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Industrial Symbiosis in the Greek Islands

The case of Lesvos

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To the mountains of my life….

Goldfish.

Abstract

Greek islands face a series of problems that can put their sustainability at risk. Overexploitation of natural resources, limited waste and wastewater management practices, and energy shortage are such problems. Lack of cyclic behaviour in resource flows is a factor tightly linked to these problems. Here, the concept of industrial symbiosis appears to offer an important potential in addressing some of the sustainability challenges in these areas, by minimizing the resource flows and generated waste through more efficient systems. In this thesis, the potential of IS in contributing to sustainability in the Greek islands is investigated, by attempting to apply the concept to Lesvos Island within an action research framework. The study revealed the potential for considerable benefits, however significant barriers exist in regards to the development of such IS networks.

Executive Summary

Greek islands appear to face the same challenges over the time:

i. Overexploitation of natural resources
ii. Waste management
iii. Energy shortage
iv. Water shortage

This thesis investigates the potential for addressing these challenges through the application of the industrial symbiosis (IS) concept, taking Lesvos Island as a case. Lesvos appears to have considerable similarities with other islands. The research identifies the potentials for establishing synergistic relationships among regional activities and assesses the benefits that these relationships could provide. It also investigates potential barriers that may jeopardize their applicability and other constraints that a scheme coordinator may face during the implementation phase.

Industrial symbiosis is a concept that tries to identify the non-sustainable attributes of an industrial system and aims to uncover and implement necessary changes so as to improve the sustainability of such a system. As a part of Industrial Ecology, IS partially tries to imitate natural ecosystem processes where waste of one species can be the input for another. Through more efficient industrial production processes and enhanced reuse and recycling, that are enabled through synergistic relations among regional activities, IS may reduce the necessary amount of raw materials and the amounts of waste. However the success of the IS developments will be dependent on various factors. Technology, legislation and policy, economy, organization and finally informational exchange can be among such factors.

Lesvian industry is mainly based on olive oil extraction, milk processing, ouzo distillation, cattle breeding and energy generation to cover both municipal and industrial needs.

In this thesis, a range of possibilities for synergistic relationships are identified. Although at this stage they are only theoretical, these relationships could link the above mentioned industries. Examples of such synergistic relationships include the following:

- Biogas from abattoirs that can be used to cover the energy needs of other nearby industries;

- Use of waste heat, generated by the energy plant to preheat the distillation equipment of an ouzo distillery;

- Olive oil waste and use to produce cosmetics and cover energy needs by the generated biomass;

- Milk processing waste (whey) partially used as an input to pig farms and the creation of new types of cheese following the Norwegian example.

Each of the above mentioned synergies is assessed for the benefits that the participants will realize and also for the drawbacks and constraints that will be faced during both the organization and implementation phases.

The above mentioned synergies may be applied not only in the Lesvos case but also in other Greek islands with similar industrial diversity based mostly in the agriculture sector. However, it appears that the difficulties during the organization and implementation phases follow a similar pattern, with a lack of trust for new ideas being demonstrated. University representatives, as well as foreigners to the Lesvian community, do not seem to attract the appropriate attention from representatives of the local industry who often appear to face the IS tool with skepticism and sometimes even with secrecy. Participants' credibility must also be ensured to the greatest extent possible in order for the scheme to be operational over a certain time period. Moreover, changing the way that the local industry is operating is another potential challenge the coordinators may face, together with the conservation of local tradition and morals.

In order for IS to be implemented and be operational to the greatest extent possible, several ideas are being recommended. First, there is a need for a more strict and absolute implementation of the current Greek and European legislation. Furthermore, it might be beneficial for the success of IS to use a locally embedded coordinator. This coordinator will act as a middle man between the organizers and the participants, thus creating a pillow of trust amongst them. Further measures shall be taken to ensure the credibility of the participants, also creating an adequate level of trust between them. Moreover, the local university shall act as the kernel of knowledge, taking innovative (for the Greek actuality) steps to promote concepts like IS amongst the community. The university can help with the collection of necessary data, which will assist in the completion of more safe and reliable assessments.

The implications mentioned in the previous paragraphs shall be used in order to implement IS schemes in all Greek islands that have similar economic and industrial characteristics.

Industrial symbiosis is not a tool that will magically solve all of the problems of Lesvos and other similar Greek islands. Numerous actions and cost benefit analyses must take place to assess the overall feasibility of the proposed synergies and to change the locals' mentality towards these very new activities. However, if implemented correctly, IS may add one more brick to the wall of sustainable development in the Greek Islands.

Table of Contents

List of Figures

List of Tables

1 Scene Setting

1.1 Introduction

Greek islands seem to face a series of critical problems that are jeopardizing sustainable development. Competition between European country members has brought these problems to the surface of the Greek actuality once again, making the need for an imperative solution obvious.

Some of the main challenges that Greek islands appear to face are, on the one hand, water and energy shortages and, on the other hand, constraints concerning solid waste and waste water management. None of these islands are connected to any sort of mainland grid (supplying water or electricity). Thus there is a need to generate sufficient amounts of energy and water and also to manage both municipal and industrial waste so that the local environment is sustained.

Lesvos Island, as part of the "Greek Islands family", represents some of the main characteristics that the biggest Greek islands possess. In addition, Lesvos is facing, to a certain extent, the aforementioned challenges that need to be overcome in an effort to promote the three pillars of local sustainability.

Several tools that promise to change unsustainable systems to sustainable ones exist. Concepts like Cleaner Production, end-of-pipe solutions and so on are frequently used and nowadays there is enough knowledge regarding how to make them operate within specific contexts. Industrial Symbiosis (IS) is one of a plethora of existing tools that might convert the unsustainable attributes of a system to more productive and efficient characteristics, adding in this way a small stone to the wall of sustainable development. However, IS, as much as the other tools for sustainability, cannot guarantee positive results in any case. Thus, there is a need for adapting the IS tool to each context and assessing its applicability.

Finally, the concepts of Industrial Ecology (IE) and IS have never been used in any Greek case (at the time that this thesis is being conducted) and it is a challenge for the writer to assess if and how the theory shall be modified to suit the Greek island context.

1.2 Research Problem

Lesvos Island is one of the biggest Greek islands and perhaps one of the most remote from the mainland. Thus, the local economy is developed by using local resources and by being based on fossil fuels for energy generation. Some problems are already floating to the surface of the Lesvian actuality: The energy plant is not properly designed to cover the local household and industrial needs – especially during summer – while the percentage of the renewable energy sources (RES) is not considerable. Furthermore, problems concerning the waste management sector have appeared while, at the same time, the local market searches for innovative solutions to become more cost effective and less material based.

In order to achieve a greater degree of sustainable development, the island has to implement frameworks and use specific tools which currently do not seem to have been applied in the Greek context. The idea behind that is that, firstly, the efficient and effective use of raw materials and the island's resources shall be promoted and that, secondly, waste streams shall be minimized. In this way, both environmental and fiscal sustainability will be promoted since the local industry will be able to minimize production costs and gain credits towards product competitiveness without jeopardizing the environmental quality of the island.

Moreover, one has to think of the limited space that exists on an island, leaving less space for waste handling and management. Bad management of waste and the generation of large amounts of waste can jeopardize environmental sustainability by contaminating the air, the aquifers and by reducing the aesthetics of the natural environment.

Industrial symbiosis has the potential to be one of the tools used in the Lesvos case. Initially the marginal benefits seem to be promising. Even though the implementation of IS seems to be problematic in some cases, in the long run it might be profitable and more prosperous for a region having Lesvian characteristics to implement this tool. It is part of this study to assess how useful the IS tool will be for the Lesvian actuality and local development. This local development differs from growth in the sense that, in addition to local economy, environment and society are also taken into consideration. Following this assessment, the replicability of the tool is then assessed in islands with similar characteristics and variables.

The connection between IS and Lesvos may also work in reverse: Perhaps, after the completion of the research, new factors that may benefit the IS tool will arise due to the fact that the research is taking place on an island state. It might also be the case that some characteristics of the IS tool have to be altered (or even stressed in a different way) to enable more effective use in an island setting, keeping in mind that, due to its smaller area, problems that may be easily solved in another region may become severe obstacles towards the implementation of new tools such as IS in an island context.

Much research has been done concerning the implementation of IS tools in different regions around the world. Sweden, Denmark and England can show multiple cases with different variables. However, there is no research concerning a Greek territory and, more specifically, a Greek island with defined boundaries and administrative issues at the moment that the present thesis is conducted. Thus, there is a need to assess how IS, being a tool for environmental sustainability, can help the regional development of Lesvos and to determine if this case can perhaps be replicated for other remote regions, or islands with similar characteristics.

1.3 Objectives and Research Questions

The main objective of this thesis is to set the foundation for further use of the IS tool in the Greek actuality. One of the goals is to assess any possible cases where IS could be used in order to promote sustainable development of Lesvos Island, and calculate the benefits for the actors while assessing the barriers and other constraints. As Mirata specifies, there are specific factors that can determine the success of an IS concept network (Mirata 2005). The ambition is that, after the research, a better understanding of the islands' potential will exist. At the same time, a baseline will be set for further development into more specific areas, in that way helping the local community to develop a profitable and successful synergistic network.

The basic idea behind the research is to assess the applicability of IS in a Greek island using Lesvos as a case-study. In order to do so, it is necessary to use the following sub-questions:

1. *How could the IS-concept contribute to sustainability in an island setting and especially in the case of the Greek Islands?*

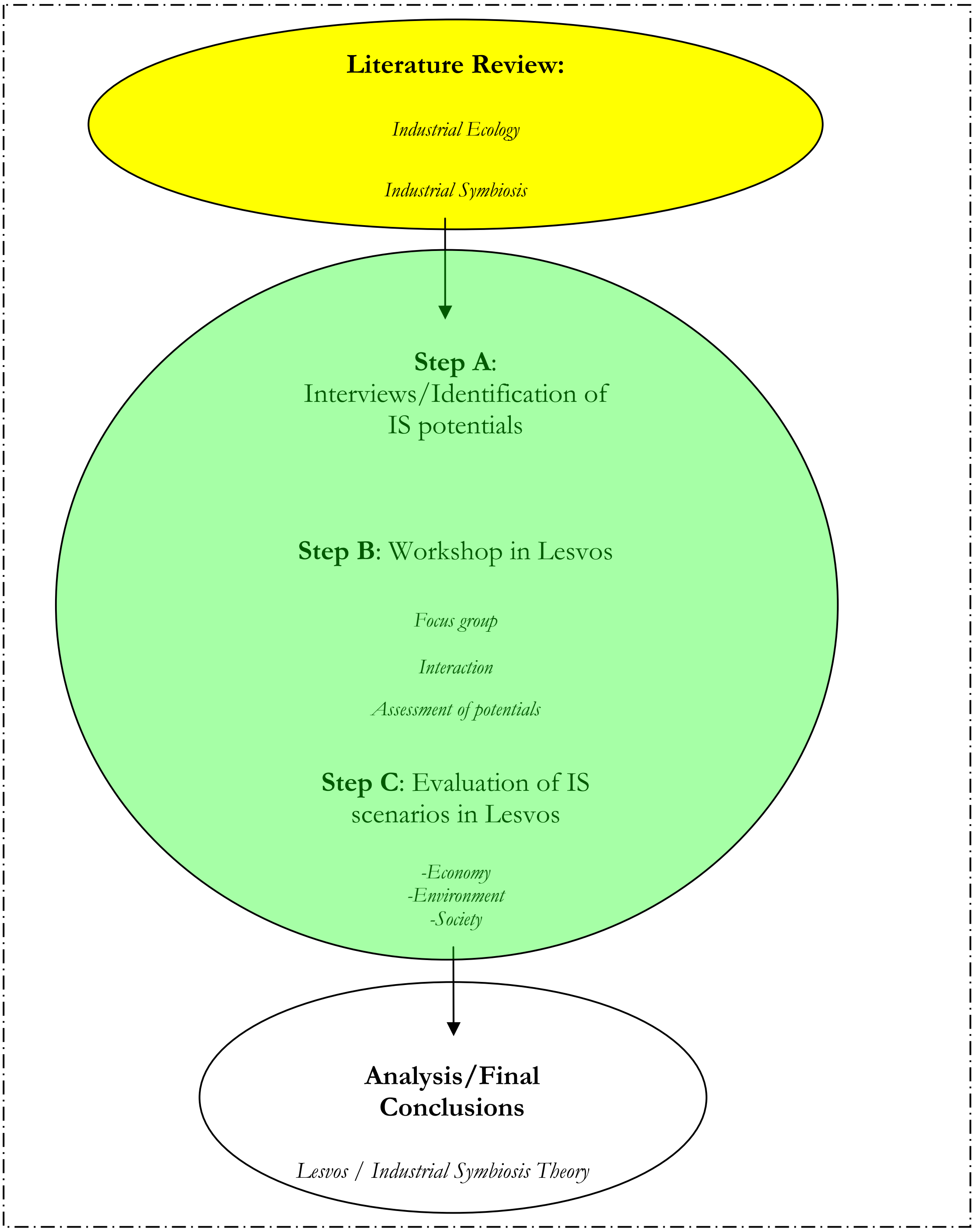
2. *What are the specific conditions on a Greek Iisland and specifically in Lesvos that are affecting the IS-concept? Where are the barriers towards the implementation of IS schemes?*

3. *Where are the potentials of minimizing the resource and energy consumption and how can the local actors use them?*

1.4 Methodology

The methodology that is followed for the current research is described in Figure 1.1. The research is divided in three major sections: The **preparatory** phase, the **onsite** research, and the **analysis** of the findings that leads to a series of conclusions. Finally, part of the analysis phase will include some recommendations for future thinking.

Figure 1.1: Research process for IS potentials in Lesvos



Preparatory Phase

During this phase of the research, which took place in Lund, Sweden, data were gathered through a literature review. Secondary data concerning the IS theory were gathered mainly from academic literature as well as relevant reports and internet sources.

On-Site Research

Part of the conducted work, while situated in Lesvos, was to observe, influence and, if possible, change the current mentality of the locals towards IS and generally pioneer new ideas. The IS workshop, to which many representatives from the local industry, university and municipalities were invited, was part of this effort. Primary data were collected from interviews and observations on site.

Since the researcher tried to create interest in the IS tool by providing the necessary data and information, while at the same time using the experience to gain a better understanding of the IS tool for himself, the conducted research has the partial characteristics of both a case study as well as of action research.

Action research is defined in a number of ways in the literature. However, behind the available definitions, there is a common basis underlying the strength and the characteristics of this research tool. This is because action research has the characteristics of a more interactive process, where, through exchange of knowledge, feedback and experiences, all parts participating are benefited by empowering their knowledge, collaborating and transmitting their knowledge to other participants (Zuber Skerrit as cited in Masters 1995). Therefore, action research is described as a systemic inquiry that is collective, collaborative, self-reflective, critical and undertaken by participants in the inquiry (Masters 1995).

The actual on site research was held in collaboration with the Aegean University, under the financing of the BIOBUS European funding project[1]. For the purposes of the BIOBUS project, part of the current thesis is presented as a deliverable of it.

The actual research was divided into several steps**: Step A**, was the collection of data through interviews with local actors who have the potential to play a determinant role in the evolution of the potential synergies in the island. Some of these actors were:

- *Commercial representatives*: The author was in continuous contact with some of the local industry representatives, for data collection and evaluation. Farmers, cheese producers, ouzo producers, and slaughter houses managers were some of the target group.
- *Local authorities*: As mentioned above, the administration of the island needs to be aware of the research scope, so that the opportunities for further development are clear.
- *University representatives*: This group consisted of researchers and other actors who have the appropriate know-how, and can promote and educate other actors. These people can identify potentials, at a local scale, and also identify major players.
- *Environmental authorities*: The environmental authorities are aware of the resource availabilities in the island. The political/administrative structure gives freedom to the environmental authorities to decide and give permission for projects. Therefore it is

[1] More information concerning the BIOBUS project available at: http://www.biobus.gr/isite/el/page.asp?uid=28

necessary to obtain a clear and highly standardized route of connection so that targets of this research and further opportunities are assessed.

The big Lesvian industries were identified during interviews undertaken with some "big" players of the local economy. After gaining an understanding of the production processes of each industry, potential synergies were assessed basically depending on the geographical proximity of the different industries and cooperatives. It is crucial to mention that even synergies that seem (at least at the beginning of the research) optimistic are going to be presented under the theoretical umbrella of IS theory. The scope of this study is not only limited in identifying IS cases among existing activities but also inserting into the Lesvian industrial scheme innovations that can promote environmental, economic and social sustainability. These innovations seem to exist in other European cases; however the limitations that result from the scale of the local Lesvian economy determine the feasibility of these techniques.

The data collected from the initial interviews was evaluated and, in order to trigger participation of the previous referred actors, a workshop was organized in the facilities of the department of Environment in the Aegean University, as part of **Step B**. The target of the workshop was to gather the actors and their representatives and show the development possibilities for the island's economy by using the tool of industrial symbiosis. Enhanced competitiveness through certain strategies was stressed during the workshop and all identified possibilities for synergies were then assessed.

Furthermore, it is absolutely critical for the participants to understand that collective work is essential for the ideas of IS to work successfully. Thus, the workshop was an introduction to future engagements.

During **Step C** (last phase of research), the results of the workshop were evaluated. The most attractive cases of potential synergies which arose from the workshop were further developed. After the development of different scenarios of IS, an assessment and analysis took place, based on barriers that may arise as well as on benefits for the actors and the local economy. Finally a suggested framework for igniting each project and transferring the scenario into practice was put forward.

Evaluation / Analysis Phase

All the data and ideas that were gathered through the research and the workshop were evaluated and put into a specific framework. Each potential synergy was evaluated according the following criteria:

- Firstly, the overall feasibility: How possible it is for this synergy to evolve? Is it cost effective and, if so, what is the outlook for payback of the initial investment?

- Secondly, indication of the results (both in the short and long run) for three different sectors: The attractiveness of the product/service, the environment and the society.

- Evaluation of the future of the synergy. Can it generate a new product, creating thus a new market locally/nationally? Moreover, can each specific synergy trigger more symbiotic relations, if it proves to be effective and profitable?

- Finally, is it possible for these synergies to be replicated in other islands that present more or less similar characteristics? Furthermore is the specific framework suitable for other types of remote regions (not only islands)?

Apart from the assessment of each synergy, analysis of findings and personal observations that were made during the research are presented together with some recommendations that may solve some of the observed problems.

1.5 Scope and Limitations

The scope of this paper, as mentioned before is to assess the applicability of IS theory in the Greek islands using Lesvos as a case. Over 2000 islands are situated in the Greek territory and only 227 of them are inhabited[2]. Lesvos was chosen amongst other Greek islands because it can be considered as a region with some preconditions already in place that are favourable for IS: Resource flows and waste handling, together with intense agriculture development. Hence, boarders and administration issues are well defined, aiding the progress of a short, time-limited research. Finally, Lesvos appears to have critical industrial diversity, based on agriculture, sustaining and promoting local economy and society**.**

Since there is no previous research done regarding the current issues, either in Lesvos Island or in any other Greek territory (at the time that this report is being written), the research will begin at the fundamental level, mapping the local industrial system and then identifying possible synergies and/or similar.

It is crucial to mention that "synergies with software"[3] also come under the scope of this research. Transportation, education, learning and administrational exchange/share can provide first class synergies, since they can lead the companies towards resource efficiency and competitiveness, while at the same time providing an environment with significant benefits.

The majority of the proposed synergies are hypothetical and, due to the lack of data, the economic viability of each synergy is not assessed in detail. However they seem to be profitable but, before advancing to their implementation, it is necessary to conduct a more thorough analysis of the economic figures.

In fact, the results extracted must come under some skepticism. The research period was limited to three months and it is difficult to drawn a definite conclusion, even with very specific observations that the researcher made. Moreover, the researcher found extensive difficulties trying to gather data that could help the IS assessment.

The replicability of the results is limited to other Greek islands that appear to have characteristics that are more or less similar to that of the local Lesvos economy: Essentially islands that do not rely heavily on tourism and that present a sort of industrial variability, based on the agriculture sector.

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[2] Ministry of Greek tourism. Available at: http://www.biobus.gr/isite/el/page.asp?uid=28

[3] By synergies with software, the author means light cases of Industrial Symbiosis: Synergies that do not include the immediate exchange of raw materials, waste or anything tangible.

Finally, no mininum limit concerning the number of participants in each synergy, or the number of synergistic exchanges is set towards the identification of each symbiotic case. All major possible synergies (material, energy, management and so on) are assessed.

1.6 Thesis Structure

The thesis is structured into a number of chapters. The second chapter provides a brief idea of some of the sustainability issues that remote regions may face and introduces the reader to the concepts of industrial ecology and industrial symbiosis. In the third chapter, the island of the case study, Lesvos Island, is presented so that the reader may understand the island's basic characteristics, the status of economy and other similar variables. In Chapter 4, the identified IS potentials are presented. This presentation is followed by an assessment of each potential synergy (Chapter 5). Chapter 6 includes conclusions and personal observations of the author while, in the last chapter (Chapter 7), recommendations for future thinking are provided.

2 Sustainability Concerns and Tools

It was until recently when humans had to manage with an upcoming problem: The unlimited extraction of sources together with non sustainable energy use. The energy crisis of 1970s together with a series of other incidents made clear the need for a more specific framework concerning environmental issues (Buhagiar 2006).

A widely accepted definition for sustainability was developed by the World Commission on Environment and Development (WCED) as cited by (Maltin 2004). Sustainable development is defined as development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

Some years later, in 1996, Goodland et al, in "Environmental sustainability: universal and non-negotiable" state that there is a mystification around the term of sustainability and in order to develop a more clear definition of the concept, it must be separated into social, environmental and economic sustainability (Goodland R. 1996). Moreover, the author provides another definition, not so different from the one available in the previous paragraph: "Sustainable development is development without growth in throughput of matter and energy beyond regenerative and absorptive capacities"(Goodland 1996).

The primary goal of sustainable development is to improve the quality of life for human beings and for the following generations. In order to achieve this goal the theoretical framework is divided in three well known pillars: namely, environmental, economic and social (Buhagiar 2006).

Before continuing, and in order to comprehend deeper the concept of sustainable development, it is crucial to introduce the term of carrying capacity of a system. The maximum number of individuals of a specific population that a system can support without reducing its ability to support the same type of population in the future is called the carrying capacity. Another misconception that has to be avoided is the difference between growth and development. Growth basically means increasing in size, amount or degree of something, while development has a more deep idea of progress meaning to become more advanced and stronger (Oxford 2003). Development is a concept that should continue for all nations without any barriers. On the other hand, growth cannot. Sustainable development is achieved when development takes the place of growth. To sum up, it can be understood that sustainable development can be defined as development under the umbrella of constrained economic growth (Jeffrey C. 1999).

Another definition of sustainability is provided: "*Sustainability in economic terms can be described as the maintenance of capital*"(Goodland R. 1996). Capital can be current amount of money or even the natural environment (natural capital[4]).

Some basic prerequisites that may assist in attaining environmental sustainability exist in the literature. The following are not the only elements that may lead a system towards environmental sustainability (as each system is unique in terms of characteristics), however they are the most common:

[4] Natural capital the natural environment in which we leave in and is basically the stock of resources that nature has.

- Waste production should be able to be under the carrying capacity of the given environment, without jeopardising its quality, or its ability to absorb waste;

- Each system has a certain capacity to regenerate renewable resources. Human activities and use of renewable resources should not exceed this capacity;

- Part of the money earned by liquidating non-renewables shall be allocated funding research for non-renewable substitutes. The rate of these substitutes shall not be exceeded by human use of non-renewables (Goodland R. 1996).

2.1 The Island Context

Territories like islands that are located far from the mainland seem to have very similar characteristics. These are presented in the next paragraphs:

Islands are clearly bounded and can also be considered isolated. The level of isolation depends on its remoteness from the mainland. However, even presently, when transportation is quicker and reliable than in the past, the cost for connecting an island with the mainland or other islands is still considerable. Based on the level of remoteness, some scientists consider the islands to be closed systems (Chertow 2004). This takes place especially in big islands, where there is not significant dependence on the mainland.

Moreover, in an island perspective, the resources (fresh water, electricity) have to be produced internally since the connection to a mainland's grid can be have tremendous a cost. It seems that this enhances the dependence of the island on fossil fuels. Waste management is also limited, considering the well defined space (the island's area) and the use of land.

Three seem to be the fundamental virtues that should be followed towards environmental sustainability of a region (Goodland R. 1996):

1. Waste should not be released in the system at a rate that endangers future assimilation;

2. Renewable sources should be used with rationality, allowing for the system to regenerate the appropriate amounts of them;

3. Non-renewable sources should not be used faster than substitutes can be developed.

These three basic virtues apply to any type of ecosystem that is being challenged by sustainability issues. Specifically, societal systems have to come to terms with these virtues in order to promote environmental sustainability. However, sustainability issues are much more critical for islands or remote mainland regions, because of the limited chances and opportunities existing on site.

Barriers to sustainable development may be magnified for remote areas, such as small islands, and the level of magnification can be directly connected with the level of remoteness of the island. This argument applies only to specific islands that concentrate certain characteristics, like small size, energy independency and so on. However, it is understood that island cases should be treated in a different way and not by following traditional models of research.

Following Doikos (Doikos P. 2002), in order to obtain sustainable development in a remote area (including an island), there is a need for a strategic approach that will open up new perspectives. That strategic approach can determine and formulate the following categories:

- Enhancing quality of life;
- Integration of environmental, economic and social aspects, based on common interests;
- Competitiveness of the regional industry;
- Attractiveness of the region.

One may think that the aforementioned categories are also applicable to any kind of region; not only remote islands. However, it should always be kept in mind that, for example, in remote regions due to the geographic distance from the mainland or from other developed regions (with all the constraints that these facts entail), regional industry is not attracted to operate there, thus creating possibilities for increasing quality of life (potentials for employment, possibilities for investments). The results from the above mentioned strategic categories can affect, to a much greater extent, the remote regions (mainland or islands).

The island approach consists of the existence of the anthropogenic network on a regional scale. It is easy to comprehend that the interaction between the ecosphere and regional systems is much more intense, always in comparison with other regions that do not present characteristics like remoteness from mainland and so on (Wallner H. 1994).

Not only do islands include characteristics that can be easily found in other remote mainland regions, but it is quite common that constraints are also created by transportation issues, even though technology and conditions evolve, supplying safer, quicker and to some extent less expensive transportation.

The trade system that is operating on islands is another special characteristic that can be attached to the island approach. It is easy to understand that islands are not only based on their own raw materials, due to material constraints. There are cases where even the potable water is transported by boats (Chertow 2004). Moreover, most of the Greek Islands are importing fossil fuels, food or other items from the mainland (Mihalakakou G. 2001). Resource security is always an issue in these types of remote regions. The market does not present any sense of flexibility in scarcity of those materials and the results of the absence of certain materials in the market can be huge.

Islands are regions with specific characteristics (Chertow 2004). By definition islands, have very precise geographical and administrative boundaries. Usually there is a level of remoteness from mainland that defines the level of autonomy. However, even in the present day when transportation is quicker and more reliable than in the past, the cost for connecting the island with the mainland or other islands is still considerable.

In "An island approach to Industrial Ecology", Deschenes and Chertow try to classify the islands according to the similar characteristics that they have. Islands can be considered as closed systems, depending on their level of remoteness from the mainland or other islands. This characteristic can become a barrier towards importing heavy fuels, electricity and other goods that the local economy cannot produce. The view that access to resources varies greatly from island to island is also enhanced (Brown 1997). Moreover, waste management capabilities are limited due to the constraint of available land on the islands (Chertow 2004).

Finally, in an island perspective, the resources (fresh water, energy, electricity) have to be produced internally since connecting to a mainland's grid can have a tremendous cost. This seems to enhance the dependence of the island on fossil fuels. Lastly, the habitants have to develop the local economy based on the available resources.

Island Sustainability

Before entering into the concept of sustainable islands, a clarification of what a sustainable community/region is is required. The definition of a sustainable region is not altered from the main definition of sustainability, apart from applying the concept to a more specific geographic scope and to the characteristics of the area.

The ideal sustainable region (or else a region in order to be sustainable) may follow some characteristics. These characteristics do not come only under the scope of remote islands but it is well understood that their impact on islands is more noticeable than on other mainland regions. Some of these characteristics may be:

- Local Economic Diversity: There is a need for multiple commercial actions in the region so that it will be easy to adopt development strategies without the need of external powers;
- Self Reliance: Linked directly with the economic diversity;
- Energy Reduction and Improved Waste Handling: This addresses the Brundtland report's demands;
- Protection of Biological Diversity and Natural Resources (Jeffrey C. 1999).

Wallner, in an effort to support and explain the idea of regional sustainability, divides the regions into independent areas, calling them islands. These "islands[5]" have clearly defined boundaries (geographically and administratively). As mentioned above, sustainability in a region is reached locally by using the available resources and this is the assumption from where the concept of islands of sustainability (IOS) is initiated (Wallner H. 1994). Information and the level of communication with other "islands" affects the goal of sustainable development.

However it is easy to understand that islands may face problems, towards environmental sustainability, similar to other remote mainland regions. Sustainability in islands follows two basic key points: The communication activities and the interaction with other systems (inside the island, with the mainland, other islands and so on). The former includes any exchange of matter or energy, also taking into consideration informational, cultural, and capital share, while the latter takes into consideration the intensity and speed of internal and external interactions.

Summarizing, Wallner mentions that sustainability in a region is reached locally. Moreover, there is a need for a specific framework for IOS to be effective. The system is divided into three levels. In each level several different concepts have to be applied. At the initial level, which is the level of economic elements, the concept of Cleaner Production shall be applied.

[5] Islands in this case are not parts of land surrounded by water. The term "islands" is a metaphor used by Wallner. What it is done is that regions are divided into smaller areas in order to achieve sustainability locally and these areas are called islands.

In this way strong foundations for future development are set. Following up, in the next hierarchical level, the concept of industrial ecology is applied on an inter-organizational level. Finally on the third systemic level a more specific approach towards regional networking economy has to be introduced so that the main idea of industrial symbiosis can be set (Wallner H. 1994). In between the premises, there is a need for change concerning the regional commercial complexity and the trade system that exists in the islands. Moreover the techniques inside the island and the way that these are communicated have to be reassessed and formulated in such a way that will suit the island's characteristics. Finally the characteristics of each island have to be taken under serious consideration before implementing any scheme. Problems that exist in each area, the political situation, and the interaction between other regions/islands are just some of the criteria that should drive a framework for islands of sustainability (Buhler-Natour C. 1999).

The basic features that a system has to meet to achieve sustainability (that were presented previously) have to be reassessed for the concept of islands of sustainability:

- Primarily, material flows generated by humans must stay under the assimilation capacities of the local region;

- These material flows should ensure as much as possible that the quality and the quantity of the regional cycle will not be jeopardized;

- The variety of species and landscapes must be kept in the same quality (or better) for future generations (Wallner H. 1994).

Main Concerns for Island Sustainability

In order to assess the possibilities for sustainable islands, there is an important need to understand the potential barriers that an island may face in any case. These constraints may arise in the case of mainland regions that also appear to have a high level of remoteness from the centers.

- One of the barriers that island communities face, is the availability of fresh water: Water seems to be the most limited resource in agriculture for most island nations and territories (Brown 1997). The basic constraints towards water resources appear in the next paragraphs:

    - Inefficient use of water use due to the existence of non up-to-date techniques and an inefficient water management system. Secondary factors can be the low capability for storing water masses and also the existence of crops with high water demands.

    - Competition for water between agriculture and development. As mentioned in the island definitions, the local economy is sustained by local products and by using local resources. However, this can cause a main dilemma: Should the water be used for agricultural purposes (irrigation and so on) or for industrial purposes? This problem is even more significant in cases (islands or remote mainland regions) where, on one hand, water resources are scarce and, on the other hand, where annual mean temperatures exceed a certain level.

    - Variability of rainfall and weather patterns: The geographical position and characteristics of the island can play a major role in the availability of water masses. Moreover, as mentioned above, the climate type can also play a determinant role towards water supplies.

- Biodiversity: Many animals and plants have been eliminated from ecosystems to which they belong. Human beings may also alter the biodiversity, since there is a need for a more intense use of natural resources. This may increase production rates and perhaps development in a short run, but in the long run it is proven to be a barrier towards environmental sustainability.

- Waste: Waste always seems to be a problem with regards to environmental sustainability, and this is worsened by the land constraint that, by definition, exists in an island. The increasing level of welfare, together with the small areas of land that are allocated for landfills is, one of the main causes of the waste problem (Brown 1997).

- Energy: Islands that are not connected to the mainland have to produce energy locally. Dependency of the local economy on fossil fuel prices (the most common way to produce energy) makes it more unstable and the concept of sustainability is even more difficult to apply. The energy issue seems to be the same in all remote islands and sometimes in remote mainland regions. In order to generate a sufficient amount of electricity to cover both domestic and industrial needs, these regions rely heavily on fossil fuels, that normally are imported either from the mainland or from other nations (Stuart 2006). Consequently the results from this interdependence are easily observed: Fluctuations in oil prices have measurable impacts on small economies, and this seems to be the case in an island perspective. This fact, in connection with the higher price per produced energy unit (due to smaller scale of production) and the importance of these regions to connect to the mainland's grid, makes the energy issue more crucial for managing sustainability issues and development. Environmental quality is also compromised by the combustion of heavy fuels in order to produce energy.

However, upon further investigation, it appears that there are some extra factors that can be a barrier towards an island's sustainability. These factors can include:

- External dependency (or dependency on the mainland): Especially in the cases of islands that are situated far away from mainland or other bigger regions, this dependency can play a significant role in development. Established ways of linking regions (mainland to islands) seems to be a temporary solution, when the circumstances allow[6].

- Unemployment: Inhabitants of islands have to seek out employment opportunities in a very restricted area. Therefore, the inhabitants are exploiting the potentials of the island and in some cases (where no specific framework exists) the overexploitation is unavoidable. Unemployment rates seem to be higher than those in the mainland (Koroneos C. 2003).

[6] It is very common that islands that are dependent on mainland can be "cut off" especially during winter times when shipping transportation is not allowed by the weather conditions.

- Social change and cultural shifts: Certain historical and social backgrounds seems to be a barrier towards the adaptation of new ideas/tools that can help the regional development.

2.2 Towards More Efficient Systems

During the past decades, and after a series of crises, the need to create more efficient systems was born. As mentioned above, several tools were created that tried to convert the non-sustainable attributes of a system into more sustainable characteristics. Industrial ecology (IE) and industrial symbiosis (IS) were only some of these tools.

Industrial Ecology (IE)

"*Industrial ecology, is another concept and field of study without a single agreed upon definition*" (Mirata 2005). The first widely known attempt to parallelize the industrial system with an ecosystem came from Frosch and Gallopoulos back in 1989. At that time, the magnification of production streams in order to cover human needs and services led to an excessive use of raw materials and generation of waste, alarming humanity that non-renewable sources may soon achieve a threshold and reminding mankind at the same time that waste was never integrated fully into the web of industrial relationships. As Ausubel stated in the beginning of 90s, to meet the needs of a 10 billion-person world in the future, a four-fold increase in agriculture, energy use, and industrial production is necessary, if the majority of people are to have better housing, diet, transport and other services than today (Ausubel 1992).

The traditional concern of ecology is interactions of plants and animals. However it is also the branch of science that considers how organisms are embedded in their environment and how they interact with it (Ausubel 1992).

In nature, the ecological ecosystem operates through a web of connections in which organisms live and consume each other and each other's waste (Frosch 1992). Following Boons and Baas' article, (Boons F.A.A 1997), basic features existing in almost any biological ecosystem can be determined. These are:

- Energy requirements are minimized as well as waste generation and the consumption of scarce resources;

- Generated wastes are used as an input (or a resource) for other organisms or parts of the ecosystem;

- The system is diverse and flexible in order to absorb and recover from unexpected shocks.

Frosch and Gallopoulos, having identified the upcoming threat of natural resources overuse and waste generation, presented in The Scientific American the concept of the "Industrial Ecosystem" (Frosch R. 1989). The industrial ecosystem has the following characteristics:

- Optimization of energy and material consumption;

- Minimization of waste;

- Use of waste as input for other industries, parts of the industrial ecosystem.

In 1997, Erkman, in a historical view of Industrial Ecology, added to the existing theory by clarifying the differences between the term of "Industrial Metabolism" and "Industrial Ecology" (Erkman. 1997). This new term doesn't seem to have significant differences since Erkman defines it as *"…the whole of materials and energy flows going through the industrial system*", while industrial ecology "…*goes further. The idea is to understand how industrial systems work, how are they regulated and their interaction with the biosphere", or, "industrial ecology is concerned with assessing and reducing the ecological effects of a group of firms rather than with the ecological effects of individual companies"* (Boons F.A.A 2001).

The basic target achieved by studying industrial metabolism in a descriptive and analytical way is to understand the circulation of materials and energy flows. Erkman recognises the similarity of these two terms and strengthens his argumentation by mentioning that, even though there is not a straight forward definition of industrial ecology, researchers agree that this concept has certain characteristics:

- Industrial ecology tries to identify and comprehend all the components of the industrial economy and how they are related to the biosphere;

- It emphasizes the connection between human activities and nature;

- It takes into consideration technological evolution and its potentials in contributing to a viable (and sustainable) industrial ecosystem.

The industrial ecosystem would function as an analogue of biological ecosystems, following the features stressed by Boons and Baas. Continuing the comparison between nature and industry, Boon and Baas mention that efficiency is developed almost automatically in a natural ecosystem as part of evolution (Boons F.A.A 1997). There is no need for an external driver to "ignite" this further step, while in the industrial ecosystem, a new approach must be adopted by manufacturers, users (consumers) and other parts of the web. Industrial ecology, in an effort to link and promote several connections between the natural world and the technological society generates the idea of an industrial ecosystem (Lifset 1997). Moreover, Frosch and Gallopoulos underlined the difficulty of this ecosystem to be attained, and also stressed the position of manufacturers and consumers in this web by referring to a significant behavioural change in order for an industrial ecosystem to be created, leading to more sustainable use of raw materials, minimization of waste and pollution prevention (Frosch R. 1989). The main objective that IE faces is to achieve sustainable production and consumption patterns, thus leading towards sustainable development. Finally the main operational objectives of IE can be summarised as follows:

- Increased resource efficiency;
- Reduced emissions and waste;
- Closing of material cycles;
- Increased use of renewable materials and energy; and
- Dematerialisation (Starlander 2003).

Industrial Symbiosis (IS)

In general, the term symbiosis is used to describe a natural relationship available in an ecosystem. More precise, symbiotic relations can exist between at least two unrelated species.

These relations can facilitate the exchange of energy, raw materials and even information in a mutual manner. IS is one of the concepts where the principles of IE (mentioned in the previous chapter) are pursued. In general, IS belongs to the plethora of concepts for which there is no specific agreed upon definition (Mirata 2005). Thus, the two most common definitions available in the literature will be presented below. These were chosen because they present the two sides of IS: The theoretical view by Chertow and the understanding of the idea after its implementation by Christensen, the ex-manager of one of the key companies in the case of Kalundborg Denmark. According to Christensen, IS is:

"*A cooperation between different industries by which the presence of each increases the viability of the other(s)." (Mirata 2005).*

In 2000, Marian Chertow, the guru of Industrial Symbiosis (IS), gave the following definition:

> *"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." (Chertow 2000).*

Chertow underlines five types of exchange that can take place in an IS network, defining practically different types of IS. These relations can be based on:

• waste exchanges;

• a facility or firm level;

• different firms collocated in a defined eco-industrial park;

• local firms that are not collocated;

• Firms organised "virtually" across a broader region. [Chertow 2000 as cited in (Starlander 2003)].

Companies that work under an IS network can enjoy benefits that seem to be greater than the benefits that each company would achieve if working individually. These benefits can be divided into two sections: Economic benefits for the participants in the IS network and improvement of the overall performance of the product or service. Other social, environmental and regulatory drivers exist but these have different influences on the participants, depending on the culture and the part of the world in which the system is implemented (Chertow 2007).

Chertow continues and implies that this type of collaboration can advance social relationships among the participants which can also extend to surrounding neighbourhoods (Chertow 2000). Basically, if the IS tool is implemented with positive results for the participants in the scheme, then it is possible that more actors would like to participate in the network, imitating the prime movers, with positive benefits for both the actors and the natural environment.The population adapts and modifies characteristics that can increase the competence in parallel with the environmental characteristics (DiMaggio Paul J. 1983).

Cooperation and networking are the preconditions for IS to work. By networking industries, the extra benefit of flexibility enters the scheme. Companies working under the same framework are less vulnerable to market changes. However it is crucial to be mentioned that the level of flexibility of a network has a strong dependency on the degree of reliability of each member.

Learning issues and transference of know how are another very common characteristics that come under the IS umbrella: Different companies that decide to enter a symbiotic circle exchange different ideas and techniques that may benefit each other. For the latter to happen, a non-homogenous group is required (Boons F.A.A 2001).

The main focus of IS is the exchange of both tangible and intangible resources. Resources like energy and raw materials belong to the original concept of IS, while, on the other hand, information and know-how sharing belong to a sub-concept also known as "soft symbiosis".

The effects of IS as found in literature are:

- Reduction and more sustainable use of raw materials;
- The amount of pollution can be reduced;
- Energy efficiency in an IS network can be increased leading to extra savings from the energy market;
- The minimized amount of raw materials contributes to the reduction of the amount of disposed waste with the added benefit of preventing disposal related problems;
- Generation of new by-products (or new services) with significant market value is common in IS networks (Mirata 2005).

Going through the literature, the role of the coordination in IS networks is always severe (Boons F.A.A 1997; Mirata 2005). The coordination and, of course, the emergence and the sustainability of synergistic relations is influenced by certain factors specified by Mirata (Mirata 2005). These determinant factors are:

- Technical. Is the appropriate technology available between the actors of the IS network? The availability of the appropriate technology can be a major determinant, facilitating the participation of an actor to the IS network. Mirata specifies that synergistic relations can be based on the sharing and exchange of other resources such as logistics or knowledge resources, thus the role of technology is even bigger;
- Informational. The main objective of informational support includes the identification of possible synergies. Moreover, the management bodies will study where the need for minimizing the generated waste or changing the consumption patterns is and generally provide help to discover possibilities for material, informational and other types of exchange that may lead to symbiosis (Mirata 2004). Mirata later on states that the informational processes have to be improved continuously in order not only to help synergies operate but to trigger further symbiotic relations. The existence of the appropriate technology, as mentioned above, plays a significant role in the development of IS networks. Information answering the following questions shall be available within the network:
    - Who has what?
    - Who needs what?
    - Who uses what?

- ➢ Who does what?
- ➢ Who can do what?

However, it is critical to mention that these are only some of the questions that should be answered with the available data. Moreover, the IS members shall be informed about existing and future legislative frameworks, market prices and trends, subsidies and funding opportunities. After the successful creation and initial operation of the IS network, a "*continuous functioning of an appropriate information management system appears as one of the key enablers for an IS network to successfully operate and evolve* "(Mirata 2005).

- Economic. The synergies must be attractive enough to create incentives for the actors to participate in an IS network. This attractiveness, as stated by Mirata, can be quantified both in monetary and non-monetary terms. The economic incentives are dependent on direct costs, transaction costs, and savings and revenues coming from the direct operation of the IS network. Market prices, taxes, fees, subsidies, technological risks and governance mechanisms are only some of the factors that can shape how strong the economic incentives may be. In addition, some non-monetary benefits can arise from the operation of the IS networks. These can be the improved image of the actors (through the enhanced environmental concern), better supply security and so on.
- Political. Policy elements can jeopardise the success of a IS synergy, if not properly designed. As until today, certain political situations are considered to be a great driver for changing the behaviour of an industry, in order to minimize the production cost and have some extra benefits that arise from having a better environmental image. Moreover, legislative and regulatory elements can sometimes be a hurdle, since they make industry operate in a specific way (limiting in this way possibilities for synergies and, of course, innovations). In addition to the latter, sometimes the transaction costs are high, providing an extra barrier to the attractiveness mentioned in the previous paragraph.
- Organizational and Institutional. "*Efforts to plan and organize industrial ecosystems to achieve the benefits…have resulted in many failures"(Chertow 2007)*; The significance of the organization of an IS network can be understood from the previous quote. Schwarz and Steinenger cited by Mirata, state that "*these factors can present the biggest surprises leading to the failure of IS ambitions when all the other factors appear to be in place". (Schwarz Erich J. 1997; Mirata 2005).* Mirata (2005) adds that if the organizational factors are properly designed, then they can form the "Trojan Horse" (backup effective solution) for overcoming difficulties. Inter-organizational collaboration was a prerequisite for the successful implementation of the proposed solutions in the Landskrona example, however, learning exchange was also triggered as a side-effect (Mirata M 2004).

The industrial symbiosis tool seems to be a potential solution to address the unsustainable attributes of a region and, especially, of a Greek island, even though there is no guarantee that it can ignite the evolution process. Moreover it promises less waste generated and dumped into the environment with more raw materials available in it. However, it appears that there are views that IE and especially IS lack power to address the sustainable goals (Ehrenfeld J.R. 2007). IS, trying to mimic ecosystem's exchange, leaves out the term of competition that, in nature, can produce negative impacts on one or both species involved. Other difficulties may exist. Mentality, comprehension of new ideas from the locals, assurance, commitment and mood for pursuing the commercial activities further and in a less sustainable way (since the profit might be bigger in a short term prospective) may be some.

Lesvos Island, due to the nature of the operating industry and the premature solutions of environmental sustainability that exist, can be an excellent case of assessing the creation of several synergies from scratch. In the next chapters, the IS potentials discovered in Lesvos island are presented and their feasibility is assessed.

For the purposes of the current study, attributes like systemic efficiency, use of raw materials, waste generation and management are considered as main sustainability characteristics around which the research is built. At the same time, special respect is shown to the tradition that these regions appear to have and follow.

Finally, industrial symbiosis is one very promising tool but it is not always successful or easy to implement. Thus, there is a need for assessing and recording how a synergy may operate (or not) in a specific context, and, for the purposes of this thesis, the context will be the Greek Lesvos Island.

3 Lesvos Island

3.1 General Information

Lesvos Island is situated on the North East side of the Greek territory (*see image 1*). It is the third largest Greek island and the seventh biggest in the Mediterranean Sea, covering 1 630 km^2. The population of the island is approximately 109 000 people, with almost a third of them living in the capital of the island, Mytilini.

Figure 3.1: Lesvos Island

The remaining population is distributed in small towns and villages. The climate is mild Mediterranean. The mean annual temperature is 18°C, and the mean annual rainfall is 750 mm. Its exceptional sunshine makes it one of the sunniest islands in the Aegean Sea. Snow and very low temperatures are rare. Five geothermal sources exist on the island (Thermi, Gera gulf, Polichnitos, Eftalou, Lisvori) producing hot water (nearly 95°C)[7].

[7] Data retrieved from the Chamber of Commerce. Available at http://www.lesvos-chamber.gr

The local industry is dominated by the following sectors: Production of olive oil and other olive oil by-products, tourism and products like ouzo and dairy products. Since the island lacks any source of indigenous solid fuels (apart from wood), there is a strong dependence on imported fossil fuels to cover the need for energy generation and transportation (Haralambopoulos D.A. 2001; Mihalakakou G. 2001; Koroneos C. 2003).

Finally, Lesvos, as a remote island, has developed an economy that is based on the diversity of the local industry. Both energy and fresh water supplies are generated on the island. Thus there is a strong relation of the local economy with the fluctuation in prices and availability of the fossil fuels.

3.2 Main Industries

The industrial system in Lesvos is based mainly on food/ agricultural products and beverages. As seen, there is industrial diversity on the island however for the sake of this thesis, the biggest industries (in production sizes) were selected. In the following table the basic products and the corresponding amounts produced are presented:

Table 3.1: Amounts of domestic products produced on Lesvos Island

Type of Product	**Total Production**
Olive oil	20 000 tons
Cheese (all types)	40 000 tons
Ouzo	10 000 litres

Source: Commercial Chamber of Lesvos

Agriculture

The sector of agriculture is divided in the following major subsectors in the Lesvian territory: Olive oil production and dairy processing. An extensive presentation of these sectors is available in the following paragraphs:

Olive oil production

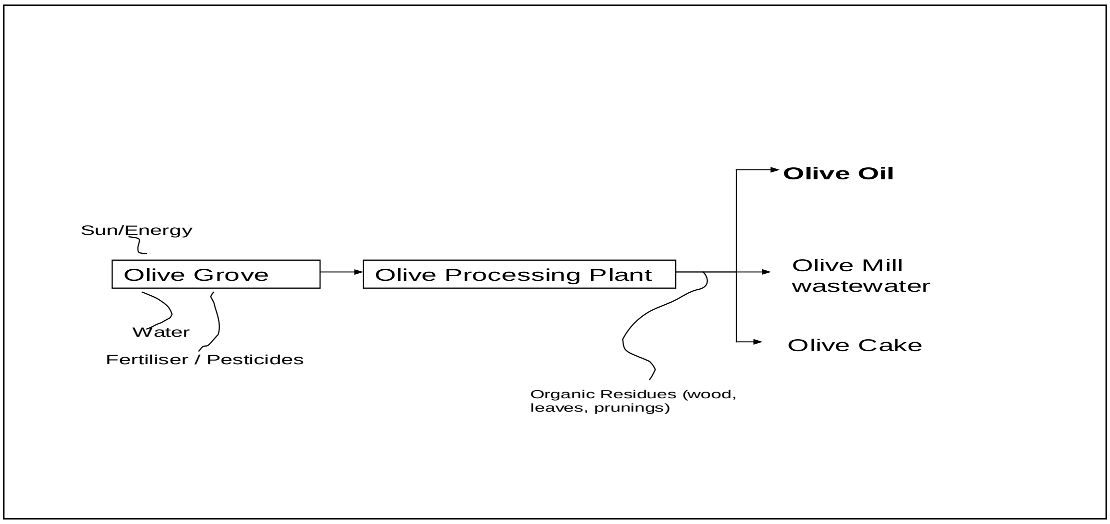
Olive oil is the basic Lesvian product. Twelve million olive trees exist on the island, while the mean annual olive oil production is approximately 20 000 tons. According to statistics, 10-15% of the olive oil produced is being bottled under big manufacturers and exported to other Greek regions, while the rest is either bottled under smaller companies or even shipped unlabelled worldwide (Mirogianni 2006). Finally, only 2% of the bottled olive oil is exported to the international market.

The excellent quality of Lesvian oil is an immediate result of the traditional ways of cultivation. It is worth mentioning that no pesticides residues were ever found in the olive oil samples, because of the very well organized network, run by the local administration that spreads the pesticides at only the corm of the olive trees and not at the leaves and the olive fruits

(Mirogianni 2006). Finally, almost 10 000 tons of slurry waste is generated annually as a result of the olive extraction.[8]

In order to record the unsustainable attributes that may be overcome by the use of IS, there was an extensive need for understanding the material circle of the olive oil extraction process, emphasizing mostly the parts of the chain where inputs and outputs exist. A scheme of the olive oil extraction process is presented below.

Figure 3.2: Inputs and outputs, olive oil extraction



Energy coming mainly from the sun and from nutrients in the soil, together with water and some amounts of pesticides and fertilisers are the main inputs of the process and can be found at the olive grove. From here, the olive fruit is collected and transported to the olive mills, where the olive oil is extracted. A part of the prunings is given to the local farmers and combusted mainly for heating purposes, during the winter period.

The most common procedure that is used at the moment for olive oil extraction in Greece and especially in Lesvos Island is the two phase centrifugal system, that is used by 70% of the olive mills (Halvadakis C.P. 2004). This technique has two material exits. From the first exit, olive oil is collected, while from the second waste is gathered for further treatment. The olive oil is refined, packed, labelled and sold either to the local or to the international market. As seen in the above scheme, the production process generates quantities of wastewater (Olive Mill Waste Water – OMWW), olive cake, stones or pits and some organic material like leaves and wood cuttings that arise from the initial treatment of the olive fruit. It is crucial here to mention that types of waste and by-products may vary dramatically depending on the extraction technique used. So, by using other methods of olive oil extraction that require the initial extraction of the pit from the olive fruit, there is also olive pulp generated[9].

[8] Data retrieved from Lesvos' official Chamber of Commerce. Available at http://www.lesvos-chamber.gr

[9] Introduction to Olive Oil Processing. Available at http://www.oliveoilsource.com/olive_waste.htm

The OMWW is heavily organic and has to be treated before being disposed of in the environment. However, in Greece there is not any specific legal framework concerning OMWW treatment, and the responsibility for that is assigned to the local prefectures. In the Lesvos case, the OMWW has to be initially pre-treated[10] with lime before it is disposed of in the Lesvian natural environment (Halvadakis C.P. 2004).

Almost 46-54% of the incoming olive fruit appears as olive cake at the end of the extraction phase according to the Waste Management Laboratory of the Aegean University. However, there is still a small amount of oil (2-3%) in this cake that needs to be extracted. After the secondary oil extraction, the residue is called "exhausted olive cake" and it can be used to cover heating and energy needs. The extraction is undertaken by smaller industries that are using a series of chemical substances (like hexane).

Cheese production

There is a significant amount of pasture available on the island. This, in combination with the mild local climate, is favourable for of cattle breeding. Milk quality is altered easily by variables like climate, soil and nutrients that the cattle consume.

The main types of cheese produced in Lesvos are the well known Feta cheese (soft cheese), the yellow cheese (also known as "kasseri") and finally the yellow cheese matured in olive oil ("olive oil cheese"). Almost 150 tonnes of milk are processed on a daily basis on Lesvos Island (Thimelis I, Interview). As a result, according to the Lesvian Chamber of Commerce, 40 000 tons of the aforementioned types of cheese are produced annually and are partially exported both nationally and internationally. From this generic data, it is understood that almost 15 000 tons of whey are disposed of in the local environment.

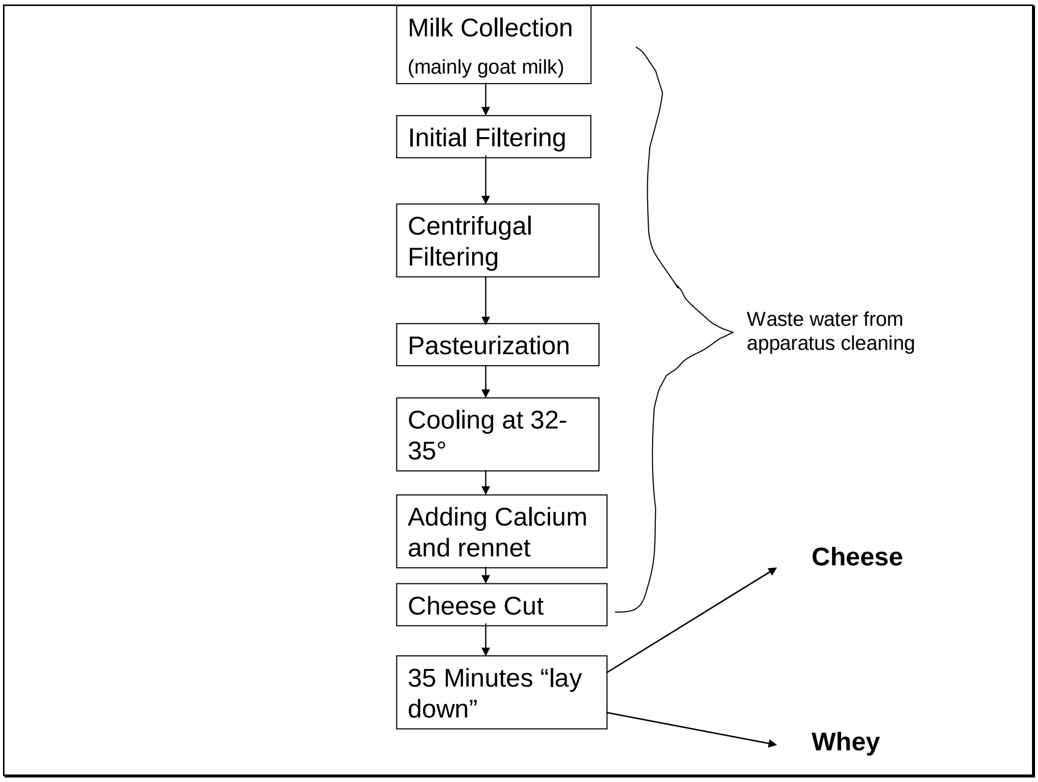
It is difficult to calculate the efficiency of the cheese making industry, since it varies according to the type of cheese that is produced. The efficiency in the feta cheese producing system is around 25% (depending on the producer) however for other types of cheese, efficiency can be even higher. The rest is comprised of by-products and waste - mainly whey (80-90% depending on the process) and some water used for cleaning the apparatus (Andonellis, Interview). The generated whey appears to be rich in protein levels. The protein level varies significantly amongst the different kinds of cheeses[11].

There are not enough data to describe the dairy production processes in Lesvos. The unique type of Lesvian cheeses (feta, olive oil cheese, kasseri) render the milk processing as an original process for which there are few details and facts recorded. After conducting several interviews with some of the big milk producers, the following production flow was created:

[10] The pre-treatment with lime helps coagulation and separation of heavy pollutants from the rest of the sludge.

[11] There is a straight analogy of the amounts of protein available in each type of cheese and the protein levels in the produced whey. However these levels are not directly proportional to each other.

Figure 3.3: Cheese production process



Source: Multiple interviews with cheese producers

Initially, milk is either collected on site or gathered in trans-shipment stations from where it is then transported to the cheese producer. If the amount of the milk exceeds the capacity that the producer can handle daily, then it is cooled and stored. Otherwise it is directly conveyed to the next step of the production process, the milk filtering.

The filtering procedure is basically divided into two parts: Firstly, fabric filters of different porosity are used to remove large particles from the milk. Then, the milk is transferred into a fugitive filtering apparatus which is the last part of the filtering procedure.

In order to remove any undesirable organisms, the next step of the procedure is pasteurizing. Two techniques of milk pasteurizing exist: The open type and the closed type, named after the type of the "baskets" where the operation takes place. When the milk is being pasteurized the temperature reaches 64-67° Celsius. Thus there is a need to cool it down before moving to the next step. The desired temperature is around 32-35°C and for this case small heat exchangers are used.

Calcium and rennet are used in order to allow the necessary microorganisms to grow. After that the cheese mass is being cut and is left for 35 minutes. Finally, the two main products of the procedure (cheese and whey) are extracted. Cheese is cast and then sold to the market. There is not a specific use for the generated whey in Greece, therefore it is being dumped into streams and other natural ecosystems.

Other outputs of the process, apart from the generated whey, are cream and a considerable amount of wastewater used for cleaning the equipment and the initial filters.

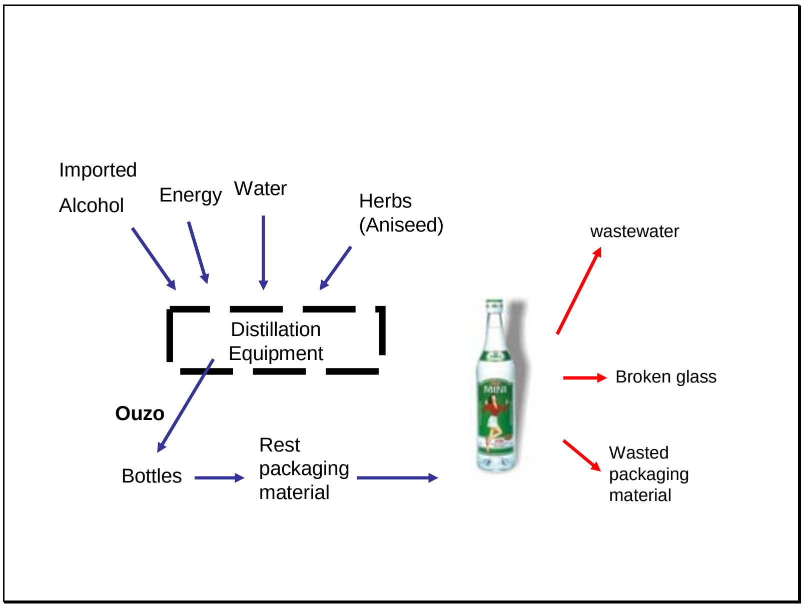
Ouzo production

Ouzo is one of the most popular Greek alcoholic beverages. In terms of consumption it is the second most consumed drink in Greece after wine. Statistics show that 20 million bottles are consumed in the Greek territory, while 10 million are exported mainly to Germany and Scandinavian countries every year (Chtouris Sotiris 2002). Ouzo used to be a very well known product in the Black Sea and parts of Minor Asia since the very past (Mirogianni 2006).

Lesvos currently covers 50% of the total Greek production of ouzo. Only 15-20% of the local production is sold and consumed within the island's territory. The rest is exported to Athens (the capital of Greece), Thessalonica (the second capital) and to the worldwide market.

The ouzo production can be altered, always depending on the recipe of each company. For the present case, details are taken from the company EPOM operating under the multinational Pernod Ricard distilleries. As mentioned above, each recipe is unique. For this reason no numeric data were available concerning the quantities of inputs in the ouzo production process.

Figure 3.4: The ouzo production process



Source: Kouzinoglou A., Interview

In this specific case, alcohol imported from other regions is mixed with aniseed and water (that follows specific hygienic characteristics) and is distilled. The extensive energy needs of this process are covered mainly by combusting fossil fuels (diesel oil) in order to obtain the necessary temperature at the distillation columns and dixies. After the liquor is produced, it is bottled in glass bottles and then placed into carton packages.

Finally, it is either exported to the Greek or to the international market. From the ouzo production process, the main generated waste is an amount of broken glass (mainly from the bottles), some paper and carton from the packaging materials and finally some wastewater generated from the washing processes. All the waste apart from the wastewater is recycled. It is worth mentioning that the specific ouzo company (EPOM) is certified for the ISO

14001/2004 and is under continuous environmental improvement of its products (Kouzinoglou, Interview).

Fisheries and Abattoirs

Finally, another product that Lesvos is producing in large quantities is the "Kalloni Sardine", which is treated in a traditional way, maintaining in that way high levels of sustenance. Kalloni Sardine is basically exported to the other Greek Territories. Worldwide exports are not considerable at the current time. However, quantitative national export data is not available due to the absence of an organized monitoring system for fishermen and similar products. [Sotiropoulos A, Interview, (Mirogianni 2006)].

Moreover, due to the considerable and intense cattle breeding on the island, several abattoirs are operating in Lesvos. Almost each region on the island has an abattoir that is state owned but run by private corporations (Mantzouranis, Interview). The animal is transported to the local slaughter house, where it is initially examined by a veterinarian (who is assigned by the municipality). After the necessary tests, the animals are driven to the main site of the abattoir where the process takes place. Following the EU directive (EC - No 1774/2002), bio-hazardous waste (spine and brain) has to be incinerated in order to avoid transmissible Spongiform Encephalopathies (citation the European biogas workshop). Parts of the animal that cannot be sold for consumption are being land filled in the nearby sites. According to the authorities, almost 200 kg per cow and 8 kg per sheep are characterized as waste and dumped in the landfills that exist around the Lesvian region. A total amount of slaughtering waste is not possible to be calculated since there are no animal records in the slaughtering houses (Kardaras, Interview).

Lesvos can be considered as a self autonomous island/region in terms of agriculture. Apart from the products mentioned above, Lesvos is also producing other dairy products like yoghurt and cream, vegetables in sufficient quantities to sustain the local population and, finally, other products with less market value like bread, jar, Greek pasta and so on (Mirogianni 2006).

Energy Production

The islands of the North Aegean Sea are powered by an autonomous public supply, from individual thermal oil-fired power stations. Lesvos follows the same trend, generating electricity by combusting fossil fuels. In the following table, the amount of energy supplied to the island is provided together with the necessary amounts of imported fuels from the mainland.

The energy plant is situated almost 2 km northwest of Mytilene centre. It is state owned and it generates an average of 23500 MWh on a monthly basis (Katsanis A, Interview). The lower levels of production are observed from January until April. During summer season, there is a high peak of consumption (therefore energy production) which seems to fade out the first months of autumn (with a small peak again in December). This peak is probably based upon the number of tourists that visit the island every year.

Table 3.2: Total energy production in Lesvos and quantities of imported fuels

Year	Total Production (MWH)	Diesel (Tonnes)	Crude Oil (Tonnes)
1993	148 932	1 838	31 576
1994	157 256	1 639	33 607
1995	165 382	6 816	32 959
1996	175 940	6 842	24 799
1997	186 115	13 990	33 629
1998	195 052	13 834	33 809
1999	209 733	14 738	36 703
2000	217 839	17 614	36 338
2001	236 653	7 704	45 835
2002	245 852	5 853	48 946
2003	248 309	8 203	47 700

Source: Public Power Company

Moreover the car fleet appears to grow year by year, provoking an increase in the annual consumption of diesel and gas.

The amount of crude oil being combusted to generate electricity is considerably bigger than the amount of diesel oil (Public Source Company). It is interesting to note that even though some renewable energy sources exist in Lesvos, their contribution to the total energy demand is limited. Precisely, according to the Energy Laboratory of Department of Environment at the Aegean University, RES cover 11% of the energy demands of the island.

3.3 Main Challenges

The main challenges that Lesvos Island appear to face towards environmental sustainability can be summarized as follows:

- Water shortage;
- Energy shortage;
- Solid waste management;
- Wastewater management.

Water shortage: Lesvos is not connected to the mainland's water grid. Water supplies must be generated on site. Therefore, the water supply system cannot cover the actual demand, an issue which is exacerbated during extensive dry periods. Water system breakdowns are quite frequent, generating problems for the locals (irrigation problems) and for tourism.

Energy shortage: Connection to the energy grid of the mainland is not established. Lesvos has to generate energy by traditional means (combustion of fossil fuels) and some renewables. The current capacity of the energy plant, which is situated in Mytilene city and which is responsible for covering the energy needs for the whole island, is not enough. Blackouts are scheduled on a daily basis in order to serve critical areas (like hospitals, schools, etc.). A new energy plant is planned to be built in the next ten years, but the NIMBY[12] effect is a big obstacle towards the positioning of the investment.

Solid waste management: The actual term of waste management includes the control of generation, storage, collection, transfer and transport, and proper disposal of waste and others (Tsobanoglous George. 1993). However in the Lesvos Island case there are no means to control most of the waste management characteristics. No waste minimization policies exist, a large debate was ignited concerning the location of the sanitary landfill that has been planned to operate since 2004, and no recycling collection points exist on the island. The problem is even bigger, when taking into consideration the fact that the space for waste landfilling is already limited because of the island's geographical limitations.

Wastewater management: Practically, the means for managing the generated wastewater either by households or by industries are not enough. Only one big wastewater facility operates in Mytilene city, while numerous other smaller towns in Lesvos do not engage in treatment. The case of Andissa (a city almost 60 km western of Mytilene where all the municipal waste water is disposed of in the nearby pond) is one example of this. Many smaller offshore villages are literally dumping their waste at sea without any further treatment. Finally, the current policy implemented on Lesvos Island is not creating incentives for a more effective and wider waste water management system.

These are the more serious and provoking environmental challenges that Lesvos is currently facing. The implementation of tools such IS and IE, that have as a prime goal the minimization of the use of raw materials and the creation of a more efficient system with less waste generation, will be assessed for the Lesvos Island case. This assessment will then be extended to other Greek islands with similar characteristics.

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[12] NIMBY: Not In My Back Yard

4 Industrial Symbiosis in Lesvos Island

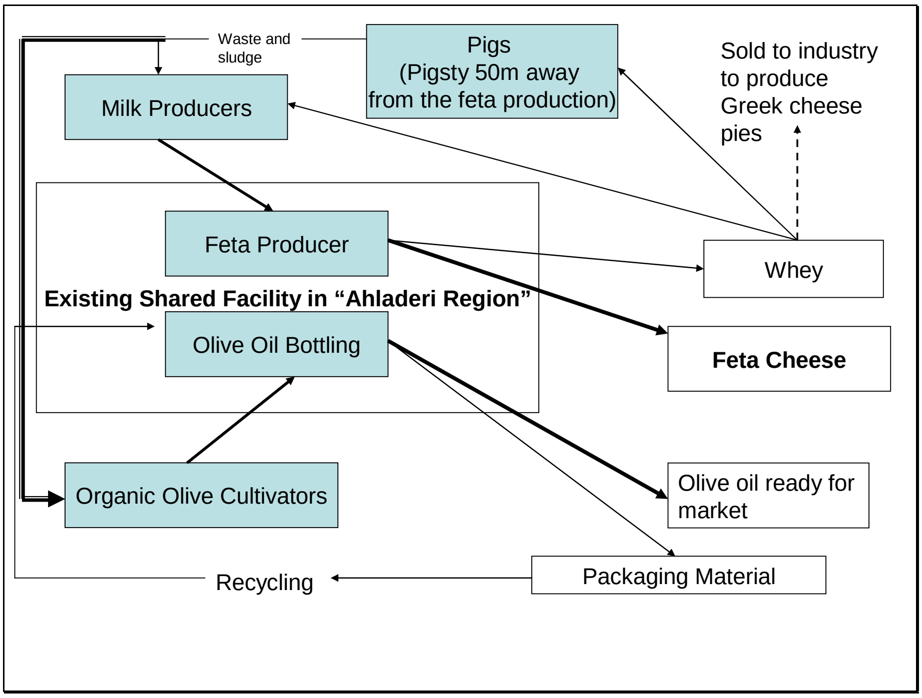
In the following paragraphs, four synergies involving different sectors of the Lesvian commercial activities are presented. Each one of them is selected based on the geographical proximity of the potential participants on the island, on the availability of data, on the willingness of the respective managers to participate in the research and, finally, on the opinion of the locals concerning the initial feasibility of each synergy.

4.1 The Existing Case of IS in Lesvos: The Case of "Terra Aiolica"

Terra Aiolica is a company which is located inside the Simadiri farm. Terra Aiolica, managed by the owner Mr Andonellis, produces feta that is exported both nationally and internationally using biological methods and raw materials. At the same time, organic olive oil is bottled and labelled at the site and then sold on the national market. Terra Aiolica and the Simadiri farm appears to be a basic case[13] of industrial symbiosis, since the majority of the generated waste is, at present time, used as an input for different production procedures.

Below, the current synergies can be observed. Firstly, Terra Aiolica is situated inside the Simadiri farm, sharing some of the facilities.

Figure 4.1: IS in Simadiri farm and Terra Aiolica



Initially, organic milk enters the process in order to cover the daily needs of the company (around 1500 kg daily). Milk is delivered on site by the milk producers or collected from

[13] It is referred to as "basic case" due to the fact that the implementation is not done consciously. It is just a natural step towards a more sustainable future of the company, since there is a big effort to minimize their impact on the environment by continuously improving the operational procedures.

specific "gathering points". Almost 25% of the milk is used to create feta, while the rest (75%) is converted into whey. However the chain does not end at this step. The majority of the whey is transported to the nearby pigsty (almost 100 pigs per season), covering up to 90% of the animals' needs (Koufelos P, Interview). The rest of the whey is given back to the milk producers at no cost.

Organic waste (wood residues, leaves) and animal waste are collected, dried down to a certain level of humidity and a certain concentration of nutrients and then used within the Simadiri farm as fertiliser or given away at no cost to the local farmers.

The olive oil bottling chain is another process that appears to have no waste generated. Olive oil is delivered to the company, labelled and bottled, and finally put to the market. Packaging material that is not appropriate for use is recycled and then re-enters the process.

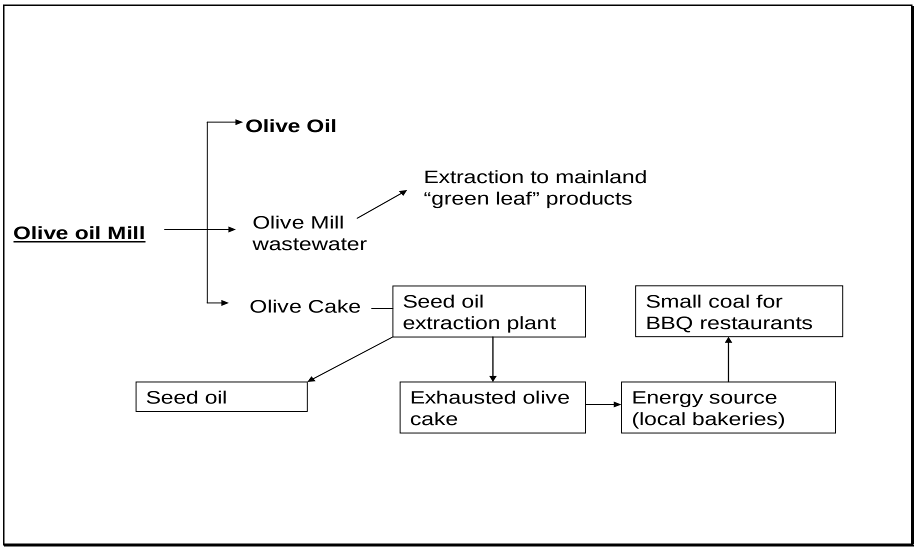
What is highly interesting is the fact that the owner and manager of the company managed to persuade a small network of farmers and milk producers to use only specific raw materials feeding the animals, in order to provide organic milk for the cheese production. "*I helped them by guiding them on what type of fodder should they use, tried to create trust to my face by giving them fertilizer for free and biomass from my territory. Covering also part of the investment for the transition to natural fodder was an extra benefit for my image that helped ensure their feeling of trust to me and to my company" (*Andonellis, Interview).

4.2 The Olive – Energy Symbiosis

As mentioned in the description of the olive oil extraction process, one of the by-products is the olive cake (which still has an amount of oil to be extracted). After the secondary extraction of the olive oil at the seed oil plants, the residue (from the now "exhausted olive cake") seems to be an excellent energy carrier. Historically, exhausted olive cake was used for space heating, especially in regions that had excessive olive oil production. Thereby, following solutions of the past and since the needs for space heating are already covered by other infrastructure (mainly oil powered individual boilers), part of the exhausted olive cake is, at the present time, sold to the local bakery shops that are situated near the seed oil extraction plant.

The combustion of exhausted olive cake leaves ashes and a small residue (that resembles small coal). The synergistic chain can be prolonged by adding small restaurants that can buy the small coal as an input for the needs of their barbeque. Thus, savings for the last two actors can be seen, while, at the same time, the use of olive cake will cover the need for energy from different sources (coal, petrol and so on).

Figure 4.2: Olive oil by-products and potentials



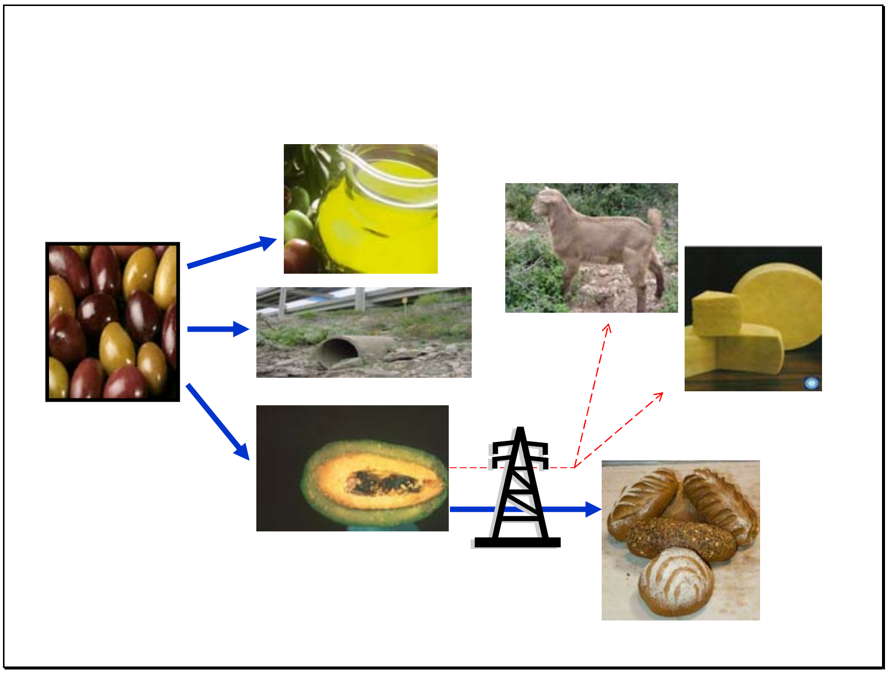
Another case that seems to be more attractive concerning the exhausted olive cake is the synergy with cheese producers. There is a demand for energy during the whole process – mainly during the milk pasteurization and washing parts of the process. At the current time, the cheese industry is either using oil or gas to cover their energy needs (Andonellis, Thimellis Interviews). Exhausted olive cake can replace gas and oil since it is considerably cheaper than the traditional fuels. The disadvantages (big amounts of ashes and the need for big storage facilities) can be outweighed (Andonellis Interviews). Moreover, the level of synergy depends on the proximity of the cheese producers to the seed oil extraction plant.

The OMWW can also be used after the pre-treatment. After interviewing Marios Ballis, responsible for the research of the BIOBUS program in the Aegean university, the potential of using the OMWW to produce cosmetics and other materials that are used on a daily basis by households and can sold in the market, was discussed. This idea exists already and some of the large Lesvian economic actors are trying to estimate the feasibility of the project. Since everything is at a very initial level, nobody was willing to provide more data concerning either the amounts of wastewater generated or the upcoming synergy. Although this synergy is in the very initial stages, it seems promising for the future of OMWW in Lesvos.

If, at the beginning of the olive fruit process, the seed is extracted, then it appears that another by-product can be used as a medium to apply the IS theory: The dry olive oil skin appears to be excellent animal feed especially for goats and sheep (Chalvadakis, Interview). The dry olive skin can either be sold to cattle breeders or, when the olive production is large, sold to the industry for further use.

A schematic of the "olive oil" synergy is presented below. The potentials synergies are marked with dashed lines:

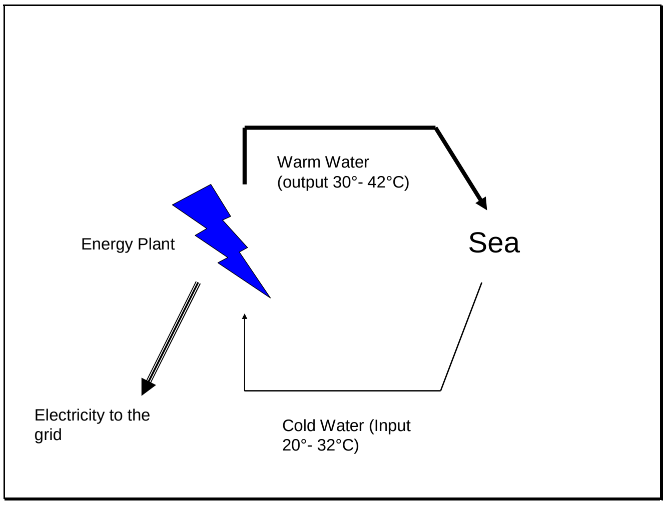
Figure 4.3: Current and potential olive oil uses



4.3 The Ouzo – Energy Plant Symbiosis

As mentioned in Section 3.2, the energy plant is situated near Mytilene city and only some meters from the sea shore. There are extensive needs for cooling agents and, at the moment, the plant uses large amounts of sea water passing through heat exchangers to cool down the engines. The plant requires 4-5.5 m^3 of sea water per hour to cover the consumption needs. The temperature of the incoming seawater varies, starting from 20°C during winter and reaching 32°C during summer. After the water passes through the warm equipment its temperature may be increased by up to 10°C from the input temperature, reaching 27-30°C during winter and 40-45°C during summer months (Katsanis A., Interview). At the end of the process, the warm sea water is discharged via pipes into the gulf (see Figure 4.4). Consequently, the energy plant wastes huge amounts of heat every day by discharging warm water into the sea.

Figure 4.4: Current water input and output of the energy plant



Nearby the energy plant (and in a direct distance of about 30 metres), one of the biggest Lesvian ouzo distilleries is situated producing ouzo and other alcoholic beverages.

EPOM (ISO 14001/2004 certified) distilleries is part of the Pernod Ricard multinational, the second biggest alcoholic beverages association worldwide[14]. EPOM produces almost 1000 tonnes of ouzo, 300 tonnes of liqueur and 800 tonnes of vodka annually, which are shipped and sold both nationally and internationally (Kouzinoglou A., Interview).

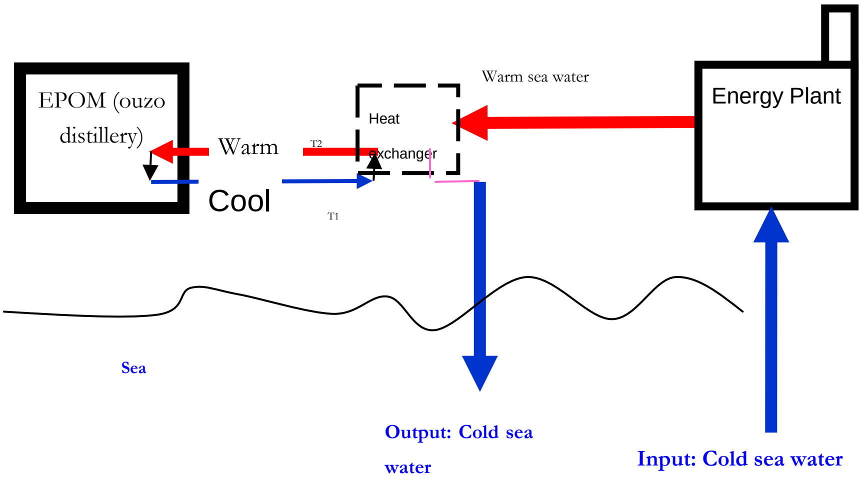
Due to the nature of the products, extensive amounts of energy and warm water are required. Water is used for the main production of ouzo, for cooling the apparatus and finally for cleaning purposes. Water that is used directly for the ouzo production has to be pre-treated (certain level of ions have to be reached), however this doesn't appear to be the case for the other usages of water.

The distillery uses light fuel oil and gas oil to cover the biggest part of their energy needs, while at the same a considerable amount of energy is being bought from the local energy plant. A big percentage of the operational costs are dedicated to purchasing light fuel oil and gas oil and there is a need to minimize these costs to become more cost effective (Kouzinoglou A, Interview).

This energy need gives rise to the potential synergy described here. The nearby energy plant, situated within walking distance from the EPOM industry, wastes heat in the form of warm water that is discharged to the sea every day. That water can be bypassed to the EPOM industry. The responsible for quality assurance and technical manager, supports that it can be used to maintain a certain temperature at the distillation dixies. After the end of each daily shift, the oil boilers are turned off and the distillation dixies are cooled down to a temperature of approximately 15°C. Keeping the dixies at a certain temperature (that varies from 30-45°C) by using the heat from the warmed up sea water can result in immediate savings in petrol, since less energy is needed to bring the dixies up to operational temperatures. The investment costs are limited to the piping and pump installations. For a better understanding of the synergy, the following scheme presents a more concise scenario:

[14] According to presspoint.gr, available at: http://www.presspoint.gr/source.asp?id=2579

Figure 4.5: Schematic representation of the distillery-energy plant synergy



Using basic thermodynamic equations, the amount of energy carried by each m^3 can be calculated. After that, the energy found is converted into oil equivalents in order to estimate how much oil the company will save. Two scenarios are taken under consideration: In the first scenario (which will take place during winter times) the temperature of sea water will be 32°C, while in the second scenario the water temperature will be around 42°C (summer period).

For the calculations, the following assumptions are made:

- Initially, the temperature of the dixies is 15°C when cooled down by the end of the daily shift;
- The sea water exiting the energy plant is 30°C during winter and 42°C during summer, which gives a temperature difference of 15°C and 27°C respectively;
- There are no losses at the heat exchanger situated between the two companies;
- The losses because of the piping installation are approximately 7-10%;
- The warm water flow is estimated at around $5m^3$ per hour (for 8 hours which is the daily shift);
- The energy plant will remain in the same place for the next 10 years (Katsanis, Interview).

The following thermodynamic law gives an estimation of the energy that each unit of a liquid can carry:

$$Q = m \times c \times DT$$

m: the mass of the liquid

c: the liquid coefficient

DT: the temperature difference/temperature of the liquid

Due to the fact that each type of sea water has different salinity, the liquid coefficient is not always the same for all sea waters. Thus, another assumption enters the calculations: The average coefficient for most sea water is around 4.2 kJ per kg and degree temperature[15]. After converting the volume of $5m^3$ to mass by multiplying the volume by the average sea water density, and keeping in mind that in the worse case scenario the temperature difference will be 20°C (during winter times), the total energy carried by the specific amount of sea water is estimated to be around 1.110 kWh (or 4GJ per day). Since one tonne of oil equivalent can provide 10.465kWh per hour when combusted (Haralambopoulos, Interview) and using simple division, the result is that the ouzo distillery can save up to 106 litres of oil on a daily basis.

The next step of the calculations is to multiply the 106 litres of saved oil with the price of oil in the market in order to price the savings. Due to the fact that oil prices are not constant, and after checking the annual data of the ouzo distillery, the average oil price is calculated around 0.75 €/litre. Thus, based on the aforementioned assumptions and calculations, the company will save 79.5 € on a daily basis. Here it is crucial to mention that the savings are totally dependent on the oil price and, of course, on the temperature difference, which means that the savings are going to be considerably larger during summertime.

The investment cost for this project does not appear to be significant. Due to the geographical proximity of the two plants, which is estimated to be around 60 meters, cost for insulating the piping is low (not exceeding some hundreds of Euros), while, at the same time, a pump with a 6-$7m^3$ hourly capacity costs around 200 Euros (Strupeit, Interview). Together with the installation of a small heat exchanger it is estimated that the total investment cost (material and labour) will not exceed the amount of 2 500 euros. Keeping in mind that the distillery operates 5 days per week for 8 hours, the investment will pay off from the 34^{th} operating day, and, from that day, the distillery will generate profits that can reach approximately 25 000 euros annually.

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[15] http://www.kayelaby.npl.co.uk/general_physics

Table 4.1: Investment and payoff figures

Distillery – Energy Plant Symbiosis	Initial Investment Cost (€)	Daily Savings (€)	Annual Savings (€)	Payoff Period (Operating days)
	2 500	79.5	25 000	33

Another symbiotic relation that is under consideration for development is the usage of the warm water for cleaning, cooling purposes and also for steam generation purposes. For these usages there are no quality requirements for the input water (Kouzinoglou A, Interview). Moreover, the company's needs for steam, cooling and cleaning are covered by purchasing water. The current expenditure is estimated to be approximately 4 270 Euro per year. This estimation is done based on the current price per purchased m^3.

Table 4.2: Cost of purchased water for secondary procedures

Purpose of use	Amount (m^3)	Cost per Cubic Meter (€/m^3)	Total Cost per Process (€)
Steam Generation	300	1.22	366
Cleaning	3000	1.22	3660
Cooling	200	1.22	244
Total	*3500*		*4270*

The energy plant, as mentioned above, generates 4-5.5 m^3 per hour of warm sea water that is being discharged into the sea. Assuming that the energy plant works without any shutoff, then as seen in the following table, the total amount of warm water generated annually can vary between 11 680 m^3 and 16 060 m^3.

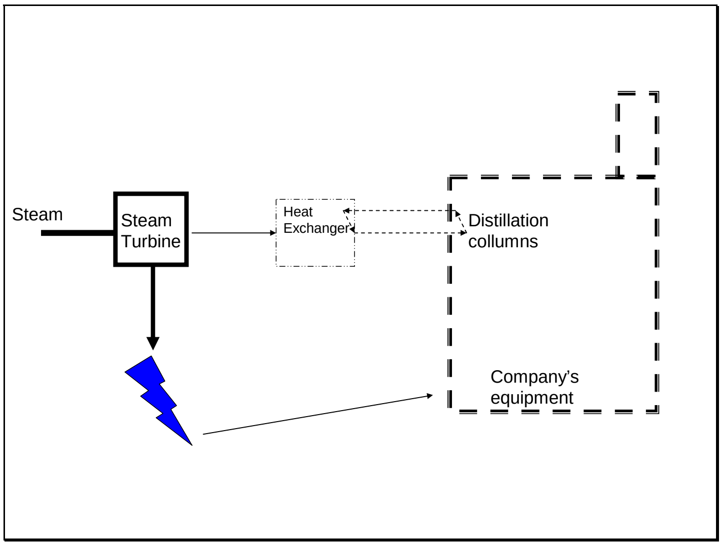
Table 4.3: Warm water input/output at the energy plant

	Hour Basis (m^3)	Daily Basis (m^3)	Monthly Basis (m^3)	Annual Basis (m^3)	Mean Annual Output (m^3)
Minimum Water Input	4	32	960	11 680	13 870
Maximum Water Input	5.5	44	1320	16 060	

Warm water coming from the energy plant will be used to heat up the dixies as mentioned in the previous paragraphs. After the energy extraction, the cold sea water can be used for purposes that do not have any specific quality requirements. Here it should be reiterated that the energy plant works 24 hours a day, so that there is a continuous supply of sea water that can be transported via the existing – from the above synergy – piping installation. Assuming that the ouzo distillery will substitute almost all of the water used for cleaning purposes (at least for those purposes that do not have quality requirements) with the sea water, then the profit is estimated to be approximately 3 660 Euros annually, while the savings for cooling purposes are estimated to be approximately 250 Euros annually.

There is another potential synergy that can be developed between the energy plant and the ouzo distillery. This synergy is presented in Figure 4.6.

Figure 4.6: Synergy based on steam



The steam generated from the contact of the cold sea water and the warm equipment can be used immediately to operate some kind of steam turbines that can be installed in the distillery. Thhe rest of the steam (steam of lower temperature that does not carry enough energy to spin the turbine) may be used (through heat exchangers) for passing by the distillation columns. In this way the ouzo distillery will be able to generate its own electricity (through the steam turbines) and, on the other hand, cover the energy needs for condensation of the alcohol.

It might be the case that the ouzo industry will become totally energy independent, thus saving a considerable amount of money on a regular basis. However, here it must be stressed that the initial investment cost for this type of synergy will be higher than the previous proposed synergy. However the benefits for the ouzo distillation company may still outweigh the costs. Finally, it must be taken into consideration the the energy plant will operate at the specific site only for the future 8-10 years (Katsanis, Interview).

Going deeper into the assessment of this synergy was difficult at the specific time period of the the research, however the idea was put forward and shall be taken into serious consideration by the managers of the distillery.

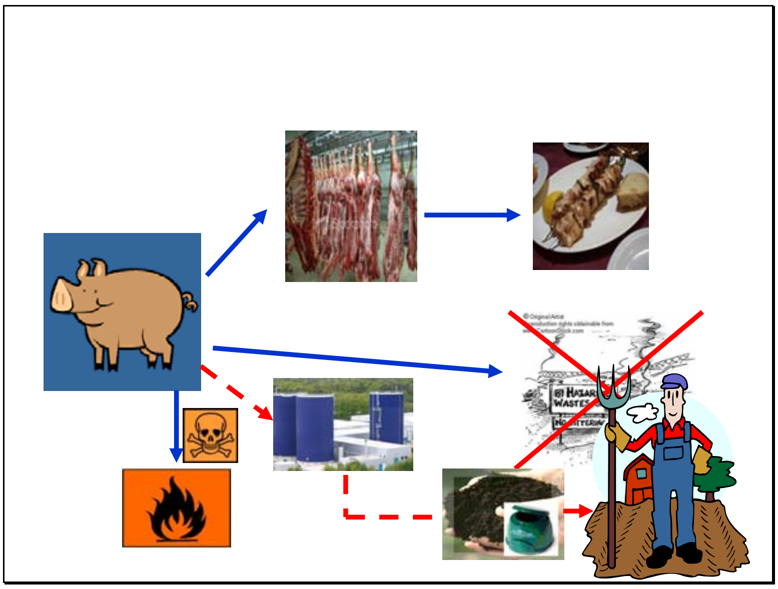
4.4 The "Bio-Slaughter"

Lesvos, as mentioned in chapter 3, seems to have an excessive network of cattle and sheep breeders. From the sheep, the milk is extracted and used to produce dairy products (mainly cheese) and then the animals are slaughtered for their meat to feed both the Lesvian and mainland market. In almost every big municipality there is a state-owned slaughterhouse operating.

When the animal is examined by the local veterinarian it enters the slaughterhouse. The main product of this process is the meat. As declared by the EU legislation, the remaining biohazardous waste is combusted and the rest of the waste is dumped either in organized landfills (where possible) or in local dumps.

However, the organic non-hazardous waste can be treated by simple means to generate biogas. A simple installation of anaerobic digestors where solid and liquid parts of the animal are digested can generate biogas. Several technology suppliers exist in the European market that can provide the slaughterhouses managers with the appropriate apparatus and know-how. The biogas, always depending on the generated amounts, can be used firstly to cover the needs of the abattoir and secondly to serve as an energy carrier for other purposes. The circle of the "bio-slaughters" ends with generated amounts of fertilizer that can be sold (or given away for free) to the local farmers. A schematic representation of the symbiotic chain is available in the following figure.

Figure 4.7: The "Bio-slaughterhouses" symbiotic circle



Source: Own research

To make the synergy more concrete, the case of Eressos was examined. Eressos is situated on the west south side of Lesvos Island and one big slaughter house is operating in that region. In a close geographic proximity to the slaughter house (around 40km) there is a cheese production facility. The cheese producer currently uses natural gas as an energy carrier, mainly to cover heating needs (pasteurization, cooling, and so on). The idea behind this synergy is that the slaughter house can sell biogas to the cheese producer and, at the same time, the second by-product (fertilizer) can be sold to the farmers that exist in the greater Eressos-Antissa region.

There are examples worldwide that take these types of symbioses even further. In the case of Saveh, Tehran, after the biogas is purified[16] the generated CO_2 is used to feed a factory producing dry ice (Taleghani G. 2005). In another Swedish region, Kristianstad, there is an excessive bioenergy system that includes a biogas anaerobic digestor. This digestor is fed by manure, abattoir waste and cooking residues. The generated biogas is used (after being purified) firstly to cover the needs for space heating of the region, and then is used to cover municipal and private transportation needs. Finally, a considerable amount of biogas is sold to one of the biggest energy companies, E.ON, which is responsible for putting it onto the local market[17].

For the researcher to estimate the amounts of produced biogas, the amounts of waste dumped at the landfills must be calculated. Since there are no recorded data from the Eressos slaughterhouse (Kardaras, Interview) data concerning waste amounts from another slaughterhouse in Lesvos will be used, by the benchmarking method. Data available in Table 4.4 is derived from the environmental impact assessment of the Kalloni slaughterhouses, and is from the year 2006.

Table 4.4: Amounts of slaughtered animals and waste in the Kalloni Abattoir

	Animals /Week	**Total weight per animal (kg)**	**HW/Animal (kg)**	**Waste/Animal (kg)**	**Meat (kg)**	**Waste/Week (kg)**	**HW/Week (kg)**
Cattle	10	500	60	200	240	2000	600
Sheep/goats	80	20	0	7	13	560	0
Total						*2560*	*600*

Source: Kalloni Slaughterhouse E.I.A

In order to calculate the amounts of biogas that a slaughterhouse of this capacity can generate there is a need to make some assumptions:

- The amount of animals slaughtered is stable over time;
- The total amount of waste includes both solid and liquid parts of the animals that cannot be sold as by-products;
- The technology being used will not change dramatically over the next several years;

[16] Methane concentration in biogas varies from 60-70%. In order to have efficient combustion in specific industrial uses there might be a need for purification which is basically extraction of the CO_2 and water.

[17] More information for the case of Kristianstad is available: www.kristianstad.se

- The wastes put into the anaerobic digestor are firstly hygienised so that the fertilizer will not include any pathogenic micro-organisms that could negatively affect the crops and the feasibility of the symbiotic project.

Greece has specific characteristics that may determine the amounts of generated biogas. Temperature and climate conditions may be considerable variables affecting the quality and amounts of produced biogas. Since it is difficult to find data concerning biogas production from slaughterhouse waste, the example of rural Ghana is used again for benchmarking.

A small scale pilot project took place in rural Ghana, exploiting the waste from the slaughterhouses, managed to generate almost $10m^3$ of biogas daily (60% methane – 40% carbon dioxide) using similar amount of animal waste as in the Lesvian case. In the example of Ghana, two small anaerobic reactors were built, in order to cover the daily amount of generated waste, of total volume around $80m^3$. The average operating temperature inside the reactors is approximately 38°C with the average pH ranging near 6.9.

Due to the simplicity of the structure, the initial investment cost was held at low levels – around 20 000€ at the time of the construction (2001). The operating costs for the facility are not significant and every six months there is a need to open the digestors' doors and remove scum from the interior. It is worth mentioning that the specific anaerobic facilities work for more than six years without any need for maintenance or any other kind of breakdown that could lead to an increase of the operational or the investment costs. Moreover, "bio-fertilizer" is produced, since the waste is hygenised before entering the digestor and given away to the vegetable farmers for free (E.D. Aklaku 2006).

The similarities between the two cases are obvious. Ejura (rural Ghana) appears to present similar environmental conditions to Lesvos Island: The temperature varies from 26°C in the winter to 39°C during summer in Ejura, where in Lesvos the average winter temperatures can vary between 17°C - 21°C. Summer temperatures can reach even higher levels in Lesvos than the Ghana example, varying from 33°C - 42°C. Furthermore, the amounts of generated waste from the slaughterhouses are very similar to those in the Ghana example. Therefore, the final assumption is that the Eressos slaughter house is capable of generating $10m^3$ of biogas on a daily basis. By benchmarking with a biogas plant implemented in Linkoping, Sweden (with similar amounts of biomass) the generated amount of fertilizer can be almost 100 tonnes per year. This amount can be distributed to the farmers at no cost (IEA 2005).

From the literature, $1m^3$ of biogas (60-65% methane) includes almost 10.8 kWh (Herbert 1991) of energy that can be used for heating purposes (i.e. pasteurization of milk in the cheese production facility) without the need to purify the biogas[18]. This biogas could substitute a large percentage of the natural gas currently used at the Andissa cheese production facility, while substitution of technology is not necessary. Actually, since the energy content of the natural gas is around 162 kWh, a simple division proves that for every $1m^3$ of substituted natural gas the cheese producer will need $1.5m^3$ of generated biogas. The same boilers/combustion chambers may be used for the case of biogas. The amounts of energy that the cheese producer is already using were not available for a further analysis. However, each cubic meter of natural gas costs (currently) approximately 50€ for the producer. It is obvious that with a reasonable price both parts of the symbiosis may realize a significant profit: The

[18] In order to upgrade the concentration of methane in the biogas, sometimes it is necessary to extract humidity, CO_2. This is the process of purification.

slaughterhouse by selling a new product (the biogas) and the cheese producer or any similar type of industry from the substitution of the expensive – due to the local market monopoly – natural gas.

Finally, the initial investment cost may be slightly higher for the Eressos' slaughterhouse (compared with the Ghana case), since labour costs will be higher in absolute numbers, while, on the other hand, the technology will be almost the same since there are more or less the same conditions in both cases. Since the equipment was installed six years ago in the Ghana case (2001), a small price change in relation to the technology must be also expected, potentially increasing initial investment costs.

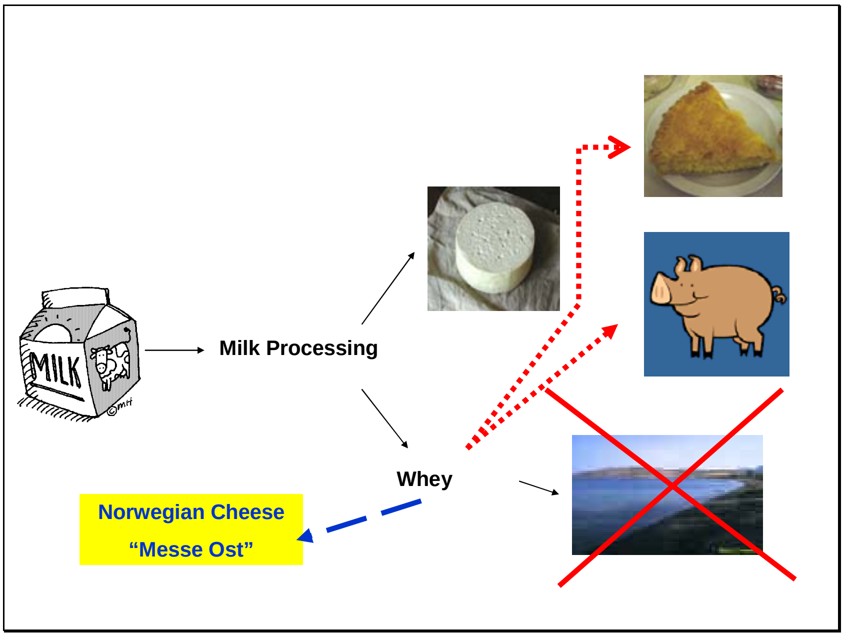
Table 4.5: Generic results of the bio-abattoirs

	Waste not disposed of into the environment (kg)	**Generated Biogas (m^3)**	**Fertilizer (kg)**
Daily	365.7	10	100
Monthly	10 971	300	3000
Annually	132 000	3650	36 500

4.5 The Cheese Symbiosis

As mentioned in chapter 3, milk processing is another big industry operating in Lesvos. At the present time, generated whey from the process is mainly dumped either directly to the sea or to streams that are situated near the production facility. As an immediate result, areas situated either in the mountains or generally away from sea shore suffer from the effects of the whey disposal. These effects can be bad odour, aesthetic debasement and concentration of insects and rodents (Thimelis, Interview).

Figure 4.8: The milk processing potentials



The total amounts of whey that are generated in Lesvos on an annual basis vary, and are generally around 15 000 tonnes. After conducting several interviews with cheese producers, the following potentials were identified concerning the milk processing chain:

- Initially, the whey can be used without any further treatment to feed pigs. In this way there are no prerequisites apart from geographic proximity between the cheese producer and the pigfarm that will make this sort of symbiosis viable. Some pigfarmers are already covering the majority of the pigs’ needs with whey that they are getting for free from the cheese producers all over the island.

- Another idea that was introduced during the conducted workshop was that the generated whey can be sold to forage companies that will extract useful micronutrients. This extraction is basically based on membrane techniques (M. Minhalma 2007). After this step, the micronutrients will be blended with other useful elements for the growth of animals like sheep and goats and sold to the market. The final product (animal feed) can be promoted in this way as more “ecological” since otherwise chemical methods have to be used to create the necessary nutrients for the animals’ diet (Koufelos, Interview).

- Another option that was introduced at the workshop was the use of whey to produce giza. If whey is heated up to 87°C - 91°C, giza is generated. Giza is the material used as filling for a traditional Greek meal else called “cheese-pie”. This meal is one of the most famous around all the Greek territory, and giza as a product from “wasted whey” can be a very good solution for closing the material circle of the milk processing.

- As mentioned in chapter 2, it is very common in the IS networks that new products are created and sold as products with high value. This seems to be the case with the Norwegian cheese also known as "Messe Ost". In this case, the generated whey is mixed with cream. Cream is another by-product of the cheese production. Therefore by creating the "Messe-Ost" cheese both main by-products from the cheese production are utilized, increasing the efficiency of the whole process and also inserting a new taste into the Greek actuality.

- Whey can also be used as a material input to the previously mentioned synergy, where it can be entered into an anaerobic digestor. However, this is not considered as a primary solution, since with the synergies proposed in this section, whey can be used to produce products with significantly higher market value.

5 Analysis of IS Options in Lesvos

In this section further evaluation of the synergies mentioned in the previous chapter will be held. Each synergy will be assessed according to the following:

- The results (short and long term, if possible) of the application of the synergy for the three sectors of environment, economy and society. However, it is quite clear that the three sectors are strongly connected to each other and sometimes differentiating the outcomes can be difficult.

- The drawbacks that may arise during the implementation phase of the synergy, and how these possible drawbacks may be overcome.

- The future of synergy. What is the estimated duration period of the synergy and how can it evolve over time?

- Finally, how unique is each specific synergy? Can it be replicated in any case, or are there any specific conditions that may bind the synergy only to a remote island case?

5.1 The Olive – Energy Symbiosis

This synergy will use the olive pit as an energy carrier that can be exploited in multiple sectors. However, for this research, the olive pit can be used to cover the energy needs for cheese producers, replacing other means of energy carriers like petrol and natural gas. The olive pit in this case can be considered as a sort of biomass since its origins are natural. Historically, biomass has been the main input for energy generation from the beginning of human civilization and in some cases it was connected with poverty and underdeveloped regions. Nowadays, it is realized that there is a strong connection between biomass and sustainable development (Domac K. 2005; Silveira. 2005). Moreover, olive fruit skin can be used to feed sheep and goats and OMWW can be sold to a new type of industry that is not available in Lesvos, creating cosmetics and other derivatives.

The results of the implementation of the "Olive – Energy Symbiosis" are multiple and can be classified with respect to their effect on the environment, society and economy.

Economy: The profits for the cheese producers appear to be considerable, especially for those that are currently using natural gas as fuel, due to the monopoly that exists in the Lesvos case. This monopoly is the cause of the threefold price of natural gas in Lesvos, compared with the rest of Greece (Thimelis I., Interview). Even in the case that the cheese producers use oil to cover their energy needs, the olive pit seems to be interesting due to the considerably lower price per kilogram.

However, substitution and use of olive pits will require the construction of silos big enough to be able to house the supplies for a certain period. Therefore, there might be a need for extra space near the cheese factory facilities and this might increase the initial investment cost of the synergy.

On the other hand, profits are also expected for the olive cultivators and producers. If the olive pits are sold at the right price (hwere the price will create an "interesting" market) then more money will be available in the olive oil sector allowing the producers to shift to more economic (but with bigger initial investment costs) solutions of extracting the olive oil. At the present time quantification of the benefits for the olive producers cannot be undertaken with any degree of certainty. Provisions for the price of the olive pit are not certain since, at the moment, there is not a market with similar economic characteristics in Lesvos. Therefore, it will be the levels of supply and demand that will designate the price of marketed olive pit, thus the success of the synergy.

Environment: The benefits for the natural environment are easy to recognize. Firstly, by using both the olive pit and the olive oil waste water, there is a closed loop with almost no waste generated and disposed of. This fact is quite significant considering the amounts of waste generated from the olive oil extraction process (10 000 tons of waste[19]). Moreover in the case of shifting to new olive oil extraction technology, less water is going to be used at the olive oil extraction phase. In this scenario, the energy amounts that are used are considerably lower (Halvadakis C, Interview). Hereby, it is worth mentioning that the secondary (small in size) industry that is extracting the small amount of olive oil available at the pit is using hexane as a solvent. Even though the system is supposed to be closed – which means that no hexane is escaping at the environment or the product – there are data (like the annual purchase of hexane) proving that leaks of hexane into the products exist. Thus, bypassing it will mean fewer emissions to the air, no hexane in the olive oil and a safer environment. Fewer fossil fuels will be combusted and fewer emissions are going to be released to the atmosphere.

However, no matter how beneficial the transition from oil/gas to olive pit may be, some dangers for the environment still exist. Firstly, the olive pit combustion allows lots of "grey ash" to be emitted to the atmosphere and discharged to the local ecosystem (Kouzinoglou, Workshop) and secondly it leaves lots of ashes in the combustion chamber that need to be taken care of. Proper organization and framework can provide a solution to these constraints. Installation of filters to keep the "grey ash" in the combustion system and holistic treatment of the ash and use as a fertilizer is a common solution with small cost. Another proper solution used worldwide is the application of the "grey ash" to the olive groves as a fertilizer. Ashes, as time passes, release potassium and other useful elements for the growth of the olive grove.

Moreover, if the olive mill waste water is finally used as proposed in order to produce cosmetics and others products, then less organic waste will be disposed of, giving a brilliant solution to the main problem that affects regions whose economy is based on the olive oil extraction. However, strict management needs to organize the operation of such industries in Lesvos, so that they follow common environmental patterns, ensuring that future environmental degradation will not result from this type of industry.

Society: The results for the society are numerically less but equally considerable. Firstly, it is quite common in other IS cases that some employment positions are created. The problem that appears to be quite common in the islands case is the unemployment of the local inhabitants (Chertow 2004). In the particular symbiosis discussed, some employment positions can be seen in the development of the olive mill waste water plant. Moreover, if part of the used energy is substituted by the olive pit, then the need for technology provision and support will be magnified, thus generating more job opportunities. Therefore, the generation of a small quantity of employment positions is beneficial for the social sustainability in Lesvos. In addition, society, through the proposed synergy may enjoy more fine and natural products based on the olive oil extraction natural residues. However, it can be the case that locals will

[19] Source: Lesvian Chamber of Commerce, available at http://www.lesvos-chamber.gr

need a transition period, through which they will try to adapt the new products (i.e cosmetics based on OMWW) to their needs. If the new products do not enter the market together with extra incentives for the customers to test them then the symbiotic circle may be broken, creating negative spin off effects for the future of the whole synergy "Olive oil – Energy".

The implementation of the synergy in the Lesvian community may face several problems. Firstly, as mentioned also in the workshop, legislation and bureaucracy are big constraints that a hypothetical project will face. It appears that there is a great difficulty in organizing the olive oil producers in order to promote decision-making for their own products. Previous attempts, organized by the University of the Aegean/ Laboratory of Waste Management, did not seem to have a positive result, even if the proposed solutions were promising long term profits (Halvadakis C., Interview). The local olive oil producers and extractors seem not to trust ideas that are generated off of the island. This, in connection with the low level of trust to the local University, is complicating the implementation of the synergy.

Moreover, it is understandable that in case of substituting part of the demanded energy with the olive pit, a strong correlation between the olive fruit annual production and the supplied energy is created. It has to be ensured that the amounts of generated olive pits are either stable or present small fluctuations, in order for the transition to be secure. Bad climatic conditions or even natural disasters (fires, flooding and so on) can play a significant role towards the trust that the users show towards the managers of the symbiosis, jeopardizing the whole project and any other possible future attempts.

Table 5.1: Positives, negatives and neutral points of the olive-energy synergy

	Environment	**Economy**	**Society**
Olive – Energy Synergy	(+)Less waste from OMWW dumped into the environment	(+)Cheaper source for cheese producers	(+)Job potentials
	(+)No hexane to the environment	(+)More income for olive oil producers	(+)New, natural products.
	(+)Full symbiotic cycle (+)Substitution of fossil fuels	(+)Innovative solutions	(o)Transition period for adopting the new products
	(o)Grey ash created	(-)Investment costs for silos and filters	

Estimations for the future/duration of the synergy cannot take place under the current circumstances. Even though the constraints are not insurmountable, they are determinant for the future results. Finally, this particular synergy is not only bounded to the island's case. It seems that the main idea can be replicated in any other region with similar characteristics. The only requirement will be the absence of OMWW treatment and similar olive oil production figures.

5.2 The Ouzo – Energy Plant Symbiosis

The synergy between the ouzo distillery and the state owned energy plant seems attractive enough for both members of the synergy. Continuing the classification seen on the previous section, the benefits and constraints for both parts are discussed below:

Economy: The synergy will use warm sea water from the exit of the energy plant. Until today, the ouzo plant is using oil boilers in order to preheat the dixies where the distillation takes place. By applying the proposed synergy, considerable savings will arise for the ouzo plant, that may briefly reach the level of 26 000€ annually. The savings are only the result of the minimization of oil used by the company. This, together with the small investment cost (and the small payoff period) and the fact that the company is less dependant on oil use, makes the symbiosis more attractive. However, no economic incentives for the energy plant will arise from this symbiosis.

Environment: Practically, the reuse of warm sea water and the energy extraction before re-disposing it into the sea coast, presents multiple benefits. Firstly, due to the absence of any waste heat disposed into the marine environment, more dissolved oxygen will be available in the cold water reaching the coast, without compromising the coastal biodiversity[20]. Moreover, the whole process is more energy efficient, less oil is used from the ouzo distillery (minimizing the amounts of raw materials used), leading to smaller amounts of combustion gases emitted to the atmosphere, promoting in that way sustainability and environmental quality. Another benefit that this synergy will bring is the fact that the ouzo distillery can use the aforementioned savings for improving further the environmental performance of their products, which is part of their policy since the distillery is ISO 14001/2004 certified.

Finally, the environmental image of the energy plant is enhanced since they promote the island's development for local products, assist with the operation of a less energy demanding distillation and, at the same time, avoid disturbing the marine ecosystem by returning cold and not warm water back into the sea.

Society: There is no direct employment creation through this synergy between the energy company and the ouzo producer. In the short run, environmental conditions are going to improve, since the distillery will use almost 100 litres of petrol less everyday (fewer emissions). However, since both plants are situated outside of Mytilene city, one may question any social benefits of the synergy.

The application of a framework to promote the synergy may face the following problems: Firstly, between the energy plant and the ouzo distillery, there is a piece of land that is privately owned. The owner may not agree with the installation of underground pipes crossing his land (Katsanis, Interview). Secondly, there is always a big difficulty trying to combine the activities of private-owned companies with those of state-owned companies. Bureaucracy is the main reason and it is very common for projects to pass the design phase and practically collapse under the power of bureaucracy (Andonellis, Interview).

The investment cost will payoff in 35 operational days. Since the synergy is based on the sea water that is used by the energy plant to cool down the equipment, and also having in mind that the energy plant is going to be relocated in 8-10 years (Katsanis, Interview), it can be understood that the maximum operational period of the synergy cannot exceed the aforementioned period. However the benefits still appear to be considerable.

[20] Source: http://www.newton.dep.anl.gov/askasci/chem03/chem03334.htm

What makes the synergy special is the fact that the energy plant is situated some meters away from the coast line and almost neighbourly to the ouzo distillery. Hence, the replicability of this synergy can be questioned, since we speak for very specific conditions: Geographical proximity and certain processes of distillation set very specific conditions for this synergy to work. Moreover, it should be kept in mind that ouzo is a traditional Lesvian product and the production recipe is unique.

However, in any case, the heat generated by energy plants can be used for other purposes, through heat exchangers, in cases where quality demands do not allow sea water as an energy medium. District heating and transition to alternative means of energy can be some of the applied ideas. Ideas such as the example of an ethanol plant that captures waste heat from a nearby power plant to use it in order to produce ethanol exists worldwide (Powerplants, 2007 (Gronkvist Stefan 2006; Stefan Gronkvist 2006; Scott W. Golla. 2007)).

Finally, examples are available in the literature concerning heat waste used for desalination of water, a very efficient solution for remote regions that are not linked into any kind of water grid (Shih Henry. 2007). These examples may also be beneficiary for the Greek Islands' cases, since none of them are connected to any sort of mainland water grid and water shortages are a common feature, especially during summer. Costs and benefits of this alternative cannot be quantified in this study. However, it is suggested that in the future, this could be done, promoting local sustainability by pioneer techniques.

In Table 5.2, effects for the environment, society and economy are summarized and presented:

Table 5.2: Evaluation of the ouzo distillery – energy plant symbiosis

	Environment	Economy	Society
Ouzo Distillery – Energy Plant Symbiosis	(+)Less warm water to the marine ecosystem	(+)Less dependence on fossil fuels	None
	(+)Less emissions through oil substitution	(+)Considerable savings from warm water use	
	(+) More efficient use of materials	(+)Small investment costs	
	(+)Continuous environmental improvement (ISO certification).	(o) Maximum operational period: 10 yrs	

5.3 The Bio-abattoirs

This synergy is less concrete than those proposed in the previous sections. There is no specific case for this synergy, however the implementation of this new – in the Greek context – idea, may ignite more synergies based on the exchange of biogas that can be used for multiple purposes. Specifically for this synergy, the slaughter house of Eressos was used as an example, due to the geographical proximity with the Andisa cheese production facility that already is using natural gas to cover its energy needs. The benefits, constraints and limitations are going to be presented into the following paragraphs:

Economy: Both parties of this theoretical synergy will benefit from such a co-operation. On the one hand, the cheese producing factory can use the biogas without changing technology since its main input is natural gas. Keeping in mind that the natural gas is sold at a price almost three times higher than in the rest of Greece due to an energy monopoly that dominates the Lesvian market, the savings for the cheese producer are expected to be considerable. On the other hand, the Eressos abattoir can generate profits by selling the biogas. Here it must be emphasized that for the synergy to be profitable, the price of biogas has to be planned well in advance so that it will be an incentive for both parts of the synergy. Moreover, it will soon be the case that the European Union will start fining the EU countries that do not comply with Directive 91/689/EC, which prohibits organic waste from being dumped in sanitary landfills.

These profits, if managed well, can be used for multiple reasons: The abattoir facilities can be updated with high end technological solutions, promoting energy efficiency, hygiene and environmental protection. Finally, the slaughterhouse can use part of the generated biogas in order to cover its energy needs, saving more money from alternative uses thus making its services much more attractive to the Lesvian market.

Environment: The benefits for the natural environment are numerous. At the time being, the slaughterhouses are dumping the residues of the process that do not have a market value at nearby sites, creating both environmental degradation and aesthetic pollution. Bad odours, rodents and intense pollution of underground waters are only some of the characteristics that exist at these sites (E.D. Aklaku 2006). Moreover, the liquid residues of the process have a very high organic content which is responsible for multiple types of pollution. Thus, by using the residues as an input material for biogas, theoretically the landfill dumping will come to an end. The quality of the local environment will stop deteriorating and one of the targets of environmental sustainability (minimization of waste disposed into nature) will be accomplished. On the other hand there is the risk of transportation of biogas to the cheese production facility that needs to take place following all the up-to-date safety instructions and rules, in order to avoid any possible accident that will have as an immediate result, biogas disposal in the atmosphere.

Society: It appears that the hypothetical synergy between the slaughterhouse and the cheese producer can generate some kind of employment positions both in the short and the long run. Some people will be needed for the installation and operation of the anaerobic digestors while, at the same time, there will be a need for monitoring and recording of details that can affect the quantity of the generated biogas during the operational period. In addition, a contract with a transportation company shall be signed for the frequent transportation of the biogas to the cheese production facility that can increase the employment rate in the area. The step-up of the environmental conditions around the area of the abattoir will also benefit the local society, since the aesthetic disturbance can reach minimal levels, allowing internal and external tourism to flourish[21] (Koufelos P, Interview).

The researcher faced several problems in an effort to collect data from the Eressos abattoir: First of all, the responsibility for the development, maintenance and operation of the slaughterhouse lies with the mayor of the municipality and this seems to be the case in all slaughterhouses operating in Lesvos. Therefore, it is understandable that the mayor cannot devote enough time in an effort to research future potentials. Secondly, there were no data concerning the amount of animals being slaughtered monthly, or even amount of waste disposed of in the environment (Kardaras, Interview). Furthermore, the mayor (also manager of the slaughterhouse), most likely because of an extreme work load especially during the summer period, appeared to not know details of the operational process of the slaughtering facilities or any similar details.

The result is that the Eressos slaughterhouse appears to be in a not so organized period. Without recorded data for the types of animals and the quantities of waste, no significant feasibility study can be made in order to estimate the amounts of generated biogas and to determine, in general, if the synergy with the Antisa cheese producer is feasible. In addition, there was a lack of willingness from the manager to help in gathering any possible data, which can present another obstacle when trying to persuade this actor to join an IS scheme.

In this case, the bureaucratic boundaries mentioned in the previous synergies were more than obvious. It appears that the slaughterhouse does not comply under the Greek and European legislation therefore it has no operational permit (Koufelos, Interview). However, it operates without any problem (perhaps due to a complex political situation) and this can explain the

[21] Eressos is one of the more touristic regions in Lesvos

manager's declination to support the IS research with any data. The clash between legislation and regional mentality is obvious in this case.

No matter how difficult the implementation of such a scheme may seem, the potential benefits for both parties appear highly attractive. The symbiosis can be replicated in other parts of the island. In Lesvos, five big slaughterhouses operate and the biogas that can be generated in the case of anaerobic treatment of waste can be used firstly to cover the regional needs for energy and then, if the amounts are considerable, to cover the needs of other regions of the island. Finally, it is quite clear that the importance of these types of synergies is strengthened for an island that is not connected to electricity grid of the mainland. In Table 5.3, the results of such a synergy are summarized and classified according to their effect on the environment, society and economy.

Table 5.3: Evaluation of the abattoir – cheese producer synergy

	Environment	**Economy**	**Society**
Abattoir – Cheese production	(+)No residues from slaughtering at the landfills	(+)Less dependence on fossil fuels	(+) Short term employment for installation
	(+)Better use of "raw" materials	(+)Biogas can be cheaper than natural gas in Lesvos	(+)Long term employment for operation
	(+) No odours and aesthetic environmental degradation	(+)Use of the same equipment at the cheese industry	(+)Positive impact on tourism
	(+)Fossil fuels substitution	(-)Transportation of biogas can be an extra cost	

5.4 The Cheese Symbiosis

As explained in chapter 3, there are several potentials that are included in the cheese process chain and that can ignite synergistic relations. For the purposes of the analysis, benefits and drawbacks are assessed, assuming that all the synergies are applied:

Economy: Through enhanced co-operation with the cheese producers, the benefits can be enormous. The generated whey can be given for free to the pigfarms. As the whey can cover almost 90% of the daily needs of a pig, the amount of savings are going to be considerable. These savings, under the appropriate management and investment plan, can lead to the development of fully up-to-date facilities that will be able to overcome issues like market competition from the imported slaughtered pigs. Secondly, if the pigs are fed with this kind of natural material, then the sold animal can get extra value in the market, since nowadays organic products are more appreciated by the consumers (Mirogianni 2006). Moreover, any forage company that will operate inside the Lesvian boundaries using the generated whey will not be depending on imports from the mainland and this, as seen, can be a critical issue on an island especially during winter days when transportation by sea is facing serious problems. Finally, the creation of the Messe Ost (Norwegian cheese) can open the doors for a new market. If marketed correctly and with organized planning, perhaps more benefits can be added in the future by resizing the market also to the Greek mainland.

Environment: The benefits for the environment are significant, noting that the cheese producing sector is the second bigger sector in Lesvos. As mentioned in chapter 3, the generated whey is being disposed of for the time being, either in the sea or in ponds and streams. As an immediate result, the environmental degradation around these areas is noticeable and in some cases unendurable, especially by tourists that try to reach different areas in the island. With the proposed synergies, no whey is expected to be disposed of in the sea, pond or other kind of unprepared sites, aiding at the amelioration of the ecosystem situated around the cheese industries. Moreover, since the pig farmers will shift to more natural means of feeding the animals, less chemical substances will find their way to the environment. Summarizing, by implementing these synergies, the amount of raw materials used in the circle will be minimized while at the same time, waste is re-entering the production process with considerable potentials. In any case, if all the amounts of generated whey are going to be used further, then the Lesvian natural environment will enjoy 15 000 tonnes less of whey annually.

Society: At the time being, treatment of generated whey seems to be a critical problem that the Lesvian community is facing. One of the biggest cheese producers (Aigaion Cheese producer) stopped operating during the past month (July 2007) since the amounts of whey that were disposed of in the environment were exceeding the limit set by the Greek authorities. The operating ban for this factory is leading to another major problem: There is not any demand for production inputs. Therefore the milk producers are practically littering huge amounts of fresh milk everyday. The cost for the milk producers is enormous, while the political cost of this fact is not shouldered by any public carrier at the moment. However, the proposed synergies provide a tangible solution. Implementation of the synergies will mean that the generated whey will be re-used and the cheese producers do not have to end their activities on the island. In this case, both the milk producers and the employees of the cheese producers will be benefitted.

The main drawback that these synergies will face is the lack of commitment from the head of the chain: The cheese producers. At the current time that this thesis is being written there is no policy framework concerning the disposal of whey. Hence, since there is a lack of "polluter pays principle" or any other policy tool that will make the producers responsible for either treating or reusing the generated whey so that there is no environmental degradation, there is no incentive to persuade them to participate in any IS scheme. During an effort to evaluate these synergies, the author tried to interview some of the "big players" in the cheese companies without any luck. Actually the biggest of all (Kolios Aigaion cheese producer) refused any sort of contact that could be beneficial for the outcome of this thesis. This is why strong management and perhaps application of policy instruments is viewed as a prerequisite to lead these synergies to success.

The implementation of an action framework that would set the foundations for an IS scheme (as mentioned above) would require devotion from all participants, while the people working for the specific industry appear to believe only in solutions with obvious, short term results. Consequently, absence of vision for the future of their products will be another constraint.

The future of the synergy is again connected with the amounts of the generated "waste". If, in the long run, the amounts of generated whey are not enough to cover the animals' needs or else, then the synergy will collapse.

Finally, in case of a legislative framework that will compel the cheese producers not to dispose of the whey into the environment, the former can also enjoy savings either from the installation of treatment facilities or from governmental fining.

Table 5.4: Evaluation of the cheese synergy

	Environment	**Economy**	**Society**
The "Cheese" synergy	(+)No ecosystem degradation	(+) Savings for pig farmers	(+)No end in milk processing in Lesvos
	(+)Less chemicals to the environment	(+) Profit for milk producers	(+)Job positions will be maintained
	(+)Less use of raw materials and natural resources	(+)Potential benefits for future forage companies	
		(+)New product with promising benefits (Messe Ost)	

6 Discussion

In the present chapter, an analysis of the findings of the research is performed. This analysis may provide some "key" results but in any case these shall come under some critical review before any conclusions are drawn.

6.1 Observations - Findings

After examining some IS schemes that exist and operate worldwide, it is understood that they require strong collaboration and sense of responsibility from the participants. In order for these to be obtained, there is a sense of trust that has to be built in two chains: Firstly between the managers of the IS scheme and the participants and secondly amongst the participants of each synergy.

Here enters the first crucial observation in the Lesvos case:

The locals and especially the representatives of the local industry were highly skceptical towards the implementation of the IS tool and in almost all of the cases they were afraid that the researcher was acting on behalf of a bigger player that wanted to monopolize the Lesvian market. This fact was much more intense in the case of small to medium sized companies. Questions like "what will the manager of this scheme win" or "who ensures to us that the operational manager will act for our benefit" were a common part of the dialogue to explain that all participants in a theoretically implemented IS project would be benefitted in some way.

Absence of trust towards the research was obvious from the very first moments of each contact (interview, telephone call). Some of the interviewees declined to provide any data from their production processes even after the researcher's guarantee that this data would have been used only for academic purposes. A general phobia towards university representatives was observed during the research period and industry representatives opened up only in some cases.

Moreover, as was mentioned above, during the research period, Lesvos was facing a major issue with the milk processing industry that finally led to the end of the biggest milk processing industry (Aegeon) with several costs for the local economy and society. Perhaps this fact can explain the negative position of other cheese producers towards IS. The whey issue was a flammable topic that no cheese producer wanted to speak about, being afraid for the future of his company. Their argumentation for this denegation was sometimes without logical thinking, since the requested data were available and so retrieved by other means, such as taxation records.

Another main observation was made: When information or data were asked for on behalf of the researcher by somebody that was part of the local community in any way, then the interviewees were outstandingly more open and much more approachable. For example, for the case of the "bio-slaughters", no data could have been retrieved by the manager of the abattoir concerning the amount of animals that are being slaughtered each week. These data were requested in order to assess the amount of biogas that could be generated to be used by other industries. However, data were collected by another member of the municipality offices that "did not have any problem" providing this information.

Therefore, this obstacle could have been reduced if a "messenger" was hired for this purpose: To approach the industries' representatives and communicate the IS tool, while presenting a very specific framework of operation. This messenger shall be a Lesvian citizen and since the locals appear to present such a low level of trust, the messenger shall not have a clear political identity or any other characteristic that may jeopardise the locals' trust towards them.

The collaboration and level of trust amongst the participants of an IS scheme was another issue. Being in an island where the population is not frequently mixed with newcomers (that come from other regions or the mainland having new and different experiences/ideas) makes certain disputes much more lasting and intense. During the research two of the biggest players in the milk processing industries were approached and asked to collaborate in order to make a more collective waste managing system. The response from both company representatives was that due to a dispute between the ancestors of the two owner families, there is not a single possibility for collaboration between them even if the profits are tremendous. These kind of "aboriginal" vendettas exist in the Lesvian case and their presence can affect catalytically the success of any synergy. Several university representatives stressed that "it is very difficult to put two Greeks together" (Halvadakis C, Interview) in order to work under the same umbrella framework to achieve a certain collective target.

An effort by the Aegean university was made in order to link the olive oil producers to promote a shift to a new, less energy and water intense technology. For this purpose several workshops and other actions took place but the result was not even near that which was expected. Generally speaking, the collaboration issue was a point that was criticised in almost any contact with commercial representatives. This issue was even raised before the on site research was initiated, when the author was explaining the purposes of the project in other Greek (not only Lesvians) actors and can be the broken link in the IS implementation chain.

The level of trust was not increased even when the researcher mentioned his academic identity. As a consequence, it was realised that university is not seen as a carrier of knowledge and a flare of development but as "a bunch of academics that want to use some money from EU funds in order to promote research for their own benefit and sake". This quote does not represent all the local Lesvians, but it can show how the locals see the university research. However even industries that in the past were part of EU projects, were not willing to help at all with the current research. Varvagiannis distilleries for example, were part of an innovative responsibility scheme organized by the Department of Environment of the Aegean University in the recent past. Surprisingly, the public relations representative indicated that the managers did not wish to be interviewed for the purposes of the IS assessments in Lesvos.

Going further down, another critical issue that may affect the success of an IS scheme was observed: The credibility of the participant members. If the members are not credible and faithful with the targets of the IS scheme, then not only the current project, but also any future effort to use the IS tool in the local community may be jeopardised, as this will automatically be connected with failure in the mind of the locals.

It was a surprise to the researcher that there was a company that showed interest on a potential synergy. That company had a certified environmental management system in operation and since an EMS requires that the environmental performance of the product or service is continuously improving, this could explain why the level of acceptance of the idea of IS was higher with this organization than with the rest of the industrial actors in Lesvos. However, even in that case, the synergy remained part of a theoretical future development, even though the profits seemed to be considerable.

From the above discussion it is understood that the extremely low level of trust towards other people is not the only issue that arose during the research period. It was also observed that it is very difficult to promote a change in the operation of several industries. These have been operating and producing in a certain way over a number of years and since the result is the same (generation of products attractive for the market) they don't find any purpose in shifting to new technologies that could require some kind of investment and, of course, a payoff period. Even if the savings seem to be considerable in the long run, the response is the same.

It has to be stressed that, especially in the case of a remote island, traditions are conserved more intensively than compared to a city on the mainland. It is common for these areas to keep and use certain dialects, be more direct when approached by other Greeks (but not Lesvians), and it seems that this – together with the absence of legislation and other policy principles – can help explain the resistance to change.

Another observation that the researcher made while assessing the IS potentials in Lesvos Island had to do with the currently implemented environmental policy and frameworks. It is a fact that there is a strong gap in this area. No polluter pays principle or any other tool that can create incentives for the producers to minimize the generated waste through a more efficient production process is implemented. Producers do not have to bear the cost for managing their waste and no upper limit for the amount is set by the government or any other kind of authorities.

Apart from that, implementation of the existing legislative framework is another issue: Some cheese producers have a permit to emit a certain amount of whey to the environment, but the actual amount that is generated and disposed of in the natural environment is considerably bigger, creating huge environmental problems. After a series of interviews it was discovered that one municipal slaughterhouse in Eressos region operates without having all the appropriate permits and without any kind of waste management control. In both cases, the state does not take any measures to prevent these kinds of "freeriders". No upper limit for milk processing can be set, because there is no other way of using milk on the island, and then the producers will have to litter huge amounts of produced milk. Thus, the political cost is going to be enormous for a stricter implementation of the environmental legislation or the reform of some sections. Finally, for the case of the slaughterhouses, it is very difficult to lock down any facility operating without the appropriate permits, since the managers of these facilities are parts of the government. For example the managerial position of the slaughterhouse belongs to the mayor, Mr Kardaras. Therefore it is easily understood that in order to have a more environmentally sound operation, there is a need to separate these positions from any connection with administrative positions that may endanger the future of the local environment.

6.2 Answers to the Research Questions

As mentioned in the first chapters, the main scope of this research is to assess how applicable the IS tool is to the Greek islands, through the remarks and observations in the Lesvos Island case. For a more analytical approach, some sub-questions were used.

1. *How could the IS-concept contribute to sustainability in an island setting and especially in the case of the Greek Islands?*

IS and IE concepts are assessing synergies and collaborations, with a primary target of minimizing the use of raw materials and a secondary target on minimizing the amount of generated waste through a more efficient production process. Concepts like re-use and recycling are included in the current production and consumption system (see figure below).

This application of the IS concept can benefit remote regions and islands that follow specific characteristics. Especially in the case of the Greek islands, where no island is connected to any kind of mainland grid (neither electricity nor water), the implementation of such concepts can become extremely beneficial for the local development. Islands have to import large amounts of fossil fuels to cover their needs. More efficient systems will mean less dependence on fossil fuels and, on the other hand, less emissions to the local environment (as a result of the fewer combustion processes). Moreover, reuse of energy (such as the use of waste heat) can benefit the development of new markets (i.e. fish cultivations), especially in shore areas.

Waste management is another issue that jeopardizes environmental sustainability in the cases of Greek islands. Limited space for landfilling, absence of strict legislation, and "gaps" in the implementation of existing legislation make the minimization of waste generation necessary. Waste can be minimized following two basic paths:

- Initially, through more efficient systems, less waste is going to be generated, benefitting both the local environment and economy;
- Secondly, reusing and/or recycling the existing waste either in the same production process or in a different one.

From the above, the implementation of IS and IE appear to have numerous possibilities in an island perspective.

2. What are the specific conditions on a Greek Iisland and specifically in Lesvos that are affecting the IS-concept? Where are the barriers towards the implementation of IS schemes?

Apart from those mentioned by Mirata (Mirata 2005) (that are presented extensively in the second chapter), the research in the Greek context showed that perhaps more factors can determine the success of an IS scheme.

- Culture and background: Culture of the members of the scheme is always connected with the geographic location and it seems to represent a major issue in the Greek context. Lack of trust towards the organizers and the managers of the scheme makes it even more difficult for people that have adopted the practice of "idea-killing" to understand the concept of IS or any other new ideas.
- Relations in the region: It is very common that disputes between people may last long enough to become a barrier towards any potential synergies, no matter how profitable the synergies may seem. This may be particularly prevalent in the case of an island setting, where the "closed" type of society does not allow privacy and "vendettas" are more obvious and intense as "part of a local tradition".
- Implementation of current legislation: Mirata specifies that the existing legislative framework is an issue that may determine the success of a synergy. However, it was clearly proven that in Lesvos Island case, the implementation of the existing legislation is a major issue. Even if the legislative framework exists and seems to cover every possible gap, its implementation remains the issue. Due to the closed type of society (i.e. there are not enough new people with fresh ideas mixed into the society), legislative implementation does not follow same paths for all members of the local society.

- Dependence on the mainland: Greek islands are not connected to any mainland grids, apart from the telecommunication grid. Therefore they are totally dependent on imports of fuels, products and other materials from the mainland. Consequently, a big percentage of the local GNP is expended in this sector. In order to promote local economic sustainability, all this capital has to stay and be used within the Lesvian boundaries. This factor can act in favour of the implementation not only of the IS tool but of other similar and perhaps equally beneficial concepts that will have as a target promotion of the island's sustainability.
- Attractiveness of local products: Due to the nature of industry, the products have to be attractive both nationally and internationally. IS can promote this attribute: Since the amounts of used raw materials are minimized through more efficient production processes, then the products can be less vulnerable to market changes since the level of flexibility is increased. Fewer raw materials will mean either a bigger profit (keeping the prices at the same levels as at the pre – IS implementation era) or a smaller profit but a much more competitive place in the markets (lowering the product prices).

3. *Where are the potentials of minimizing the resource and energy consumption and how can the local actors use them?*

The potentials identified in Lesvos Island are found in the sectors of renewable energy, waste reduction and generation of new products. It is critical to mention that these potentials are not available only in the Lesvian case but in any Greek island with similar characteristics.

Below, the synergies that are based on the above three sectors are mentioned: Three major synergies were assessed and analysed under the current research:

- Olive oil synergy: This involves, on the one hand, reuse of olive mill waste water (OMWW) in order to produce cosmetics and other similar products and, on the other hand, use of exhausted olive cake as an energy source for other type of industries. Suggestively, it can be used to cover the energy needs in the milk processing industry (milk pasteurization, etc.) and finally, if specific methods of olive oil extraction are used, then a possible synergy with the animal breeders may arise. (For more details see chapter 4).
- Cheese producers' synergy: This involves the reuse of generated whey in different ways: Firstly covering the daily nutritional needs for pigs, secondly producing giza, and finally "replicating" the Norwegian idea of mixing whey with cream to create Messe Ost.
- Bio-slaughter synergy: This involves the anaerobic digestion of organic non-marketed slaughtering residues to produce biogas that can be transported to the Andissa cheese producer. The specific producer is currently principally relying on natural gas to pasteurize the milk and for heating purposes.
- Ouzo distillery-Energy plant synergy: This involves a synergy between the privately owned distillery and the state owned energy plant. The latter is wasting enormous amounts of heat, dumping warm sea water into the environment, while in a nearby location the distillery needs energy to preheat the distillation equipment before the process starts. By transferring the warm waste water from the energy plant to the distillery, the economic savings for the distillery will be large and, at the same time, the state owned energy plant can create a more ecological image in society and avoid damaging the local environment.

It seems that there is enough potential in Lesvos Island for IS. The variety in the industrial sector provides with some excellent cases where the IS tool may be used. This argument is enhanced by the lack of any kind of newly implemented technologies in the island and also by the fact that the level of remoteness enforces a high level of independence from the mainland. The current situation shows that measures to create an environmentally sound island exist on a very small scale. There is no sanitary landfill at the moment, a significant amount of illegal dump sites exist, no recycling exists extensively in the island, and, at the same time, the environmental awareness of the locals is disappointingly low. Some may claim that there is growth in actual numbers of exported products (olive oil, cheese, and liquor) but unfortunately this argument does not prove any regional development keeping in mind that growth is not always associated with development.

From the analysis chapter, it is shown that almost all the proposed synergies are going to generate enough monetary profit, providing the investments with small payback periods and other incentives to make the local industry operate under the IS umbrella. Moreover, the results for the local environment are going to be considerable (no organic waste at the landfills, no waste littered to the natural environment, better use of raw materials, more efficient systems, and better consumption systems with reuse and recycling ideas), moving the island one step closer to environmental sustainability.

7 Final Recommendations

A number of potentials were assessed, linking the main industries in Lesvos and in the Greek Islands having similar characteristics (such as level of remoteness, type of industry and dependence on the mainland). Based on the personal observations made by the author while researching the Lesvos Island case, some recommendations to achieve the triple bottom line (environmental, social and economical) are presented below:

Initially, there is a need for a better legislative framework. At the moment, there are no incentives for the producers to minimize the generation of waste. The polluter does not have to bear the cost of waste management in any case. As such, large amounts of waste are disposed of into the natural environment, jeopardizing any effort towards more sustainable systems. Concepts like IS are based on the cost of waste management to persuade industry representatives to participate in IS schemes.

Not only there is a need for a stricter legislation, but also for a more successful implementation of it. Personal contacts and relationship have to be moved towards a more effective application. Equity must dominate and all polluters must have the same responsibilities to achieve a better environment.

As mentioned above, the locals appear to have a low level of trust for non-Lesvian individuals even if these individuals appear to have a genuine interest in the local development. In this case, it might be advisable to hire a person from the local society, that will build a certain plan of how to achieve high trust from the future participants of an IS project. This messenger has to be accepted by the locals and at the same time be trustworthy in the opinion of the organizers of the IS scheme. The point is that the messenger will be the "middle-man" for the implementation and operation of any potential IS synergies, persuading local actors to participate in the beginning and overcoming barriers that may arise during the operational phase of a project.

The level of trust towards the University and its representatives (students and staff) has to be increased. Perhaps each department shall communicate in a more extensive way any programs and research efforts to the society. In this way, locals may understand and comprehend the benefits of the existence of an academic institute in a region, enhancing their level of trust towards this institute. University researchers are not connected in any way with tax offices, police departments or similar organizations. This is why the industry representatives must be willing to present a thorough picture of their business to researchers with exact data and figures. Moreover, since the University is the source of "know-how", when the appropriate level of trust is achieved, then the academia representatives must move towards becoming the coordinating body in the future implementation of an IS scheme. The University has easier access to similar projects worldwide that may be used to benchmark the local performance of the symbiotic network. With careful and well designed steps, even a local industrial symbiosis program, following the British example of NISP[22], may be created in the long run.

[22] NISP (National Industrial Symbiosis Program): A national program where numerous synergies, hardware and software, are being promoted. More information available online at www.nisp.org.uk

It is totally respectable that especially in remote islands people preserve their traditions and language. However, it was observed that the locals from Lesvos follow a specific way of operating and this operating method, in the majority of the aforementioned cases, is not taking into consideration technological evolution and up-to-date pioneer ideas. There is a strong need for the local actors (especially the most powerful) to understand that the current positive result of a process does not guarantee sustainability in any way. Looking back at the results of policies implemented by narrow minded people makes the above argument even more concrete. Perhaps a perspective which takes into account the long term future of the island is vital in order to be able to overcome the possible difficulties that will jeopardize sustainable development.

In the case that an IS scheme is implemented, in order to create assurance amongst the members a special framework must be set. This framework can have the look of a contract or any other legal document that will guarantee as much as possible loyalty of the participants. In the case that one or more of the participants decides not to operate under the IS scheme's common interests, then there shall be some kind of legal punishment (perhaps like a fine that will have been set when the contractor originally agreed to participate). In this way credibility of the participants may be ensured.

Greek islands appear to face the problem of water shortage quite intensively especially during the summer periods. Therefore a possible synergy that can use waste heat (from different processes) to desalinate sea water may take place. However, a more extensive cost benefit analysis is advisable, since variables such as level of remoteness, climatic conditions and population can alter the results dramatically.

One may contemplate how these synergies can be transferred to other Greek islands, since there is such an absence of trust from the locals towards foreigners[23]. Greece is divided in prefectures and each prefecture has its own administration board. Islands with similar characteristics to Lesvos (like Samos, Chios and so on) fortunately belong to the same prefecture. Thus, it could be the case that the personnel responsible for the regional development of each prefecture can communicate the IS tool by showing successful examples from other cases. It might also be beneficial to create some extra incentives that will aid the IS implementation and attract more members.

All the new means of technology shall be used in order to promote environmental awareness. For example, more recycling programs shall be initiated (here enters the University role) and intense campaigns, supported by local mass media (TV, radio, local newspapers) shall be organized. The adaptation of new ideas will become easier if more incentives are created on the island for newcomers to stay, work and transmit their knowledge and experiences in the island's context.

Finally, a full technical - economical analysis should be performed around the proposed synergies. More possibilities of industrial symbiosis may arise, giving more value to the tool and also promoting sustainable development even further.

These are some recommendations that will help promote sustainable development and that were assessed over a three months period that the researcher spent on Lesvos Island. The replicability in other islands with similar characteristics cannot be questioned since data show

[23] Greeks from other regions are mentioned as foreigners here.

similar observations as those made in the Lesvos case. However, personal responsibility and engagement of the locals may "make or break" an IS synergy!

Industrial symbiosis is not a panacea towards sustainable development of the Greek islands. As shown above, it presents deficiencies and attributes that must be taken into serious consideration before implementing it. However, it is a solution that will recognize the unsustainable attributes of the Greek island systems and provide some solutions that will engage local industry and people towards the common good: Self sustained Greek islands, protecting their biggest inheritance – the natural environment.

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Abbreviations

- I.E: Industrial Ecology
- I.S: Industrial Symbiosis
- I.O.S: Islands Of Sustainability
- O.M.W.W.: Olive Mill Waste Water
- E.I.A: Environmental Impact Assessment

List of Informants

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Appendix

On July 31st, 2007 at the facilities of the Department of Environment of the Aegean University, situated in Mytilene, a workshop titled "Industrial Symbiosis Potentials in Lesvos" took place.

All the potentials identified during the research period were presented at a focus group of ten people. Through interaction and a constructive discussion, the potentials were analyzed and more ideas enhanced the IS proposals.

Below is a list of the workshop participants:

-**Andonellis Panagiotis**, Owner and Manager of Terra Aiolika

-**Backman Mikael**, Senior Research Fellow, International Institute for Industrial Environmental Economics, Lund University Sweden

-**Prof. Chalvadakis Costas**, Head of Department of Environment and manager of the waste management laboratory.

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