a cooperative, it is in this case much more difficult for CARMIM to maintain proper management and control of all the production activities that are performed at the individual associated grape growers, namely the maintenance of the vineyard and its growing characteristics. The management of CARMIM only has absolute control of the raw material once it is delivered to the cooperative installations. This company, in comparison with Finagra S.A., produces a lot more wine per year, but its grape production is more dispersed amongst all of the single associated producers. As mentioned by one of the company’s representatives whilst being interviewed, the biggest problem that the associated grape growers have is dealing with the vast amounts of waste generated during the pruning process (as already mentioned at the Finagra S.A. site).

The general processes for the wine production are similar to the ones used by Finagra, S.A. The fact that there is less control over the single vineyard producers is to some extent reflected in the data collected about CARMIM and presented in Table 3-4. Even so, all the producers have to use approved products recommended by the Association of Viticulture Technicians of Alentejo (ATEVA) and due to the DOC (controlled origin denomination) rules on vineyard management, there are certain criteria that need to be followed by every associated.
Table 3-4 Relevant Inputs and Outputs of CARMIM.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Quantities</th>
<th>Revenues / Costs (R/ C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>White Grapes</td>
<td>4 500 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red Grapes</td>
<td>15 500 tonne/year</td>
<td></td>
</tr>
<tr>
<td>Main Products</td>
<td>Wine</td>
<td>15 000 000 l/year</td>
<td></td>
</tr>
<tr>
<td>By-products</td>
<td>Grounds</td>
<td>300 000 l/year</td>
<td>(R) 3 300 €/ year</td>
</tr>
<tr>
<td></td>
<td>Bagasse</td>
<td>1 500 tonne/year</td>
<td>(R) 63 000 €/ year</td>
</tr>
<tr>
<td>Wastes</td>
<td>Stem</td>
<td>1 800 tonne/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vine-shoot</td>
<td>2 808 tonne / year</td>
<td></td>
</tr>
<tr>
<td>Disposal</td>
<td>Offered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Energy consumption</td>
<td>Electric</td>
<td>1 700 000 kWh (external supply)</td>
<td>(C) 149 681 €/ year</td>
</tr>
<tr>
<td></td>
<td>Thermal (Natural gas)</td>
<td>38 578 kg Propane/ year</td>
<td>(C) 33 177 €/ year</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>700 000 kWh</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Potable</td>
<td>5 377 m³/year</td>
<td>(C) 3 234 €/ year</td>
</tr>
</tbody>
</table>

From Table 3-3 it is clear that CARMIM (as Finagra S.A.) also has a large problem related to the volume of wasted biomass generated by the company, namely the stem and the vine shoot. The origin of these wastes is the same as that explained in Section 3.4.1. In this company’s case the biomass is given to the associated grape growers to serve as feedstock. However, even that use it is not very effective as the animals cannot eat it after one or two days once it becomes too dry. Again, as in the previous analysis of Finagra S.A., the other value that immediately stands out is the energy that the company consumes per year (approximately 1.7 million kWh corresponding to 150 thousand €/year). Due to the analogous activities of the two companies, the energy required by CARMIM serves the same purposes as with Finagra S.A.

It is interesting to analyse the similarity in quantities of produced biomass waste, as CARMIM produces much more wine per year and has much more cultivated area than Finagra S.A., it should theoretically produce much more biomass. According to the agronomist João Maria, who heads ATEVA, the cause for the similarity of the biomass produced relates to the fact that the cultivation conditions in the CARMIM case are not homogenous. Therefore, the quality of the vineyard management is not of the same standard in all of the 500 associated vineyards, and there are much better growing conditions in some than in others. Whereas, in the Finagra S.A. case the whole vineyard is managed by the same entity and therefore much more productivity is achieved.

Also, the Finagra S.A. vineyards have undergone profound changes during the last 20 years by being progressively improved. Whilst in the CARMIM case, many vineyards are 30 or 40 years old and do not therefore have the same characteristics as modern vineyards. Finally, the cultivation period for the vineyards is also different and influences the future growth.

Although not indicated in the previous table, an estimate on the potential biomass waste derived from the pruning of olive trees was also provided by CARMIM. It is estimated that approximately 3000 ha of olive grove in Reguengos de Monsaraz belong to the CARMIM
associates. Theoretically, and under optimal conditions, the pruning is done every 3 years with a total amount of pruned biomass of approximately 12.5 kg/tree. This means that if there are on average 100 trees per hectare, 3 750 tonnes of biomass could be generated from the olive grove every 3 years. Unfortunately, at this stage there is very little control over this as the pruning is not controlled in an effective way by the CARMIM technicians. Nor is there a recent inventory on the number of olive trees per hectare.

3.3.3 Maporal – Matadouro de Porco de Raça Alentejana, S.A.

Maporal (Matadouro de Porco de Raça Alentejana, S.A.) is a slaughterhouse located in the western part of Reguengos de Monsaraz. It has a total area of 5 400 m², 40 employees and an annual turnover of 2 000 000 €. Its activities relate mainly with the reception of full-grown pigs, their slaughter and all of the intermediate processes required to dismantle the dead animals. The activity of this company is seasonal, and only operates for six months of the year. Based on that, all of the data presented in Section 3.4.3 is on a 6 month basis, but for consistency with the other sites, and for simplicity, it is presented in a way that it relates to an entire years worth of production.

Table 3-5 characterises Maporal’s needs and capacities.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Quantities</th>
<th>Revenues / Costs (R/ C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw Materials</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigs</td>
<td>27 125 pigs/year</td>
<td>(C) 457 €/year</td>
<td></td>
</tr>
<tr>
<td>Propane gas</td>
<td>10 127 m³/year</td>
<td>(C) 1 120 €/year</td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>10 190 l/year</td>
<td>(C) 1 120 €/year</td>
<td></td>
</tr>
<tr>
<td><strong>Main Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pig abate</td>
<td>27 125 pigs/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcass dismantle</td>
<td>93 tonne/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>By-products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bones</td>
<td>265 tonne/year</td>
<td>(C) 23 850 €/year</td>
<td></td>
</tr>
<tr>
<td>Guts, blood and hair</td>
<td>806 tonne/year</td>
<td>(C) 96 720 €/year</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1 281 tonne/year</td>
<td>(R) 192 150 €/year</td>
<td></td>
</tr>
<tr>
<td><strong>Wastes</strong></td>
<td>Sludge</td>
<td>146 m³/year</td>
<td></td>
</tr>
<tr>
<td><strong>Disposal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric</td>
<td>674 338 kWh/year</td>
<td>(R) 48 760 €/year</td>
<td></td>
</tr>
<tr>
<td>Thermal (Propane)</td>
<td>101 m³/year</td>
<td>(R) 457 €/year</td>
<td></td>
</tr>
<tr>
<td>(Diesel)</td>
<td>0, 548 m³/year</td>
<td>(R) 1 010 €/year</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>Blood Boiler</td>
<td>10 bar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vertical fright tunnel</td>
<td>10 bar</td>
<td></td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>6 997 m³/year</td>
<td>6 087 €/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 m³/hour</td>
<td>Included in total water cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75 m³/hour</td>
<td>Included in total water cost</td>
<td></td>
</tr>
</tbody>
</table>

From the data presented in Table 3-5, it is clear that this company’s major concern is related with the disposal of by-products derived from the pig dismantle. Maporal incurs quite an expense from the disposal of bones, guts, blood and hair: up to 120 570 €. On the other hand, the fat has a high market value. All of these by-products are currently shipped to Spain where
they are introduced in other processes to make feedstock. The other value that immediately stands out is the energy that the company consumes per year (approximately: 674 338 kWh/year corresponding to 49 thousand €/year). Their energetic needs relate to their electric necessities, use of propane to heat water and carbon dioxide to anaesthetise the pigs. Maporal also uses fossil fuels, such as diesel, to feed the heat necessities of its activities. Following on from this, Maporal’s willingness to use more alternative sources of energy, such as renewables, was made clear by its representative. The representative also stated that they acknowledge their large industrial cooling and electricity requirements.

The only waste that the company has is the sludges derived from the treatment of their industrial effluent. These sludges have a high organic content and, according to the statement from the representative of the company, needs a proper treatment to be used in order to have an economic value. The company is considering buying equipment that will enable dehydration of the sludges, which as they understand is to be the first step towards enhancing the market value of the sludge. Maporal is also very willing to use specialised workers that can commute from other companies, or vice versa, because their activities are mainly seasonal as in the activities of other companies.

3.3.4 EuroEste - Sociedade de Agricultura de Grupo, Lda.

Situated in the southern part of Reguengos de Monsaraz in the civil parish of Campo, EuroEste S.A. is the largest pig farm in the region. EuroEste S.A. is a company of national level, having its activities distributed through pig farming, cattle breeding and agriculture. It is one of the largest livestock breeding companies in the country, producing over 100 000 pigs per year and exploiting 180 ha of intensive agriculture.

In the pig farm activities investigated within this research, piglet breeding and fattening are the dominant processes of this company. The pig farm has 850 reproductive female pigs that give birth during the entire year.

Table 3-6 shows the needs and capacities as described by the representative of EuroEste S.A.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Quantities</th>
<th>Revenues / Costs (R/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>Feedstock</td>
<td>1 000 tonne/year</td>
<td>(C) 170 000 €/year</td>
</tr>
<tr>
<td>Main Products</td>
<td>Piglets</td>
<td>16 500 animal/year</td>
<td></td>
</tr>
<tr>
<td>By-products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wastes</td>
<td>Liquid effluent</td>
<td>13 140 m³/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solid effluent</td>
<td>250 m³/year</td>
<td>(C) 3 360 €/year</td>
</tr>
<tr>
<td>Disposal</td>
<td>Licensed company</td>
<td>240 m³/year</td>
<td>3 360 €/year</td>
</tr>
<tr>
<td>Total Energy</td>
<td>Electricity</td>
<td>216 000 kWh/year</td>
<td>(C) 15 120 €/year</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Potable with chlorine</td>
<td>12 045 m³/year</td>
<td></td>
</tr>
</tbody>
</table>
From the data presented in Table 3-6 two figures clearly stand out, namely the value paid for energy that the company consumes per year (approximately 216 000 kWh/year corresponding to 15 thousand €/year) and the cost for waste disposal of the solid effluents from the processes of breeding the piglets. The quantity of effluent produced by the animals is large and the money that the company pays to dispose of it is also one of the biggest expenses it has (250 m³/year corresponding to 3 360 €/year). The wastes from the pig farm usually resemble a grease (liquid composed by the total excrement mixed with the cleansing water from the pavilions where the pigs are kept) that is gathered and stored in lagoons or cesspools. The EuroEste S.A. separates the solid and liquid parts and disposes of the solid part through the services of a specialised company. According to the representative, there is the possibility to give away some of the solid waste to farmers in the surroundings due to their interest in receiving the nutrient rich waste, nevertheless this practice is not allowed by Portuguese law therefore not being conducted by EuroEste. The liquid effluent is transferred to three lagoons (in batch sequence) where it stays long enough for the water to eventually evaporate. Up until this point in time, the size of the lagoons is large enough that it has not been necessary to clean them (something that will have to be done in one or two years, according to EuroEste representative). In Table 3-6, there is no value shown for the treatment of the liquid effluent due to the latter. EuroEste also incurs a high expense from feedstock for the piglets.

The representative of EuroEste S.A. is fully aware of the negative impact (both environmental and social) that some activities of the company have on the local population. Further, the representative also stated that part of the reason for participating in this IS network was to change the perception and image that the local population has of the company. The representative of EuroEste S.A. is also aware of the potential that these waste products have in the generation of biogas for energy purposes. EuroEste S.A. has also participated in a project in another region of Alentejo, where amongst others, the researchers where assessing the potential to produce biogas and other valuable by-products from the pig farm wastes. Hence, energy is another major concern of this pig farm, as they also use electricity for refrigeration and to sometimes cool the environment where the pigs are kept.

### 3.3.5 Paixão e Paulino, Sociedade Agrícola Ltda

Paixão e Paulino, Sociedade Agrícola Ltda is located in the parish of São Pedro do Corval, in the northeast of Reguengos de Monsaraz. This is a small company with only 3 employees that dedicates itself to the growth of aromatic plants, with a total area of 5 ha, divided between a 900 m² greenhouse and open cultivated fields. They also have a warehouse of 144 m² where they store the final products. The growth is undertaken with fertilisation and irrigation, and their products are sold at the local supermarkets.

Table 3-7 indicates the needs and capacities of this company.

**Table 3-7 Relevant Inputs and Outputs of Paixão e Paulino, Sociedade Agrícola Ltda**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Quantities</th>
<th>Revenues / Costs (R/ C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>Substrate</td>
<td>4 000 l/year</td>
<td>(C) 286 €/year</td>
</tr>
<tr>
<td></td>
<td>Root</td>
<td>1 500 l/year</td>
<td>(C) 100 €/year</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>300 kg/year</td>
<td>(C) 90 €/year</td>
</tr>
<tr>
<td>Main Products</td>
<td>Aromatic plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By-products</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The data presented in Table 3-7 clearly shows that the role to be played by this company in a hypothetical IS network will be of receiver under certain conditions of exchange and other counterparts. The representatives of the company mentioned that if they were to receive additional heat supply, they would be able to enlarge their activities, types and quantities of produced plants, due to the increased plant production that it would provide. It was also mentioned that the company has refrigeration necessities that could benefit from participation in the network.

### 3.3.6 Reguengos de Monsaraz Waste Water Treatment Plant

The Reguengos de Monsaraz WWTP is an infrastructure managed by the AdCA, which is currently undertaking upgrades. As previously mentioned the engagement of this organisation into the research project allowed the request of pertinent information related to the WWTP. This WWTP is located in the parish of Reguengos de Monsaraz, being the biggest infrastructure of its kind in the region, thus the reason for the author to decide to analyse this particular plant more deeply.

This WWTP began operations in 2000. The facility was designed for a population of 6 000 inhabitants – the equivalent of a daily average stream flow of 740 m$^3$/day. The liquid effluent was discharged into the small Àlamo stream. There was no specific process to treat solid waste (i.e. sludge dehydration) and according to the available records, the existing sludges were never removed from any of the existing lagoons. In the following years up until 2004, due to a failure to achieve the minimum emission values required by law, a decision to restructure the existing facilities was taken (Águas do Centro Alentejo, 2004). Given this, the following data is related with the project currently undertaken to restructure and upgrade the existing facility to accommodate the current and predicted future situation in a more sustainable way.

The data presented in Table 3-8 was taken from the project of the new WWTP provided to the author by the AdCA.

#### Table 3-8 Mass flows for affluent conditions to the WWTP in week days

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Year Zero</th>
<th>Year 2034</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low Season</td>
<td>High Season</td>
</tr>
<tr>
<td>Affluence condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average daily flow of</td>
<td>m$^3$/day</td>
<td>1 117</td>
<td>1 651</td>
</tr>
<tr>
<td>wastewater 90%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3.7 Reguengos de Monsaraz Waste Transfer Station

Using the same strategic approach as in the case of the WWTP, after engaging the company (GESAMB) that manages the wastes from Reguengos de Monsaraz, data relevant for this research was requested, namely the types and quantities of wastes that arrived at the transfer station in the year of 2006.

This waste transfer station (WTS) receives wastes from 3 different municipalities, namely Reguengos de Monsaraz, Mourão and Alandroal, besides private people that can go and deliver their wastes there. After being collected in this intermediate destination, the wastes are gathered, weighed and finally sent by truck to the Évora landfill where they are separated, recycled or landfilled.

Table 3-9  Characterization of the waste the transfer station receives

<table>
<thead>
<tr>
<th>Types of waste</th>
<th>Quantities (tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal solid waste</td>
<td>7 334</td>
</tr>
<tr>
<td>Forestry residues</td>
<td>0.1</td>
</tr>
<tr>
<td>Wood</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 3-9 shows clearly that the type of waste that arrives to the WTS in the largest amount per year is municipal solid waste. The organic fraction present in this total value is approximately 40%. Hence, something like 3 000 tonne/ year is delivered to the WTS. The volume of wood that is delivered to the station may also be of importance if the WTS is to be engaged in this research project IS network. Following, Table 3-10 gives an overall perspective of the present situation of the various stakeholders, concerning the type of contribution they might give to the network, and areas of potential exchange.
Table 3-10 Tabular summary with the areas of potential collaborative interest for each of the companies from a regional IS network point of view

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Energy needs</th>
<th>Waste/ By-products</th>
<th>Institutional support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Biomass Organic Waste Sludge</td>
<td></td>
</tr>
<tr>
<td>Finagra, S.A.</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CARMIM</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maporal</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>EuroEste, S.A.</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AromaAlentejo</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Águas do Centro Alentejo, S.A.</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Gesamb</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C. M. Reguengos de Monsaraz</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>CCDRA</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ADRAL</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ADIM</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### 3.4 Conclusion

It is noticeable from the latter, that Alentejo and particularly Reguengos de Monsaraz, face a large number of challenges in the pursuit of development that is more economically, socially and environmentally sustainable. There are inclusively, many difficulties and barriers that have already been identified by several organisations that are present in this region.

This chapter presented the main activities of each potential stakeholder identified and also gave an indication of their willingness to embark on this IS project. Also, the factors present in each of the stakeholders that might bring success to this research project were identified in accordance with the basic requirements of an IS network. Next, the identified needs and capacities of each of the companies suitable for a hypothetical IS network in the region will be presented in Chapter 4. The possible synergies that can be created in this hypothetical network will also be identified.
4 Analysis of potential collaboration areas and synergies

After processing the data presented in the previous chapter, it was possible to identify several potential synergistic relations amongst the stakeholders. This chapter will provide a detailed analysis of the potential for creating exchanges for some of the by-products and wastes currently produced and discharged, as well as new facilities or infrastructures that might be created to best facilitate these exchanges. These synergies are intended to help the companies to deal with their individual environmental challenges, whilst at the same time improving their business performance. Section 4.1 provides an analysis of the available biomass, the synergies that might be generated amongst the companies and some potential economic considerations. Section 4.2 provides the same analysis but concerning organic waste and sludge. Section 4.3 shows some other potential minor synergies identified. Following this, section 4.4 provides a schematic view of how the RMISP would look like and details some specific considerations. Section 4.5 exposes the overall results from the sustainable development evaluation tool used in this research project. Finally, section 4.6 offers a summary of the research project findings.

4.1 Biomass for energy

Some companies, namely Finagra S.A. and CARMIM, within the research program network have quite a large quantity of biomass which is currently considered as a waste derived from its economic activities. It is worthwhile to also include the biomass generated in the municipal waste transfer station to this pool. The data provided in Table 4-1 is a summary of the total amount of biomass waste produced by different stakeholders.

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finagra, S.A.</td>
<td>Stem</td>
<td>720 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Vine-shoot</td>
<td>2,000 tonne/year</td>
</tr>
<tr>
<td>CARMIM</td>
<td>Stem</td>
<td>1,800 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Vine-shoot</td>
<td>2,808 tonne/year</td>
</tr>
<tr>
<td>Waste transfer station</td>
<td>Forestry residues</td>
<td>0.1 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>11,280 tonne/year</td>
</tr>
<tr>
<td>Total</td>
<td>Stem</td>
<td>2,520 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Vine-shoot</td>
<td>4,808 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Forestry residues</td>
<td>0.1 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>1,110 tonne/year</td>
</tr>
<tr>
<td>Total biomass</td>
<td></td>
<td>7,350 tonne/year</td>
</tr>
</tbody>
</table>

From the analysis of the previous table it is clear that a large quantity of biomass is currently wasted, as it is either given away for cattle feed, burned in open space or simply disposed of to landfill. The unsustainability of these practices, allied with the fact that better resource use efficiency can be achieved, creates valuable opportunities and could form the foundation of new collaborative dynamics.

According to Professor José Peça from the regional University the gross calorific value of the vine-shoot is approximately 15 MJ/kg at 15% moisture content wet basis (m.c.w.b.) (Peça, 1993). Elsewhere, Peça also provides information concerning the feasibility of collecting vine-shoots with balers (Grassi et al., 1992).
The other biomass waste that exists in large quantities is stem. The calorific value of stem is estimated to be around 20 MJ/kg “Avaliação do potencial de biomassa da região do Algarve” (INETI, 2006). This means that there is a promising potential for energy generation based solely on these types of biomass. This is due both to the large quantities produced by just two companies and to the high calorific value that either of the biomass types has.

Despite their considerably smaller volume, it is relevant to consider the quantities of biomass arising from the waste transfer station. This biomass has a high calorific value of 16 MJ/ kg at 15% moisture content wet base (m.c.w.b.). The use of this biomass will also save a significant number of trips by the waste trucks from Reguengos de Monsaraz to Évora, in this way avoiding fuel consumption, CO₂ emissions and occupied space in landfill. Also, as mentioned previously there is also the potential value of the pruning biomass waste from the olive grove. If properly managed, this activity can also provide a very interesting and valuable input of biomass with high energetic content.

Therefore, it is important to investigate the potential to use all of this biomass to produce energy. Such initiative is likely to secure political support as well as biomass is considered to feature prominently in the portfolio of renewable energy sources in the future of the EU. The generation of power and/ or heat through biomass is stimulating the appearance of new state-of-the-art technology, as an economic and environmentally viable production method (Gallagher, 2002). The data presented in Table 4-2 shows the energetic potential conversion from MJ into kWh for all of the analysed biomass types. No energetic data from forestry residues was introduced, as it was not possible to obtain the calorific value. Hence, it will be excluded from consideration in this stage.

<table>
<thead>
<tr>
<th>Description</th>
<th>Available quantity</th>
<th>Net calorific value MJ/ kg</th>
<th>Total energy content kWh/ kg</th>
<th>Total Potential Energy content kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vine-shoot</td>
<td>4 808 tonne/ year</td>
<td>15.28</td>
<td>4.24</td>
<td>20 385 920</td>
</tr>
<tr>
<td>Stem</td>
<td>2 520 tonne/ year</td>
<td>21</td>
<td>5.81</td>
<td>14 641 200</td>
</tr>
<tr>
<td>Wood</td>
<td>11.28 tonne/ year</td>
<td>16</td>
<td>4.44</td>
<td>49 632</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7 339 280 tonne/ year</strong></td>
<td></td>
<td><strong>35 076 752</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Based on an assumption of 100% conversion efficiency, the actual potential energy content will be presented in view of the technological choices for energy production.

From the analysis of Table 4.2, it can be seen that the amount of energy that could be potentially produced from biomass is large. This value could also be increased further particularly in the CARMIM case, which could considerably increase the volume of biomass if the associates engage in the recovery of even more of the wasted biomass. Since all five stakeholders have high energetic demands, it is logical to suggest that this highly energetic wasted biomass be used for energy production purposes.

The stored chemical energy of the biomass can be converted to electrical energy and heat. The diverse range of potential conversion technologies for this process includes grate fire boiler, fluidized bed steam gasifier, steam turbines and gasification process, which are described further in Section 4.1.1. The efficiency of converting the energy of the fuel (i.e. biomass feedstock) into electric energy will depend on several factors such as the conversion technology used, the size of the plant, properties and water content of the fuel, etc. The typical efficiency of a steam turbine, for example, to convert solid biomass into electricity in a
small-scale plant (1 MW), is 20-45% (Johansson et al., 2001). Hence, the estimated potential generated electricity from the available biomass could be (assuming 30% efficiency):

$$35,076,752 \times 0.3 = 10.5 \text{ GWh/year}$$

It is noticeable that the estimated potential for electricity generation in a one year period with the currently available biomass from Finagra S.A. and CARMIM only, is more than 2 times the total consumed energy of all the five companies in a year (see Figure 4-1).

![Figure 4-1 Comparison of the actual consumed energy and the potential generated energy from available biomass](image)

In order for it to be properly used in a synergetic way, all of this biomass must be collected, gathered in a central storehouse and dried, as most of it has high water content when collected. The EPAC silo of the region is one such facility that could be useful for biomass drying. This silo was built several decades ago and was originally used to store cereals, but due to the abandonment of that specific type of agricultural activity, it is currently not used. Its management belongs nowadays to CARMIM, and its capacity is such that it allows for the storage of biomass from the vineyards of both the companies in the silo. This silo has a total capacity of 25,000,000 tonnes of wheat. Since biomass density is not the same as that of wheat, the biomass must first be ground so that its volume is reduced sufficiently to fit into the silo. Also, the silo might have to be subjected to some technical changes that would allow for faster drying of the biomass, such as forced or thermal drying. However, due to the large scale of biomass available, the most appropriate technique would most likely be for natural drying inside the silo, which would take approximately 5-6 months to get down to 15% moisture content (Gigler et al., 1999). The use of this infrastructure may very easily enhance the economic value of this synergy, since it is already available for the stakeholders to use in the network.

### 4.1.1 Technology

Taking into account the available quantities and energetic quality of the materials under discussion, and the necessities expressed by the companies, the most logical way for this
potential Industrial Symbiosis network to take full advantage of the available waste (in this case, biomass) would be to implement a cogeneration plant\(^8\) (CHP).

This technology would fulfil other needs of the companies, namely their heat needs. This versatility provides efficiency maximisation of the running hours at high total plant efficiency. Moreover, by the adoption of this technology, local emissions are reduced, power supply is secured and benefits for local economy are achieved. Not to mention being in line with the EU policy towards renewable energies from biomass in particular (Energy and Enviro Finland, 2007). However, to fully assess the feasibility of this option, more studies would have to be made in the future, concentrating particularly on its economic feasibility.

The Reguengos de Monsaraz CHP plant would have to be built in a strategically geographic point. The plant should be placed near the EPAC silo (since the biomass needs to be transported to the plant), in this way saving money and energy from avoided transport cost. Representatives of the Municipality provided the information that the Reguengos de Monsaraz urban plan (Plano Director Municipal) is under revision and that the area surrounding the silo is soon to be classified as an industrial area. Increasing the chances for different energy products to be provided to new industries who may settle in the area.

The WWTP could also have an important synergetic role to play, as its effluent could be used to provide cooling for the CHP plant once it is in operation. Also, it is interesting to see that as the AromaAlentejo activities of growing aromatic plants is divided between a greenhouse and the cultivation of fields, they have a high potential to receive the fly ash that will be produced by the plant. This way, it can be placed back into agricultural land serving as fertilizer and completing the closed cycle loop.

As shown previously, this power plant would be for the time being, fuelled mainly by the biomass from the Finagra S.A. and CARMIM.

By-products and wastes from other companies could also play an important role in improving this facility’s power generation capacity and efficiency. This could be achieved by utilising these other by-products within a biogas digester. The use of the biogas digester and the conditions to do so will be addressed in more detail in Section 4.2.1.

Given the specificity of the region, the availability of the raw materials, the number of stakeholders engaged and the eventual willingness of the local population to accept such technology, it is fair to assume that this plant should be established on a small scale.

The plant can also be used to produce electricity and heat to help dry the biomass that is deposited in the silo, since the values presented by the author for the biomass energetic content are for 15% water content, which is normally a much lower water content than when the biomass is collected. Also, given the other big synergetic alternative (using the available sludges and organic wastes) and the hypothetical technology that can utilise this waste (i.e. a biogas digester), it is very appealing to consider that the CHP plant can also provide heat to improve the performance of that biogas digester (more considerations about this issue are given in the Section 4.1.2).

\(^8\) Cogeneration is the combined generation of heat and power (Johansson et al., 2001)
Since all of the companies in the research project have demands for different energy products, the distribution of outputs from a CHP plant must be very carefully considered and planned. The raw material sources for the energy production also have to be taken into consideration, given that from the entire network there are only two major suppliers of biomass. In this way, the municipality may also have an important role to play, since two of the infrastructures that will assist in synergies (WWTP and WTS) with the plant are to some extent under the direct influence of the municipality. As stated previously, other synergies that might be created with the plant might arise from technologies enabled by materials supplied by other companies (i.e. organic wastes or sludges utilised in a biogas digester) that will not feed directly into the CHP plant. This may be a synergetic way for all to share the benefits of the energy and heat that the CHP plant might generate.

Many environmental benefits would be gained by adopting the proposal to utilize the biomass in the CHP plant, such as lower fuel consumption and reduced emissions if compared with the separate generation of heat and power. Obviously, it may also help to reduce green house gas (GHG) emissions and other pollutant emissions such as nitrogen oxides, sulphur dioxide and particulates. A 70% carbon monoxide emission reduction can also be achieved (Shipley et al., 2001) considering that biomass utilisation is considered to be principally carbon neutral (NTNU, 2005). This technology has the capacity to offer clean, low-cost energy solutions to many sectors of the local economy. With the achieved savings, capital could then be available for other types of goods and services, in this way helping to promote economic growth (Shipley et al., 2001). The implementation of such technology would create conditions to benefit the sustainability of the region. This could be done by converting what is today considered to be waste from some of the major agricultural activities in the municipality, into a renewable energy source. Thus, setting the conditions for a decentralized system to be created and enabling production of energy, as well as safety, maintenance and supply security. This way, economic benefits would stay within the community from the energy generation (Ojala et al., 2003). Added to this, is the fact that according to the EU Biomass Action Plan (Commission Proposal COM (2005)628 final) these technologies can contribute to meeting the EU goals for adoption of renewable energy sources by 2012, as 80% should come from bioenergy (Council Directive 2003/30/EC).

4.1.2 Economic issues related with technology choice

As stated in Section 4.1, the estimated potential generated electricity from the available biomass is approximately 10. 5 GWh/ year if the stakeholders agree to the implementation of a CHP plant. Under these conditions and according to the current law pertaining to the production of electric energy from renewables sources (Legislative decree no. 313, 1995) it is established that the national grid will purchase energy produced by private generation (from biomass) for about 0.1 € for each kWh produced, or for 106 €/ MWh (Ambienteonline, 2007).

In order to choose one of the many various kinds of available technology on the market, it is necessary to perform an evaluation based on several different factors such as the power-to-
heat ratio\textsuperscript{10}, total efficiency, investment costs, etc (VTT Processes and Finnish District Heating Association, 2004). Figure 4-2 shows the biomass energy conversion routes that were considered for this research project.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4-2.png}
\caption{Biomass energy conversion routes from thermochemical conversion}
\label{fig:biomass-energy-conversion}
\end{figure}

Source: Adapted from NTNU, 2005

Concerning small scale plants, the available technologies are as follows (VTT Energy, 2001; EPA, 2002; VTT Processes and Finnish District Heating Association, 2004; Obernderger & Biedermann, 2005):

- **Grate fired boiler** is the classic method used for burning solid fuels. They are used for both hot water boilers and steam production in small scale plants. Due to the latest developments in this technology (grate firing), it is now possible to burn very wet fuels. Due to its simple construction, it offers a competitive alternative in the small scale line.

\textsuperscript{10} The power-to-heat ratio is the relation of gross generated electricity to useful heat (this relation is not a constant value) (VTT Energy, 2001).
Despite that, grates are less flexible than fluidised beds regarding fuel quality and are less suited to variations both in fuel mixtures and quality;

- **Fluidised bed gasification process:** There are two types, the bubbling fluidized bed (BFB) and the circulating fluidized bed (CFB). BFB technology, due to its simplified construction and cheaper technology, is consequently considered a lower investment. Also this type is usually a better option for plants fuelled exclusively on biomass or similar low-grade fuels containing highly volatile substances. The fluidized bed combustion technology enables ecologically clean combustion to be carried out with minimal emission at minimal loss of unburned fuel. Added to this, is that it has an efficiency of over 90% even in the presence of difficult low-grade fuels;

- **Gasification** though intensively researched has not been applied very extensively on a small scale. Normally it is applied on a large scale due to its complexity and high specific investment costs. Nevertheless, small scale gasification plants have been tested and some problems have been identified, but the concept looks promising (not having achieved a level of development which allows commercial adaptation). Gasifiers can be combined with small steam turbines or steam engines, yet despite this alternative have a lower power-to-heat ratio and is considered to be the only alternative fully commercially available. One other option technology would be the fixed bed gasifier with a sterling engine;

- **ORC (Organic Rankine Cycle) processes** operate as a conventional Rankine\textsuperscript{11} process, having as main difference an organic working medium with favourable thermodynamic properties instead of water. The lifetime of ORC units usually exceeds twenty years. The advantages of this technology relate with its excellent partial load and load changing behaviours, maturity of the technology, high degree of automation and low maintenance cost. The big drawback is the relatively high investment cost. ORC is a technologically and economically feasible application for medium-scale biomass CHP plants; and

- **Steam turbine:** Usually generates electricity and as a by-products heat (steam). A steam turbine is captive to a separate heat source and does not directly convert fuel to electric energy. The energy is transferred from the boiler to the turbine through high-pressure steam that, in turn powers the turbine and generator. This separation of functions enables steam turbines to operate with an enormous variety of fuels from wood waste to agricultural by-products (e.g. bagasse, etc.). Although steam turbines are competitively priced compared to other technologies, the costs of a complete boiler/steam turbine CHP system is relatively high on a per kW basis. Thus the ideal applications of steam turbine-based CHP systems include medium-and large-scale industrial or institutional facilities with high thermal loads and where solid or waste fuels are readily available for boiler use.

Oberenderger and Biedermann (2005) conducted an economic evaluation of the available technologies and concluded that “the investment cost increase with decreasing nominal electric power output which clearly demonstrates the economy-of-scale effect”. What this

\textsuperscript{11} Described in 1859 by William Rankine, it is used as a standard for rating the performance of steam power plants. In the Rankine cycle, the working substance of the engine undergoes four successive changes: (1) heating at constant volume (as in a boiler), (2) evaporation and superheating (if any) at constant pressure, (3) isentropic expansion in the engine, and (4) condensation at constant pressure with return of the fluid to the boiler (Encyclopaedia Britannica, 2007).
means is that the less energy produced the less cost effective the technology will be. In the case of this research project network, it must also be recognised that the available fuel is not bought from any feedstock supplier, hence the prices of the generated energy will be cheaper than the ones shown in the available studies. This of course would only be possible if the owners of the plant are the stakeholders of the project (e.g. the companies).

As mentioned previously, the estimated potential generated electricity from the available biomass is approximately 1.5 GWh/year, or more specifically 10 523 025 million kWh/year. In order to make a simple estimation on the investment required for the implementation of any CHP technology, it is necessary to first determine the estimated electric capacity for the plant. This is done by dividing the potential electricity available in a year by the total hours of operation during a whole year, taking into consideration maintenance stops. Given this:

\[
10 523 025 \text{ kWh} / 8 000 \text{ hours} = 1 315 \text{ kW} = 1.3 \text{ MW}
\]

According to this, there is the possibility to install a plant with an electricity capacity of 1 MW.

Four different cases on CHP installations using two of the technologies previously described are presented in tables 4-3 and 4-4. These examples were chosen because they have similar installed capacity values, similar types and quantities of fuel used as well as the electrical capacity of the facility that would be required in the Reguengos de Monsaraz case, with the exception of geographical specifications and weather conditions.

**Table 4-3 Total capital costs for Gasification plants**

<table>
<thead>
<tr>
<th>Type of CHP system</th>
<th>Harboøre District Heating Plant (Denmark)</th>
<th>Biomassekraftwerk Güssing (Austria)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioned</td>
<td>1993 (reconstructed 2000)</td>
<td>2001</td>
</tr>
<tr>
<td>Power generation</td>
<td>Gas engine</td>
<td>Gas engine</td>
</tr>
<tr>
<td>Main fuel</td>
<td>Wood chips</td>
<td>Wood chips</td>
</tr>
<tr>
<td>Required quantity (tonne/year)</td>
<td>8 000 (30 to 55 % m.c.w.b.)</td>
<td>10 500 (25 to 40% m.c.w.b.)</td>
</tr>
<tr>
<td>Electrical capacity (MW)</td>
<td>1.5</td>
<td>1.85</td>
</tr>
<tr>
<td>Total capital cost (€)</td>
<td>5 100 000</td>
<td>10 000 000</td>
</tr>
</tbody>
</table>

Source: European Bio-CHP, 2006

**Table 4-4 Total capital costs for Grate Fired boiler plants**

<table>
<thead>
<tr>
<th>Type of CHP system</th>
<th>VKW Kaufmann (Austria)</th>
<th>Biomassa-centrale Lelystad (Netherlands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation</td>
<td>Steam turbine</td>
<td>Steam turbine</td>
</tr>
<tr>
<td>Main fuel</td>
<td>Wood chips</td>
<td>Wood chips</td>
</tr>
<tr>
<td>Required quantity (tonne/year)</td>
<td>8 700 (no value for m.c.w.b.)</td>
<td>17 000 (45% m.c.w.b.)</td>
</tr>
<tr>
<td>Electrical capacity (MW)</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Total capital cost (€)</td>
<td>4 500 000</td>
<td>12 000 000</td>
</tr>
</tbody>
</table>

Source: European Bio-CHP, 2006

From the analysis of the later it is noticeable that the total capital costs investment range approximately from 5 million to 12 million euros.

These examples include in the total cost, the necessity for a storage facility which is covered in the Reguengos case with the EPAC silo.
It is noticeable the high investment cost required for the implementation of a facility with this kind of characteristics, as well as the price range (e.g. related with technology). Taking in consideration the conditions made available by the national grid for the sell of energy produced from biomass (0.1 € for each kWh), and the fact that 17% of produced electricity is used for internal consumption (European Bio-CHP, 2006), the potential revenue value obtained would be in the order of 872 thousand €.

In order to make a simple evaluation on the eventual return period of investment, aspects such as interest rates, insurances or depreciation must be taken into consideration. As these were not available in the analysed examples, an assumption was made to give a simplified figure on what could be the return period of investment for the Reguengos de Monsaraz plant. If the highest investment cost of the analysed examples is taken in to consideration, then the return period of investment would be around 14 years. In the case of the example with the lowest investment cost, if applied to the Reguengos case this return period would be approximately 5 years. Again, these values are not considering necessary factors as interest rates or depreciation that might alter the values considerably.

It is also important to mention that investment costs vary significantly depending on the scope of the plant equipment, geographical area, competitive market conditions, government subsidies, special site-specific requirements, or if the plant would be located at an established industrial site with existing roads, water, fuel, electric (as would happen in this research project). In addition, the fact that the fuel (i.e. biomass) would have a very low price, given that the only cost would be related with collection, chopping and transport, brings the actual installation and operating costs down considerably.

Despite the high investment costs, there is still a potential for the companies to profit from installing the proposed technology and selling the energy produced to the grid on a long-term perspective. Since there is a centralised energy system in Portugal where one national company, Electricidade de Portugal (EdP), has the monopoly for managing the electricity, all the electricity produced by the biomass plant would need to be injected into the grid and sold at the established price, as previously mentioned. Since the companies still need energy for their activities, they will buy the energy they need back (at a lower price to which it was sold), still making a conservative profit. Also, due to the energy scenario in Portugal (with the national company monopoly) and the fact that the companies have no way to store the energy they produce, nor do they have the same energy needs all year, it is more cost effective to sell it to the national grid and then buy it back on an as needs basis. As previously shown in Figure 4-1, since there is potential to generate twice the electricity used by the companies at current time, it is logical that after all of the energetic necessities are satisfied, there is still enough electricity produced to be sold and to generate profit for its producers.

Other factors must also be taken into consideration when analysing these profit margins, for once the roles of the municipality and other stakeholders in the network (WWTP and WTS) are well defined (considering how they might want to take advantage of the network), there will be a better understanding of how much of the total produced energy can actually be considered as profit, after all the energetic demands have been satisfied. Also, it should be taken in consideration the production of heat from the CHP plant. As stated previously several stakeholders require certain amounts of heat and/ or cold for some of their activities. As well as several municipality facilities such as swimming pools or schools could benefit from the production of this by-product.
As previously shown, given the fact that the Reguengos de Monsaraz area has the potential to generate and gather more biomass (feedstock), the hypothesis should be considered to expand the capacity of electricity production from the plant and at the same time to increase the network by including other stakeholders.

As mentioned earlier, the necessities of the companies include amongst others cooling requirements. These could be covered if the technology introduced in the region was related with trigeneration. The trigeneration plant is basically a CHP plant with a chiller that enables the generation of cold, in addition to the classical production of electricity and heat (VTT Processes and Finnish District Heating Association, 2004).

Besides the companies of the network, costumers for this cooling could also be found in the several existing supermarkets of Reguengos de Monsaraz, or any other food production industry in the region. This technology was neither proposed nor analysed earlier due to the fact, that it gives more economic uncertainties has the prices would substantially increase, for it requires other kinds of turbines as well as it demands more control and monitoring activities.

### 4.2 Sludge and Organic waste for anaerobic digestion

From the data provided, the author identified that in almost all of the companies as well in the WWTP and the WTS, there is sufficient amounts of both sludge and organic waste to analyse the potential for the creation of synergies based on it. Table 4.5 presents the availability of all the types of waste produced by the stakeholders. Due to the fact that the author collected data from several different sources, unfortunately the quantities were not always provided in consistent units, instead some were provided in volume (m$^3$) whereas others were provided in mass (tonnes). Also, due to the specificity of the data it was not possible to normalize it, since, for instance the density of bones was not provided by the slaughterhouse. Given that fact, and in order to do a standardization it will be assumed that 1m$^3$ equals 1 tonne.

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maporal</td>
<td>Sludge</td>
<td>146 m$^3$ = 146 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Bones</td>
<td>265 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Guts, blood and hair</td>
<td>806 tonne/year</td>
</tr>
<tr>
<td>WWTP</td>
<td>Sludge</td>
<td>1496 m$^3$ = 1496 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Solid effluent</td>
<td>240 m$^3$ = 240 tonne/year</td>
</tr>
<tr>
<td>EuroEste, S.A.</td>
<td>Liquid effluent</td>
<td>13 140 m$^3$ = 13 140 tonne/year</td>
</tr>
<tr>
<td></td>
<td>Organic waste</td>
<td>2 933 tonne/year</td>
</tr>
<tr>
<td>Finagra, S.A.</td>
<td>Sludge</td>
<td>24 m$^3$ = 24 tonne/year</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>19 017 tonne/year</td>
</tr>
</tbody>
</table>

From the analysis of Table 4-4 it is clear that a high quantity of both sludge and organic waste of several sorts from several companies is available. In fact, in previous meetings certain representatives from the companies expressed their sensitivity to the fact that organic wastes are just being disposed, instead of being utilised in some other way. They inclusively mentioned their awareness of the potential to use this waste as a means of producing energy. It seems clear that gathering all of this material makes it more visible and viable, creating a perception that the quantities exist and to some extent so does the potential.
The use of organic wastes and sludges to produce biogas through anaerobic digestion is not new. In fact, it is very common in many countries in northern Europe, such as Germany, Denmark and Sweden. In Denmark for instance, several cities have engaged in systems of anaerobic digestion of organic industrial waste and household waste sorted at the source, together with cattle slurry and slaughterhouse waste (Sannaa, 2004).

It is worth mentioning at this stage that anaerobic digestion does not solely generate biogas, it also generates liquor digestate and fibre digestate which can both be applied directly in agriculture as a conditioner to improve soils, or as fertiliser or compost to apply to the soil (Friends of the Earth, 2004). With the creation of a common facility where the wastes and by-products of all the stakeholders are gathered and properly processed, there is a large potential for the use of these materials to produce biogas and consequently energy and other by-products.

Biogas generated in an anaerobic digestion facility represents a potentially valuable and renewable energetic resource. Biogas is very versatile and can be used in several different ways, such as in a conventional boiler to generate heat for the digester or to heat nearby buildings. Alternatively, it can be used as fuel in a stationary gas motor from combined heat and electricity. It can also be also used to fuel automobiles (ADENE, 2003). Its production will reduce water pollution by using a type of feedstock that would otherwise end up in rivers and lakes (Sanaa, 2004). Biogas is a mixture of gases having approximately 60% methane and 40% carbon dioxide.

4.2.1 Technology

After the analysis of Table 4-4, it seems that there are enough quantities to assess the possibility of implementing a centralised biogas digester for the IS network. In general, these kinds of facilities accept wastes from cattle breeding, the food industry and the organic fraction of municipal solid wastes. Given the geographic distribution (less than 10 km) of stakeholders in the research project, this type of centralised system is the most suitable option. Centralised systems are characterized by having an installed capacity between 0.1 and 1 MW. With this kind of system it is necessary to transport the wastes from their origin to the processing facility, thus increasing the operational costs and affecting the financial sustainability of the system (ADENE, 2003).

The suggestion for the implementation of a biogas digester seems to make sense, given the contribution this technology can have to sustainable growth along side a CHP plant. The biogas produced in the biogas digester can be transported and burned in the CHP plant, helping to generate more electricity, heat and cold. The use of liquor digestate and fibre digestate in agriculture allows the saving of chemical fertilizers, reducing the flux of new materials in the transformation and production cycle, contributing to the closing of cycles such as carbon, water and nutrients. Obviously biogas is a renewable energy source with a high strategic interest since it helps reducing a country dependence of fossil fuels, having an added value since Portugal exports 86% of the energy it produces (Cofagri, 2007). Finally, the controlled generation of biogas and its utilization avoids methane emissions to the atmosphere, thus contributing to the mitigation of green house gases release (di Berardino, 2005).

In the case of the biogas digester, there could be many stakeholders giving inputs, from the food industry representatives (slaughterhouse and pig farm), to the sludges taken from the waste water treatment plant, or even a small fraction provided by Finagra, S.A. This way, the raw materials to be put into the biogas digester will be very heterogeneous. This should be
seen as a strength, as mixing different types of waste such as manure, organic waste from industry and household is vital for high biogas production (Sanaa, 2004). This, according to di Berardino (2005) has an added value since it is possible to get a substrate with a more favourable composition to be biodegraded, bigger biogas production, better degradation conditions and a more stabilised waste with adjusted properties to the necessities of the agricultural fields where it is to be applied. In addition, the use of resources such as blood or guts from pigs has another kind of value, since these kinds of by-products cannot be used in Portugal for the feedstock industry, so through anaerobic digestion and consequent energy recovery, a more sustainable treatment method is used. As before, the company AromaAlentejo, given the nature of their business, has the right profile to receive much of the by-products from the biogas digester, namely carbon dioxide (if the biogas is purified), liquor digestate and fibre digestate. These can be used by the company, for instance as fertilizer. This biogas digester, besides receiving inputs from the various industries, also has the potential to accept the organic waste collected in the waste transfer station. Eventually, in the case of a high degree of mix in the municipal solid waste that does not allow for the organic waste to be separated from the rest of the municipal solid wastes, another scheme should be in place. For this, the municipality may have an important role. For instance, a door-to-door organic waste collection program could be implemented by the Municipality. In this way, by providing a valuable amount of organic waste directly, the municipality can have a valuable input of energy provided by the CHP plant, due to the burning of the biogas there. Alternatively, the municipality could receive methane from the biogas digester. This methane can be then converted into methanol and applied in the municipality’s automobile fleet (also converted to accept the renewable fuel), thus turning the fleet of automobiles of the municipality (buses, garbage trucks, etc.) into a non fossil fuel based one. It is good to take into consideration that liquid methanol will become more competitive with gasoline and diesel fuel as the tendency is to increase the prices of these fuels, as technologies for bio-fuel production becomes more mature (Johansson et al., 2001). Nevertheless, another option would be to purify the biogas by removing the CO\textsubscript{2} and convert it into commercial vehicle gas that could then be used for the municipality fleet. Both of these solutions may not be economically viable at this time, but they hold an important potential. Despite being an ambitious program, if achieved it would only contribute to further enhance Reguengos de Monsaraz potential sustainable development.

This biogas digester should be placed near the plant due to both economical and environmental reasons.

4.2.2 Economic issues related with technology choice

The use of a biogas digester may enable a certain number of benefits in economic terms due to the stable self-sufficient energy production, leading to cheap energy and yielding financial savings in the longer term (creating pathways for extra income due to the selling of energy surplus). Using this technology will allow a better solution for the disposal problems of certain organic wastes generated by the companies. Added to this is the benefit of job creation with this infrastructures’ implementation (Inforse, 2007).

According to economic feasibility studies conducted by Sanaa (2004), the highest costs associated with biogas digesters are in the construction phase. Also, the higher the capacity of the biogas plant, the lower the investments and operation cost per unit of biomass treated. Moreover, Sanaa (2004) states that these kinds of projects are usually not economically attractive from a conventional economic point of view (i.e. including costs/ benefits from energy sell). On the other hand, this technology is attractive from a socio-economic perspective, where externalities (i.e. environmental and agricultural impacts) are included.
Thus, biogas technology is profitable and economically attractive if environmental impacts are considered (e.g. reduction of GHG emissions or reduction of pollution to groundwater).

The biogas digester described below was chosen considering the quantities of organic material available and the fact that this technology allows for possible expansion of capacity. (Sanaa, 2004):

- **Soft Top Plant concept** has a storage tank that provides a membrane that inflates with the emerging biogas. This is a versatile technology that enables upgrades of technology, such as concrete digester inside a storage tank that, when the digester is full, overflows with manure into the storage tank. Biogas can then be collected at the top of the storage tank using the membrane.

Considering the available volume, it may be necessary to implement more than one of these small scale plants (usually side by side). This is a common practice when available quantities exceed the capacity of the plant.

Table 4-6 shows the potential biogas that can be generated from the quantities of organic waste and sludge available from the companies. Again, some data related with necessary conversions is missing due to the fact that it was not available. Therefore, given the lack of certain data, some values were assumed to be similar to other found in literature.

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
<th>Available Quantities (tonne/year)</th>
<th>Dry content (%) (a)</th>
<th>Biogas dry content (l/ kg) (a)</th>
<th>Biogas (m³/ year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maporal</td>
<td>Sludge</td>
<td>146</td>
<td>18</td>
<td>300</td>
<td>7 884</td>
</tr>
<tr>
<td></td>
<td>Bones</td>
<td>265</td>
<td>30</td>
<td>1 000</td>
<td>79 500</td>
</tr>
<tr>
<td></td>
<td>Guts, blood and hair</td>
<td>806</td>
<td>28</td>
<td>160</td>
<td>36 109</td>
</tr>
<tr>
<td>WWTP</td>
<td>Sludge</td>
<td>1496</td>
<td>18</td>
<td>300</td>
<td>80 784</td>
</tr>
<tr>
<td>EuroEste, S.A.</td>
<td>Solid effluent</td>
<td>240</td>
<td>6</td>
<td>370</td>
<td>5 328</td>
</tr>
<tr>
<td></td>
<td>Liquid effluent</td>
<td>13 140</td>
<td>6</td>
<td>370</td>
<td>291 708</td>
</tr>
<tr>
<td>WTS</td>
<td>Organic waste</td>
<td>2 933</td>
<td>20</td>
<td>700</td>
<td>410 620</td>
</tr>
<tr>
<td>Finagra, S.A.</td>
<td>Sludge</td>
<td>24</td>
<td>18</td>
<td>300</td>
<td>1 296</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>913 229</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Strupeit, L. (2007)

Assuming that the calorific value of biogas is 5.6 kWh/ m³ (L. Strupeit, personal communication, September 12, 2007), and the total annual value of biogas available from the materials of the companies is 913 229 m³/year, consequently, by multiplying this two values the potential energy content of the biogas will be obtained (L. Strupeit, personal communication, September 12, 2007). This, would have a value of 5 114 082 kWh that would then be multiplied by 35% electric efficiency average (assumed value), giving a final total potential electricity production of approximately 2 million kWh/ year. The electric installed capacity for a potential gas engine could be calculated by dividing the total potential electricity production by the number of hours the engine would be expected to run in a year (e.g. 8000)

\[
\frac{2 000 000 \text{ kWh}}{8 000 \text{ hours}} = 253 \text{ kW}
\]

According to this, it would be possible to install a gas engine in the digester with an electricity capacity of approximately 250 kW.
In the case of the electricity produced from biogas, according to the Legislative Decree no. 313 of 1995, the national grid will purchase energy produced by private generation (from biogas) for about 0.075 € for each kWh produced.

Table 4-7 presents some investment considerations. Given the limitations mentioned in Section 1.4 for this economic analysis, the investments showed here are not for a complete viability study and are given on a very generic base to give some indication of the feasibility of the project. For these calculations the fact that the biogas produced in the biogas digester would be burned in the CHP plant was considered. This was done so that additional investments in technology necessary for electricity production from the biogas digester itself, was avoided.

The biogas digester is dimensioned taking into consideration the annual available amount of organic matter divided by 365 days. This would give the daily amount of organic material in the biogas digester. Considering then a residence period of 32 days inside the digester as required, the value for the expected size of the biogas digester (L. Strupeit, personal communication, September 12, 2007) would be:

\[ \frac{19,050 \text{ tonne/year}}{365 \text{ days}} \times \frac{32 \text{ days}}{1,670 \text{ m}^3} \]

Also, the unit cost for m³ of plant would be in this case of 210 €.

Table 4-7 Investment considerations

<table>
<thead>
<tr>
<th>Required investment</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester</td>
<td>350,000</td>
</tr>
<tr>
<td>Construction site costs</td>
<td>47,000</td>
</tr>
<tr>
<td>Building permits and other permits</td>
<td>32,810</td>
</tr>
<tr>
<td>Additional technical and maintenance costs (a)</td>
<td>70,000</td>
</tr>
<tr>
<td><strong>Total investment cost</strong></td>
<td><strong>529,810</strong></td>
</tr>
</tbody>
</table>

(a) Strupeit, L. (2007)

As previously mentioned the biogas produced should be burned in the plant’s engine, hence the economic outcome of selling energy to the national grid (the kWh sell) would be as previously defined in Section 4.1.2. This way, the return period of the investment should take the profit from this transaction into consideration. The percentages of the profits from the sale of electricity to the grid, that relate with production from biomass or biogas, can be determined. This might be useful due to the fact that the EdP (the national electricity company) buys the kWh produced from biomass at a higher price than that produced from biogas. Therefore, it may be possible to estimate how much electricity the biogas digester can produce from the burning of its biogas in the plant. This may be useful to establish a payback period for the biogas digester investment.

Some of the potential related capital issues are analysed in Table 4-8.
Table 4-8 Potential related capital issues with the proposed technological biogas scenario

<table>
<thead>
<tr>
<th>Production electricity (kWh/year)</th>
<th>2 000 000</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% electricity used for internal consumption (kWh/year)</td>
<td>200 000</td>
<td>A x 0.1 = B</td>
</tr>
<tr>
<td>Available produced electricity (kWh/year)</td>
<td>1 800 000</td>
<td>A – B = C</td>
</tr>
<tr>
<td>Price of kWh sold to the grid (kWh/€)</td>
<td>0.07</td>
<td>C x 0.07 = D</td>
</tr>
<tr>
<td>Annual revenue (€)</td>
<td>126 000</td>
<td>C x D = E</td>
</tr>
<tr>
<td>Annual operating costs (€) (a)</td>
<td>70 000</td>
<td>F</td>
</tr>
<tr>
<td>Final annual revenue (€)</td>
<td>56 000</td>
<td>E - F</td>
</tr>
</tbody>
</table>

(a) Strupeit, L. (2007)

According to the latter, the annual revenue from the production of electricity from the biogas generated will be approximately 56 000 €. Given the fact that the investment cost predicted in this simple analysis is approximately 529 610 €, then an approximate investment return period can be estimated as about 9-14 years (taking into consideration the necessity to include interest rates, insurance, depreciation, etc. Obviously, a 9 year return period is a very low estimation that needs to take in consideration the already mentioned fragilities of this assessment. Also, the average investment return period for this type of project is around 14 years (L. Strupeit, personal communication, September 12, 2007). On the other hand, if the production of biogas is used for heating and cooling then the revenues of the biogas plant will be larger, and thus the payback time lower.

In addition, another assumption can be made related with savings that the production of heat might provide. The previously determined potential energy content of the biogas would be 511 4082 kWh. Assuming that from this total value, 40% (after considering loses) could be converted into heat, a value of 2 045 644 kWh would be available. Taking into consideration the fact that 1 toe (tonne of oil equivalent) equals 11 622 kWh (climanet, 2007), then the value of fossil fuel that could be offset from the heat production would be of 176 toe. This would mean that the equivalent to the energy released from burning 176 tonne of crude oil per year would be achieved. This way besides offsetting emissions, the consumers of this heat would also obtain it at a value lower than the one they pay by using oil for the same purposes. This would obviously also help in lowering the investment return period and enhance even more the environmental profile of this project.

At this point certain considerations should be given. The calculations for electricity revenues showed in Figure 4-8 are based in values considered for the electricity production directly from biogas, what would not be the case if the biogas is burned in the cogeneration plant. In this case the biogas would be sold as fuel to be burned, hence not having the same commercial value. Also, the potential sale of by-products (heat and cold) from the electricity production was not considered due to the fact that all the companies engaged in the research project so far are more concerned with electricity needs.

In addition, the climate conditions in southern Europe will probably require more concerns related with cold than with heat necessities, particularly in a region as Reguengos de Monsaraz that is characterized by very hot summers and mild winters. Nevertheless, the existence of several big supermarkets in the region as well as schools and municipal swimming pools may very likely become the consumers of that heat and cold.

Decisions concerning the use of the gas produced by the biogas digester (whether it be for the production of heat and cold or burned in a plant to produce electricity) should be done in the presence of more detailed economic studies, investigating more alternatives than the ones presented here.
Based on the limited assessment that has been conducted, it seems that there is little economic viability for the implementation of the biogas digester if no external funding is available or the data concerning the revenue from the sell of the heat. Nevertheless, the economic viability of this solution will be very dependent on the technologies available in the market, of a more detailed assessment and of the opportunity to apply for subsidies or available funds.

4.3 Other potential areas

4.3.1 Innovations in agro culture

Due to the potential for implementation of the identified synergies in the last two sections, conditions can be created for other areas of development to arise.

Given that the Reguengos de Monsaraz area is mainly rural, there is the potential to create a new agro culture in the region. The amounts of fly ash, liquor digestate and fibre digestate that can be generated from both the power plant and the biogas digester respectively, will serve as a nutrient and fertilizer source for a potential new agro culture. This agro culture can have multi purposes:

- Dedicated energy crop production, that will also feed the biomass demands of the CHP plant;
- Development of a type of agro crop that can have the required characteristics and be suited for provision of feedstock to the EuroEste pig farm demands; and
- Development of aromatic species, increasing the production capacity of the Aroma Alentejo company.

The fact that Reguengos de Monsaraz is located next to the Alqueva Lake, considered to be the biggest artificial lake in Europe (EDIA, 2007), may facilitate the implementation of any kind of new crop in the region. The decision to undertake energy crop production will be related with the potential for expansion in capacity of the CHP plant. In the future, if more economical actors of the region (who also work in the same line of activity) are engaged into this project, maybe the creation of a culture dedicated to the feeding necessities of the plant will not be necessary. On the other hand, the more options there are related with energy production and security, the more attractive it might be to create the conditions to invest in these kinds of crops. In addition, given the characteristics of the entire region the potential to estimate the total biomass that could be produced in the region should not be disregarded.

Regardless, and due to the economic activities of some of the companies in the research project network, it is also worth analysing the economic feasibility of beginning production of a specific crop for feedstock purposes. In the same way, the expansion capacities of the AromaAlentejo company might also increase by investing in a new culture enabled by the availability of useful wastes and by-products from the technologies that have been suggested.

4.3.2 Beauty from bagasse

One of the biggest by-products from the two viticulture companies in the network research is bagasse, producing 2 700 tonnes/year. This bagasse is currently sold and used by other companies for the production of alcoholic drinks. Given the high quantities of bagasse produced there is the potential for a new innovative enterprise to emerge in the Reguengos de Monsaraz landscape.
When processing of the bagasse is over, the recovered bagasse seeds can then be utilised. This seed has a high antioxidant contents and due to that particular characteristic it is very interesting for the beauty product industry. If this raw material becomes available on the market, there can be strong possibilities for a company in this field of activity to settle in the Reguengos de Monsaraz area, thus creating a new positive synergy in the region.

4.4 The Reguengos de Monsaraz Industrial Symbiosis Network

As a logical outcome from the analysis in the latter section and the potential synergies identified, it was possible to develop a schematic approach to how this research project network might look.

The diagram showing a representation of the Reguengos de Monsaraz Industrial Symbiosis is presented in Figure 4-3.
Potencial for implementing an Industrial Symbiosis network in rural Portugal
Figure 4-3 The hypothetical structure of an Industrial Symbiosis Network for Reguengos de Monsaraz

Figure 4-3 demonstrates a holistic view of all the synergies identified by the author. This figure helps to better understand and visualise all the exchanges the available wastes and by-products enabled and that were described by the author in the previous sections of this chapter, along with the implementation of the new technologies that will allow it to be realised.

Table 4-8 shows an overall perspective of the potential synergies that may be created through the implementation of the proposed technologies, as well as the potential for other synergies from the creation of a new crop, as previously mentioned in Section 4.3.1.

Table 4-9 Potential synergies created within the RMISP

<table>
<thead>
<tr>
<th>Company</th>
<th>Cogeneration plant</th>
<th>Biogas digesters</th>
<th>Other synergies (New crop)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Input</td>
<td>Output</td>
<td>Input</td>
</tr>
<tr>
<td><strong>Finagra, S.A.</strong></td>
<td>Biomass</td>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cold</td>
<td></td>
</tr>
<tr>
<td><strong>CARMIM</strong></td>
<td>Biomass</td>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cold</td>
<td></td>
</tr>
<tr>
<td><strong>Maporal</strong></td>
<td>Electricity</td>
<td>Organic Waste</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td></td>
<td>Heat</td>
<td>Sludge</td>
<td></td>
</tr>
<tr>
<td><strong>EuroEste, S.A.</strong></td>
<td>Electricity</td>
<td>Organic Waste</td>
<td>Feedstock</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AromaAlentejo</strong></td>
<td>Energy</td>
<td>New plantation</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td></td>
<td>Fly ash</td>
<td></td>
<td>Liquor digestate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre digestate</td>
</tr>
<tr>
<td><strong>Águas do Centro Alentejo, S.A.</strong></td>
<td>Cooling water</td>
<td>Irrigation water</td>
<td>Irrigation water</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gesamb</strong></td>
<td>Biomass</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. M. Reguengos de Monsaraz</strong></td>
<td>Electricity</td>
<td>Organic Waste</td>
<td>Methane</td>
</tr>
<tr>
<td></td>
<td>Heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.5 Risks and Barriers

From the analysis conducted so far, it is clear that there are various drivers that may enable the implementation of an industrial symbiosis network. These range from economic to environmental and social spheres. On the other hand, a certain number of factors that might weaken or endanger the materialisation of the Reguengos de Monsaraz IS network were identified.

4.5.1 Trust in the network

Although all of the engaged stakeholders showed much interest in the IS conceptual tool, its advantages and success cases, it remains something that has never before been done in Portugal and there is inadequate capacity for the required coordination. Some companies expressed doubts that when the network starts to be built, some of the actual stakeholders remaining in the program will not tend to work in partnership, since this has traditionally been the case in the Reguengos de Monsaraz region. Some stakeholders have been trying to create partnerships throughout the years with no success.

Also there is some fear that any role governmental bodies might have will create bureaucratic barriers instead of accelerating certain procedures. On the other hand, the government bodies that were already engaged in the research project stated that, due to a possible conflict of interests on a regional level (giving any alleged priority or benefit to the Reguengos de Monsaraz region), they could not be an official partner (once they provide all the required licences) of the network but that they would help in any possible institutionalised way.

4.5.2 Commitment

The various stakeholders in the project have different ways of approaching business. Each company has its own rhythm of operating. Some companies make decisions more rapidly than others, which due to their corporate nature may take more time to give their input on a common decision or may simply not have the economic viability to approve a given project immediately. Given that and the fact that not all stakeholders are in the same position related to waste and by-product possession (a vital role in the network), there is always the risk that one or more companies may quit the IS network.

If the company that quits has enough weight within the network (e.g. logistic, image, economic) and if no other company with the same kind of characteristics can be found to replace it, this might be enough to dismantle the entire network. There is also the risk that different priority of objectives and management practices disable the network as a whole, and that one company that has enough capacity, may embark on an individual project trying to achieve the same benefits it would in the network.

4.5.3 Risk of monopoly

The companies that are candidates to be part of an IS network show clear differences in their size and power. This is related to capacity, economical power, size of the company, success, influence or image. There is always the chance that one or two companies may have the institutional weight that makes the difference in securing funding or injecting its own investment. If this happens, there will be a natural increasing risk of this company steering the orientation of the network towards its own benefits first. This may endanger the objectives of the network and of the IS program towards sustainable development of the region as a whole. If the interest of one company is put ahead of the interest of the entire network, then the general environmental, social and economical benefits will be prejudiced.
4.5.4 Portuguese energy system
As mentioned previously, there is a monopoly on the energy distribution in Portugal, thus there is no decentralised energy system. As a result, this may be a barrier to the sustainable development of the region. If a system for generating electricity is created based on raw materials that are available in the region, provided at a competitive cost, and if the required technology for the production of electricity is implemented on-site, conditions would be in place for a decentralised system to function. This would be a system that might assure some independence from the import of electricity and with economic profits that would stay within the region. Instead, this electricity has to be sold to the grid. Nevertheless, the connection to the grid will always provide benefits to the companies, both from selling excess production to it and by assuring that there is enough energy from the grid for their necessities. Adding to this, is the fact that a region that produces energy based on its owned renewable fuel gets a premium from the electricity sold. Besides all these arguments is the fact that by using the suggested technologies there is a potential for the increase of self-sufficiency in heating and cooling needs.

4.5.5 Economic considerations
From the analysis performed in Chapter 4 it is clear that financial support will be required for the viability of the proposed IS network. Due to the high costs associated with the technology implementation it will be very difficult for the stakeholders alone to bear the investments. If the proper funds are not guaranteed there is the risk that the network will not become to be a reality.

4.5.6 Social factors related with technology implementation
The implementation of the proposed infrastructures in the region might be deemed unwarranted by the local population. Due to the geographical distribution of the stakeholders, the strategic position of the EPAC silo and the municipality’s urban plan revision, the most appropriate place at the moment to locate the biogas digester and the biomass electricity power plant will be in the surroundings of the silo. Given the fact that the silo is located in the industrial part of the city of Reguengos de Monsaraz, it is only logical that these two industrial facilities should be co-located.

Nevertheless, given the characteristics that the biogas digester and the CHP plant have, there is the potential for social disturbance due to its implementation. The distance from the centre of Reguengos to the industrial area is less than 2 km, which makes it very easy for complaints to arise from potential odours, noise, air emission or even visual impact from the biogas digester and the CHP plant’s daily activities (despite the fact that the EPAC silo can be seen from a distance of several kilometres due to its dimension).

4.6 Triple bottom line (TBL) assessment tool
After the analysis performed, a simplified evaluation of the sustainability profile that characterises this research project was conducted. To do this, an evaluation matrix was used (Annex 2) taking into consideration the main aspects that compose the sustainable development concept.

Given the usefulness of this kind of assessments in providing basis for decision making, it is necessary that they are analysed in a more through and reliable way. The following TBL assessment tool is just a short, simplified example on some of the potential fields of analysis. The results concerning both the economic and social aspects of this assessment cannot be
considered reliable nor representative, as the analysis performed on those fields have many flaws and are incomplete, thus being unreliable from an evaluation point of view.

The application of this evaluation tool gives more strength to the sustainable development character of this research project, due to the positive outcome obtained from all the aspects constituting the triple bottom line concept as exposed in the matrix. At this stage, these results are sufficient to allow for a characterisation of the main conditions that are required for a sustainable profile to be created in such kinds of regional projects. It is worth noticing that the values obtained from the matrix will vary depending on the specific conditions of each project under consideration, given that the chosen criteria will be better suited to some cases than others. Therefore, despite inherent potential economic benefits from this particular research project, it cannot be expected that this will be the case for every scenario. This might bring some fragility to the system, since the companies usually engage in such projects for their potential economic benefits and less because of environmental or social concerns. Yet, this is an empiric evaluation that is obviously subjected to changes given by practical evidence.

For each sustainability aspect, four different criteria were developed and classified, taking into consideration the reality of the research project. This way it was possible to create a simplified sustainability profile constructed on the premise that its conclusions might help reinforce the idea of the value that the IS network could have in boosting sustainable development at the regional level.

Therefore, the evaluation was performed using a scale from -4 to 4. The outcome was that all three sustainability aspects had a positive result:

- Economic/profit (1)
- Environmental/planet (4)
- Social/people (2)

The results were obtained according to the classification given to each sustainability aspect. For instance, concerning economy an evaluation was made as to whether there can be profit in the project for the stakeholders, the difficulty in achieving this, if there are risks in the network implementation, and to what extent the IS network can contribute to the ability to sustain value creation in the future. The evaluation was based on the findings of the research project. In this stage, given the way this evaluation was performed and the lack of further information to give more strength to its findings, its only use is to bring some light on the value and necessity of the existence of such assessment tool to assist decision makers. Clearly, in order to make a proper measurement of the sustainability of such kinds of projects, more information concerning the economical, environmental and social aspect of the project must be available.

### 4.7 Factors influencing the development and functioning of the RMISP

As a consequence of all of the synergies identified, it was possible to develop a matrix where the major factors that might influence the development of a IS network in Reguengos de Monsaraz were identified. These findings are shown in Table 4-9 and can be considered as a summary of the findings.
Table 4-10 Factors influencing the development and functioning of Reguengos de Monsaraz IS network

<table>
<thead>
<tr>
<th>Domain</th>
<th>Present conditions</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Companies energetic needs</td>
<td>Enables the increase of synergetic relations and entrance of new comers</td>
</tr>
<tr>
<td></td>
<td>Availability of unutilised wastes and by-products with high energetic content</td>
<td>Enables production of energy products using locally available sources. Increase of environmental, economic and social gains</td>
</tr>
<tr>
<td></td>
<td>Existence of common facility for storage of biomass</td>
<td>Enhances the possibility for synergies concerning use of common infrastructures</td>
</tr>
<tr>
<td>Economic</td>
<td>Extent of required investment in infrastructures and technology</td>
<td>Funding requirements</td>
</tr>
<tr>
<td></td>
<td>High value of waste and by-products due to its potential for energy generation</td>
<td>Possibility for producing competitively priced energy products.</td>
</tr>
<tr>
<td></td>
<td>Valid/ positive economic project</td>
<td>Requires feasibility studies with inherent environmental and social benefits.</td>
</tr>
<tr>
<td></td>
<td>Need for defending the economic interests from the different stakeholders</td>
<td>Necessity for suitable governance mechanisms.</td>
</tr>
<tr>
<td></td>
<td>Need for extra economic funds for the project</td>
<td>Application to available EU, national or regional funds.</td>
</tr>
<tr>
<td></td>
<td>Fuel available and independent from outside providers</td>
<td>Lower investment costs in raw materials acquisition and transportation.</td>
</tr>
<tr>
<td>Political</td>
<td>Availability of funds/ subsidies directed for renewable energies and state-of-the-art technology</td>
<td>Application requirement</td>
</tr>
<tr>
<td></td>
<td>Policies give privilege to partnerships (public/ public; public/ private) instead of stand alone companies</td>
<td>Desirable the creation of cooperative or consortium by stakeholders.</td>
</tr>
<tr>
<td></td>
<td>Profits from energy production may be reflected in the municipality policy on municipal fees</td>
<td>Positive environmental impacts, along with life quality increase and benefits from the implementation of such technologies.</td>
</tr>
<tr>
<td></td>
<td>Deadline for funding application are the procedural ones as established by the authorities</td>
<td>May enable communication between the parties in order to better identify funding entities and accelerate bureaucracy.</td>
</tr>
<tr>
<td>Informational</td>
<td>Stakeholders with different level of commitment</td>
<td>Required definition of responsibilities in the network.</td>
</tr>
<tr>
<td></td>
<td>Uncertainties related with environmental impacts, life quality conditions and implementation benefits on a social level</td>
<td>Environmental Impact Assessment and financial feasibility studies.</td>
</tr>
<tr>
<td></td>
<td>Social acceptance for the implementation of required technology and/ or programs</td>
<td>Sensitising in order for the acceptance from the population.</td>
</tr>
</tbody>
</table>
Lack of knowledge on available technology with the least environmental impact
Limits the extent of known required investment to create and maintain the synergies

| Organizational and motivational | | |
|---------------------------------|---------------------------------|
| Existence of trust and openness | Agreement on objectives and targets to help simplify the development structure |
| Cooperation levels in Portugal have a tendency to fail | Necessity of a management unit to conjugate the different interest |
| Confusion between cooperation and competition | Risks related with associateship, different agendas, interests, capacities and work velocities |
| Most of the stakeholders in the project were never able to cooperate in the past | Collaboration essential to define the part of each stakeholder in the future |

It is noticeable from the analysis of the latter that all the factors identified by Mirata (2005) can be found in this research project. Nevertheless, the conditions to which they are subjected are very particular to the site-specific details and individual stakeholder involved in this study.

In order for the five factors to be in place, identification of the “implications” is still required to bring the network into reality. It is interesting to analyse that it is not only necessary that certain conditions are in place, but also that other consequent actions take place. The identification of the factors alone will not enable the implementation of the network. After these factors are identified, another kind of work starts which is related with the identification of the particular aspects that compose each of the factors identified in a certain region. After analysing how these factors are influenced it is necessary to search for the drivers that will boost them as well as identify the barriers that might be present.

In the RMISP, the aspects identified as composing the five factors are relatively simple, and with the serious engagement of the stakeholders almost all the “conditions” can be easily dealt with. In the same line, the consequent enablers of the network will need a more practical engagement of the stakeholders. Issues as technological knowledge, necessity of coordination body creation, necessity to fund application, definition of responsibilities or engagement of local community will necessarily require that the stakeholders take their commitment to the project one step further, dealing with the necessary arrangements to enable the most factors possible.

### 4.8 Conclusions

From the analysis performed in Chapter 4, it is clear that the potential exists for a network based on IS concept to arise in Reguengos de Monsaraz. Nevertheless, the economic feasibility has not yet been proven since many details concerning costs for technology implementation where not thoroughly developed. Despite this, it has been shown that the companies have the potential to achieve a considerable profit from electricity generation, and at the same time assure energy supply at the lowest price. This can, at the same time, enhance the sustainable development profile of the region, since opportunities for electricity generation from renewable resources is created. In addition, so is the potential for job creation and environmental benefits from better use of resources.
5 Conclusions and Recommendations

The major driving force behind this research project was the interest in assessing the potential to apply the IS conceptual tool to a context such as the one existing in the Reguengos de Monsaraz region. In order to perform an assessment of the viability of the application of IS, it was necessary to narrow the research down to the one or two main questions that, as simple as it might seem, could also give simple answers that might help in the continuation of this project.

Hence, the first question posed was:

- What is the potential of IS to contribute to sustainable development in Reguengos de Monsaraz?

IS could provide important contributions to the sustainability of the region.

The proposed network based on IS clearly brings more advantages related with regional sustainable development, such as:

- Reducing dependency on fossil fuels by using a local renewable feedstock for the production of energy;

- Energy recovery by turning what was considered up until now to be a waste, into the main raw material for a CHP plant and a biogas digester;

- Potential for economic gains from the synergies;

- Increase the potential for innovation of the network and the region, by introducing state-of-the-art technology;

- Improvements in the regional environmental performance due to reduction of waste, as a result of the new destiny given to the biomass (that was open burning until now), the new treatment process for the organic wastes (avoidance of discharge to waters), the decrease of trips of garbage trucks to the landfill (CO₂ emissions) and the avoidance of land filling, and;

- Potential for job creation resulting from all of the above.

An example from these is the potential to use the biomass, that is currently considered a waste, generated from the economic activities of certain stakeholders. In the analyzed case it might be reused as extremely valuable biomass for the generation of electricity. There is potential for closing the loop of a production cycle with reduced environmental impacts, as well as potential advantages in the economical and social aspects. Also, strengthening of the so-called traditional economic sectors based in the region can be achieved by engaging in this kind of project, which has potential to allow initiative and innovation without compromising their profile.

This kind of project allows for a big step towards more sustainable regions to be taken. This is because it has the potential to create the necessary elements for a change in behaviour, local environmental conditions, economic support and energy security. By creating such kinds of IS networks on a regional scale, conditions are achieved for a change to a more sustainable
existence. When this change is supported through private actors, in partnership with local
governments, a certain degree of credibility and success is achieved over time. Then, another
step is completed to achieve more institutional support to develop bigger and better
sustainable policies at the regional level. That can, with time, become a model of sustainability
for regional areas all around the country. The development and application of the TBL
assessment tool, with its positive outcome, even taking its limitations into consideration (as
mentioned in Section 4.6), was another factor that helped to reinforce the sustainable
development character of the project itself and of the region as a whole.

This may very well be the first project of its kind in the country, demonstrating
entrepreneurship, a will for innovation, investment in research and development. It is also a
project able to catalyze attention from more potential stakeholders, and even from other
industrial activities, that might start a similar project based on the same conceptual tool.

The second main question posed was:

- How could this potential be realised?

From the analysis performed it seems that most of the necessary factors to establish an IS
network are in place:

- Willingness from stakeholders;
- Waste and by-product availability;
- Potential for synergies;
- Existing technology; and;
- Possibility of available funds.

When a situation exists where some of the stakeholders of the project are the biggest
economical actors in the region, the municipality itself, as well as two of the main
infrastructures of health and environment support (WWTP and WTS), the conditions are set
to create a system of profitable and sustained relations.

When players such as political decision makers and/or industry are engaged and when the
right quantity of motives are set, such as economical profit and job creation, then the
conditions exist for the implementation of a sustainable network that can boost the
development, not only of the actors directly involved, but of all the surroundings. Reguengos
de Monsaraz and the identified stakeholders have all the basic technical requirements to set an
IS network into motion, thus creating the conditions for more sustainable development in the
region and to become a leading example for other regions in Portugal.

Additional image benefits might be associated with the stakeholders from the creation of a
successful IS network, going from the opinions of the general public, to suppliers and
customers. This way, conditions for the creation of new markets can be achieved as well as
wealth generation, with the introduction of new stakeholders in the network providing new
potential synergies. This is intimately related with the opportunity for the creation of scale
economies by the companies within the project, in this way increasing profits and generating
opportunities for job creation. Also, the fact that the available raw materials for the proposed
Potencial for implementing an Industrial Symbiosis network in rural Portugal

CHP plant and for the bio-digester are waste and by-products of regional traditional economic activities makes the raw materials available at a very low price. In addiction to this, by using a major storage infrastructure (the EPAC silo) that already exists, and that is available free of charge for synergetic use, more economic benefits are added to this project making this as an extra incentive for the creation, maintenance and expansion of such a network.

Obviously, from the analysis conducted in Chapter 4, there are clear economic aspects that need more analysis. The feasibility of the biogas digester might be compromised due to the apparent low income generated when compared with the initial investment. In the case of the CHP plant, although profits from the electricity sold to the grid might be generated, issues related with technology implementation cost have to be considered in detail to assess its feasibility. It is also clear that there can be other economic benefits with the adoption of this project. Obviously it will require an initial investment, but given the present and future sustainability character of the economic activities of the actors in the project, it is definitely an option to consider. It may also be a strategic advantage to invest in the available resources that will bring future revenues and might even induce a change in the institutionalized Portuguese energetic sector.

It is also worth mentioning, that there is an imbalance between the raw material contributions that companies will give to this network. In comparison, there is a greater potential for biomass related profits than with those related with the available organic waste. This is reflected in the quantities available from each type of waste, or in the different price the national grid pays per kWh of electricity produced from one source of energy or the other. This imbalance might be critical and has to be taken into consideration when establishing participation quotas for the companies in the network.

Besides answering to the two main questions other issues might be considered concerning the findings of this thesis.

The proposed network, identified by the author, has a particular approach on the opportunities and necessary mechanisms for enabling synergies. All of the synergies that can be created are mainly due to the creation of several infra-structures that will enable exchanges related with wastes, by-products and energy. This research project is not based in classical direct exchanges between companies, but instead in the creation of synergies between companies enabled by central infrastructures that process the wastes and by-products into energy. This model, despite its clear reference to classical examples of IS networks, creates a new paradigm in synergies between companies, enabling cooperative work in a way that generates major benefits not only for the companies themselves, but also helps to boost local and regional development by bringing state-of-the-art technology, based on environmentally friendly processes, into the area.

There is a very interesting and new factor created by this research project, namely the fact that IS is traditionally linked to heavy industry, with very few examples where this conceptual tool was applied to a rural area. This research brings a new factor of versatility to the profile of IS, as it shows that the elements existing in the classic industrial world, that allow the implementation of such networks, may also be found in smaller rural settings. Obviously, the various factors needed have to be adapted to the particular site-specific conditions of every case. However, the setting of an IS profile in this region initiates a new paradigm for the spread and implementation of this conceptual tool in other regions of the country, not to say the world, that have a group of similar conditions enabling the possible implementation of a network based on the same type of premises. It is of utmost importance that this kind of
profile continues to be raised in other regions with the same fundamental characteristics. This will serve as an attempt to help identify or to facilitate those factors that enable the successful implementation of IS networks in rural areas and ensure that they are set in place and can be used in a way that may enable sustainable development of a community as a whole. An added value, is that by identifying similar profiles, both in Portugal and in other regions of the world, more communities might attempt to implement this concept, creating a kind of chain reaction that will spread the benefits of IS into areas that were not considered so far as suitable for this conceptual tool.

The data gathered by the author is evidence to support the use of the Industrial Symbiosis conceptual tool. Also, this research shows that if IS is applied to a case that has the necessary conditions, it is definitely a useful tool in the pursuit for sustainable development.

5.1 Recommendations

5.1.1 Expanding the network

During the research period, it became obvious that besides the already available biomass from the various stakeholders, there was the potential to collect more biomass waste than what was currently accounted for, such as the biomass waste from the olive grove maintenance. Given that many of the associates of CARMIM, besides the vineyard itself, also own the vast majority of the olive groves in the region, it would be interesting in the future to engage these producers with the collection of the olive grove biomass wastes (which could possibly achieve several hundreds of tonnes per year).

Also, with the development of the network, and with the potential growth of the energy business, its benefits and profits, more wine producers in the area (that have a significant size) or olive grove producers could be engaged. In this way the available feedstock of biomass would increase expanding the electricity generating capacity. Therefore, when the design of the CHP plant is considered, the hypothetical expansion of capacity that it might face due to the clear potential the region presents in providing more biomass to feed the power generation necessities the plant might have, should also be considered. In the same line of thought, and given the apparent economic set back of the biogas digester implementation, it would be advisable to scan the region for more potential stakeholders to increase the production capacity and lower the financial cost of the infrastructure.

5.1.2 Accurate data quantification

Despite the fact that all of the information requested by the author was provided by all the stakeholders, some of the data gathered was not provided in a consistent way, which hindered a proper general analysis. Therefore, it was not possible to give a final total available figure for some specific types of data. It is advisable that in the future, and taking into consideration the continuity of this project, a larger effort is made to avoid and/or overcome certain kinds of setbacks that stop complete understanding of the total potentially available quantities of by-product A or waste B.

Also, given the fact that almost all of the data made available to the author by the companies was based on approximate values (in some cases the data provided was almost unrealistic, given the small numbers provided and taking into consideration the size of the companies), it
is fair to suggest that all of the data provided will increase when more precise data collection is conducted.

5.1.3 Economic issues related with the network

It is advisable that the companies in the network request further economic and more profound feasibility studies in order to have a complete and independent view on the potential for profit generation, investment return period, etc. It is also fair to suggest further investigation on the state-of-the-art technology available in the market that might best suit the particular conditions existent in Reguengos de Monsaraz case. The economic analysis performed so far clearly shows that there are more chances for profits related with the CHP plant. However, this situation may change with more stakeholders entering the network, supporting the biogas digester feeding necessities, or from revenues from the sale of produced heat. Also, it is worth mentioning that there are available funds from various national and international sources that, due to the environmental and sustainable profile of the proposed project, may provide the necessary economic boost for these two technologies to be implemented.

If the production of energy from biomass or biogas actually starts, the companies in the network should also take into consideration the entrance in the market trade of green certificates, which will allow for further economic benefits not to mention the image benefits that might arise from this new market. In Portugal, the tariffs for the sector of renewable energies guarantee a remunerating stability of 15 years, in any renewable energy enterprise, due to the high investments usually associated with these kinds of projects. Moreover, there is a 5 year period for transition, after which the produced energy no longer has a guaranteed tariff. Instead, it has two payback components: one from the sell in market regime and another from green certificates (environmental award that translates the contribution for renewable energies European directive) (EDP, 2007).

The market of green certificates, which are autonomous and transactional bonds, may be a source of income for companies both in Portugal or international markets.

5.1.4 Existence of champion/ anchor tenants

Starting from the point that Finagra S.A. accepted to be the “headquarters” for the entire research project, it was obvious that they might also act as the champion that the project would need to succeed. Indeed, that became more explicit during the workshop, where Finagra’s CEO took the lead in encouraging the other stakeholders by stating his beliefs in the potential benefits of this research project and by enhancing the brainstorm session with his personal views of how the next steps of the project could be undertaken.

Also, Finagra S.A. is the biggest company involved in this research project, having huge energetic demands, and at the same time having a high quantity of biomass waste available. In the workshop, Finagra’s CEO clearly made an effort to engage other stakeholders with the immediate start of this project, assuming a leadership role, trying to assess which of the parties were really committed to the realisation of this project, or at least part of it. Immediately, Finagra’s CEO tried to divide tasks amongst the stakeholders who were present in the meeting concerning immediate steps that could be performed for the gathering of information needed for to follow up the project.

Due to all of this, plus the institutional support provided during the course of this research, Finagra is clearly the champion of the project, or the anchor tenant, assuring the commitment
of the other actors and serving as catalyser. This company should have the title of champion of the network since it has participated actively since the start of the research project, even acting as hosts for the workshop. Finagra S.A. may very well be the corner stone for the implementation and successful development of this network, by among other things, helping to assure a high level of commitment by other actors.

5.1.5 Further collaboration amongst the stakeholders

Although there was a high attendance at the workshop, with almost two thirds of the stakeholders present, some of the representatives were missing. Due to that fact, it is important, for the successful development of the IS network, that all the parties get together in more meetings, so all of the stakeholders can interact, identify new potential synergies, or just discuss and defend their own interest in the network. Also, it is desirable that these meetings are hosted by other independent stakeholders, and that study visits are organised in order for the parties to see each other’s actual processes. By doing this, conditions are created for more potential synergetic relations to be identified. It is also very important that the smaller companies are not left in a secondary position, but be taken into consideration in every step of the process of organising the network. In this way all the engaged stakeholders might have a say in the part that they are willing to play.

The creation of a consortium or a new entity that can dedicate itself to the issues related with the network is also of interest to the stakeholders. This consortium can also defend the interests of each and every one of the stakeholders. Taking into consideration the previously identified risk of monopoly, and the issue of collaboration amongst stakeholders, it is obvious that a large company with investment power will have a strong influence in the conduct of any process related with the network. Nevertheless, it is very unlikely that it might operate alone. Given this, it is necessary that this consortium creates the conditions for a consistent ownership structure. In this structure, the key stakeholders should be made owners of the CHP plant, for example. This would enable the conditions for a stronger connection to the IS network project and to raise the commitment of the stakeholders.

5.1.6 The coordinator agent

As identified in the literature, and detailed in Chapter 2, the existence of a coordinating agent is of utmost importance in the creation and maintenance of relations between the various stakeholders. This agent’s main role should be to help the companies acknowledge each other’s activities, processes and how they can work together. It should be expected that in the near future the stakeholders create this institutionalised entity that will continue the process of maintaining the close contact between stakeholders, and that will identify, contact and engage the necessary external players (i.e. technology providers, funding agencies, etc.) that will contribute to the realisation of this network. This agent shall also assure that the environmental profile of the network is safeguarded.

5.1.7 Community consultation

Due to the fact that this project brings the potential for new technology to be implemented in the region, and that technology may have some indirect impacts on the local population, it is thus necessary to conduct a proper community consultation. This consultation may be done by ADIM (non governmental organization), who has already proven its independence and true commitment in the defence of Reguengos de Monsaraz on more than one occasion. ADIM is also very aware of the potential benefits that this IS network might bring to the region.
5.1.8 Infrastructure location

As the area around the silo is to be classified as industrial area there is the potential to implement the CHP plant and/or the biogas digester in its vicinity. The offer of different energy products may create the right incentives for new industries to install themselves in the same area. On the other hand, the availability of these by-products, the potential demand from different types of costumers such as schools, swimming pools or supermarkets that are located in the region might force a re-evaluation of the location of these facilities. When all of the options are analysed it might just be that locating the plants next to the silo may no longer be the best option. If this happens, and if the facilities are settled not very near the centre of Reguengos, then the previously mentioned potential for complaints from the local population would no longer exist.

5.1.9 A regional innovation system oriented for the structural competitiveness of the production sector

This research project network has all of the necessary fundamental conditions to initiate a cultural change, by fostering the initiative of regional actors (companies) to invest in new innovative areas of technology, taking as a starting point their capacities and competences. This will allow for the competitive nature of the companies to be seen at an exogenous level, involving a range of other actors (regional, national or international) that, motivated by their own interest and objectives, will interact and enhance that competitiveness.

Clearly, it comes in line with the sustainable development strategy established by the Portuguese government, and approved on 17 August 2007 by the council of Ministers. This strategy commits to investing in the acceleration of the scientific and technologic development of regions, their sustained growth, competitiveness at global scale, energetic efficiency, and more equity, opportunity equality and social cohesion (Council of Ministers resolution 109, 2007).

5.1.10 Search of support from governmental authorities

Given that the biggest contribution for synergy creation in this research project comes from infrastructures creation, it is logical that the stakeholders of the project do their best to present and convince political decision makers that the conditions gathered in the Reguengos de Monsaraz Industrial Symbiosis project are in line with the above mentioned strategy defended by the government (a strategy that begins implementation in 2007 and should continue until 2015) concerning particular biomass projects. This includes such actions as the elimination of obstacles in the development approval and/or licensing process and other processes for which public organisations are responsible, and also to promote the concept of a “sustainable community” along side municipalities.
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Decree-Law no. 313/95 of 24 of November


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Potencial for implementing an Industrial Symbiosis network in rural Portugal


Strupeit, Lars (Lars Strupeit (lars.strupeit@student.iiiee.lu.se) (2007, September 13). Re: FW: Tech help. E-mail to João Barroso (joao.barroso.661@student.lu.se).


# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP</td>
<td>Cogeneration of Power and Heat</td>
</tr>
<tr>
<td>IE</td>
<td>Industrial Ecology</td>
</tr>
<tr>
<td>IS</td>
<td>Industrial Symbiosis</td>
</tr>
<tr>
<td>RMISP</td>
<td>Reguengos de Monsaraz Industrial Symbiosis Project</td>
</tr>
<tr>
<td>SD</td>
<td>Sustainable Development</td>
</tr>
<tr>
<td>TBL</td>
<td>Triple Bottom Line</td>
</tr>
<tr>
<td>toe</td>
<td>tonne of oil equivalent</td>
</tr>
<tr>
<td>WWTP</td>
<td>Waste Water Treatment Plant</td>
</tr>
<tr>
<td>WTS</td>
<td>Waste Transfer Station</td>
</tr>
</tbody>
</table>
Appendix 1: Spatial representation of the RMISP

![Industrial Symbiosis Network](image)
Appendix 2: TRIPLE BOTTOM LINE ASSESSMENT TOOL

This tool was based on a Sustainability Checklist for the evaluation of Product Service Systems (Tischner et al, 2003) and it works as follows:
1. 3 main evaluation aspects are discerned (People, Planet, Profit)
2. For each aspect, 4 key criteria are defined.
3. Each criteria can be scored 1 (better than the existing situation), 0 (equal) or –1 (worse).
4. Scores are totalled per sustainability aspect (hence maximum 4 points per aspect)

<table>
<thead>
<tr>
<th>A) Economic/profit aspects</th>
<th>Score ( 1 = better, 0 is equal, -1 is worse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- How profitable/ valuable is the solution for the stakeholders? Including cost of production, cost of capital and market value of the solution for the stakeholder(s)?</td>
<td>1</td>
</tr>
<tr>
<td>- How profitable/ valuable is the solution for customers/ consumers/ population? Are there a concrete, tangible savings in time, material use etc. for the customer? Does it provide ‘priceless’, intangible added value like esteem, experiences, etc. for which the customer is willing to pay highly? (both in comparison to a traditional product system)</td>
<td>0</td>
</tr>
<tr>
<td>- How difficult to implement and risky is the solution for the stakeholders? When is the return on investment expected?</td>
<td>-1</td>
</tr>
<tr>
<td>- How much does the solution contribute to the ability to sustain value creation in the future? Does it give the network that implements the IS now and in the future a crucial and dominant position in the value chain?</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>B) Environmental/planet aspects</th>
<th>Score ( 1 = better, 0 is equal, -1 is worse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- How good is the solution in terms of Material efficiency (including inputs and outputs/waste)</td>
<td>1</td>
</tr>
<tr>
<td>- How good is the solution in terms of Energy efficiency (energy input and recovery of energy without transportation)</td>
<td>1</td>
</tr>
<tr>
<td>- How good is the solution in terms of Toxicity (including input/ output of hazardous substances and emissions without transport)</td>
<td>1</td>
</tr>
<tr>
<td>- How good is the solution in terms of transport efficiency (transportation of goods and people including transport distances, transportation means, volume and packaging)</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
</tr>
</tbody>
</table>
C) Social/people aspects

<table>
<thead>
<tr>
<th>Score (1 = better, 0 is equal, -1 is worse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Does the IS contribute to quality of work in the production chain (Environment, Health, Safety; enriching the life of workers by giving learning opportunities, etc.)</td>
</tr>
<tr>
<td>- Does the IS contribute to the 'enrichment' of life of users (by giving learning opportunities, enabling and promoting action rather than passiveness, etc.)</td>
</tr>
<tr>
<td>- Does the IS contribute to intra- and inter-generation justice (equal wealth and power distribution between societal groups, North-South, not postponing problems to the next generation, etc.)</td>
</tr>
<tr>
<td>- How much does the solution contribute to respect of cultural values ad cultural diversity, e.g. customized solutions, contributing to the social well being of communities, regions etc. (cultural values)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

**SUMMARY**

<table>
<thead>
<tr>
<th>Main aspect</th>
<th>Score (between −4 and +4)</th>
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</thead>
<tbody>
<tr>
<td>A) Economic/profit</td>
<td>1</td>
</tr>
<tr>
<td>B) Environmental/planet</td>
<td>4</td>
</tr>
<tr>
<td>C) Social/people</td>
<td>2</td>
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</table>
## Appendix 3: Interviewees

<table>
<thead>
<tr>
<th>Company</th>
<th>Name</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Águas do Centro Alentejo, S.A.</td>
<td>Luisa Alves (Engineer)</td>
<td>July 6, 2007</td>
</tr>
<tr>
<td>Associação de Desenvolvimento Regional do Alentejo (ADRAL)</td>
<td>Paula Marquez (Technical coordinator)</td>
<td>June 13, 2007</td>
</tr>
<tr>
<td>Associação de Defesa dos Interesses de Monsaraz (ADIM)</td>
<td>João Cavaco (Vice-President)</td>
<td>10 July, 2007</td>
</tr>
<tr>
<td>Câmara Municipal de Reguengos de Monsaraz</td>
<td>José Calisto (Vice-President) Ana Margarida Paixão Ferreira (Architect) Sónia Almeida (Engineer)</td>
<td>June 5, 2007</td>
</tr>
<tr>
<td>CARMIM – Cooperativa Agrícola de Reguengos de Monsaraz</td>
<td>Rui Veladas (Production Manager)</td>
<td>June 12, 2007</td>
</tr>
<tr>
<td>Comissão Coordenadora de Desenvolvimento Regional do Alentejo (CCDRA)</td>
<td>Rosa Onofre (Regional Development Services staff) Joaquim Fialho (Regional Development Services staff)</td>
<td>June 13, 2007</td>
</tr>
<tr>
<td>Direcção Regional de Agricultura (DRA)</td>
<td>Joaquim Grave (Veterinarian) José Morgado (Agronomist) João Amante (Technician)</td>
<td>June 11, 2007</td>
</tr>
<tr>
<td>Évora University</td>
<td>José Oliveira Peça (Associate Professor)</td>
<td>June 19, 2007</td>
</tr>
<tr>
<td>EuroEste, S.A.</td>
<td>João Fernandes (Veterinary) António Pedro (Zoologist)</td>
<td>June 20, 2007</td>
</tr>
<tr>
<td>GESAMB - Gestão Ambiental e de Resíduos EIM</td>
<td>Ana Silva (Engineer)</td>
<td>July 7, 2007</td>
</tr>
<tr>
<td>Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI)</td>
<td>Pedro Abelha (Energetic Engineering and Environmental Control Department) Santino di Berardino (Biomass Unit)</td>
<td>July 13, 2007</td>
</tr>
<tr>
<td>Finagra, S.A.</td>
<td>João Roquette (CEO) Joaquim Pedras da Silva (Quality Manager)</td>
<td>June 07, 2007</td>
</tr>
<tr>
<td>Maporal – Matadouro de Porcos de Raça Alentejana, S.A.</td>
<td>Carla Baixinho. (Production and Quality Manager)</td>
<td>June 19, 2007</td>
</tr>
</tbody>
</table>