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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 Greek islands is investigated through trying to apply the concept in Lesvos Island within an action research framework. The study revealed potentials for considerable benefits however significant barriers exist towards 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 industrial symbiosis concept, taking Lesvos Island as a case. Lesvos appears to have the considerable similarities with other islands. The research identifies the potentials for establishing synergistic relationships among regional activities and assesses the benefits these 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 it improves the sustainability of such system. As part of Industrial Ecology, IS partially tries to imitate natural ecosystem processes where waste of one species can be 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 wastes. However the success of the IS developments will be depending 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 relations are identified. Although at this stage they are only theoretical, these relations could link the above mentioned industries. Examples of such synergistic relations 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 pigfarms and 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 enjoy and also for the drawbacks and constraints that will be faced during both the organization and implementation phase.

The above mentioned synergies may be applied not only in the Lesvos case but in other Greek islands with similar industrial diversity based mostly in the agriculture sector. However in any case it appears that the difficulties during the organization and implementation phases follow a similar pattern with lack of trust to new ideas. University representatives, as much as foreigners to the Lesvian actuality do not seem to attract the appropriate attention by the representatives of the local industry that are facing the IS tool with skepticism and sometimes even with secrecy. Participants' credibility must also be ensured –as much as 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 the coordinators may face, together with the conservation of local tradition and morals.

In order for the IS to be implemented and be operational as much as 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 IS success to use a coordinator locally embedded. 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 ensuring the credibility of the participants creating an adequate level of trust also 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. University can help necessary data collection that will aid more safe and reliable assessments to be performed.

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 solve magically all the problems of Lesvos and other similar Greek islands. Lots of actions and cost benefit analysis must take place to assess the overall feasibility of the proposed synergies and change the locals' mentality towards these very new activities. However, if implemented correctly it might add a small brick at the wall of sustainable development of the Greek Islands.

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1Scene Setting

1.1Introduction

Greek islands seem to face a series of critical problems that are jeopardizing sustainable development. Competition between European country members brought these problems again in the surface of the Greek actuality, 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 shortage and on the other hand constraints concerning the solid waste and waste water management: None of these islands are connected to any sort of mainland's grid (supplying water or electricity) thus there is a need to generate sufficient amounts of energy and water and also manage both municipal and industrial waste so that the local environment is being sustained.

Lesvos Island on the other hand, as part of the "Greek Islands family" centralizes some of the main characteristics that the biggest Greek islands have. In addition, Lesvos is facing to a certain extent, the up-mentioned challenges that should be hurdled, in an effort to promote the three pillars of local sustainability.

Going through multiple cases and examples, several tools that promise to change unsustainable systems to sustainable ones, exist. Concepts like Cleaner production, end of pipe solutions and so on are excessively used and nowadays, there is enough know how to make them operate into specific contexts. Industrial Symbiosis (IS) is one of the plethora of the existing tools that might convert the unsustainable attributes of a system to more productive and efficient characteristics, adding in this way a small stone in 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 adopting the IS tool to each context and assessing its applicability.

Finally, IE and IS has 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.

1.2Research problem

Lesvos Island is one of the biggest Greek islands and perhaps one of the most remote from the mainland. Thus, local economy is developed by using on one hand the local resources and on the other hand by being based on fossil fuels for energy generation. Some problems are already floating at 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 RES is not considerable (lots of renewable are not used). Furthermore problems concerning the waste management sector have appeared, while at the same time, the local market searches innovative solutions to become more cost effective and less material based.

In order to obtain a more 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 firstly the efficient and effective use of raw materials and island's resources shall be promoted and 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 product costs and gain credits towards product competitiveness without jeopardizing 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, generation of large amounts of waste can jeopardize environmental sustainability, by contaminating the air, the aquifers and by declassing aesthetically the natural environment.

Industrial symbiosis can be one of the tools to be used in the Lesvos case. Initially the marginal benefits seem to be promising. Eventhough the implementation of IS seems to be problematic in some cases in the long run it might me profitable and more prosperous for a region with the Lesvian characteristics to implement it. Both ways it is part of this study to assess how useful will the use of the IS tool for the Lesvian actuality and the local development being: A development that differs from growth in the sense that apart from local economy, environment and society are taken under concern. After that, replicability of the tool is assessed in islands with similar characteristics and variables.

The connection between IS and Lesvos may work vice versa: 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 on a different way) for a more effective use in an island, keeping always in mind that due to the smaller area, problems that would seem easy to be solved in another region, may become severe obstacles towards the implementation of new tools such as IS.

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 specific 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 regional development of Lesvos and perhaps, if this case can be replicated for other remote regions – or islands with similar characteristics.

1.3Objectives and Research Questions

The main objective of this thesis is to set the foundations for further use of the tool of IS 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, 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, while at the same time a baseline for further development into more specific areas will be set, helping in that way 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 as such, it is necessary to use the following sub-questions:

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

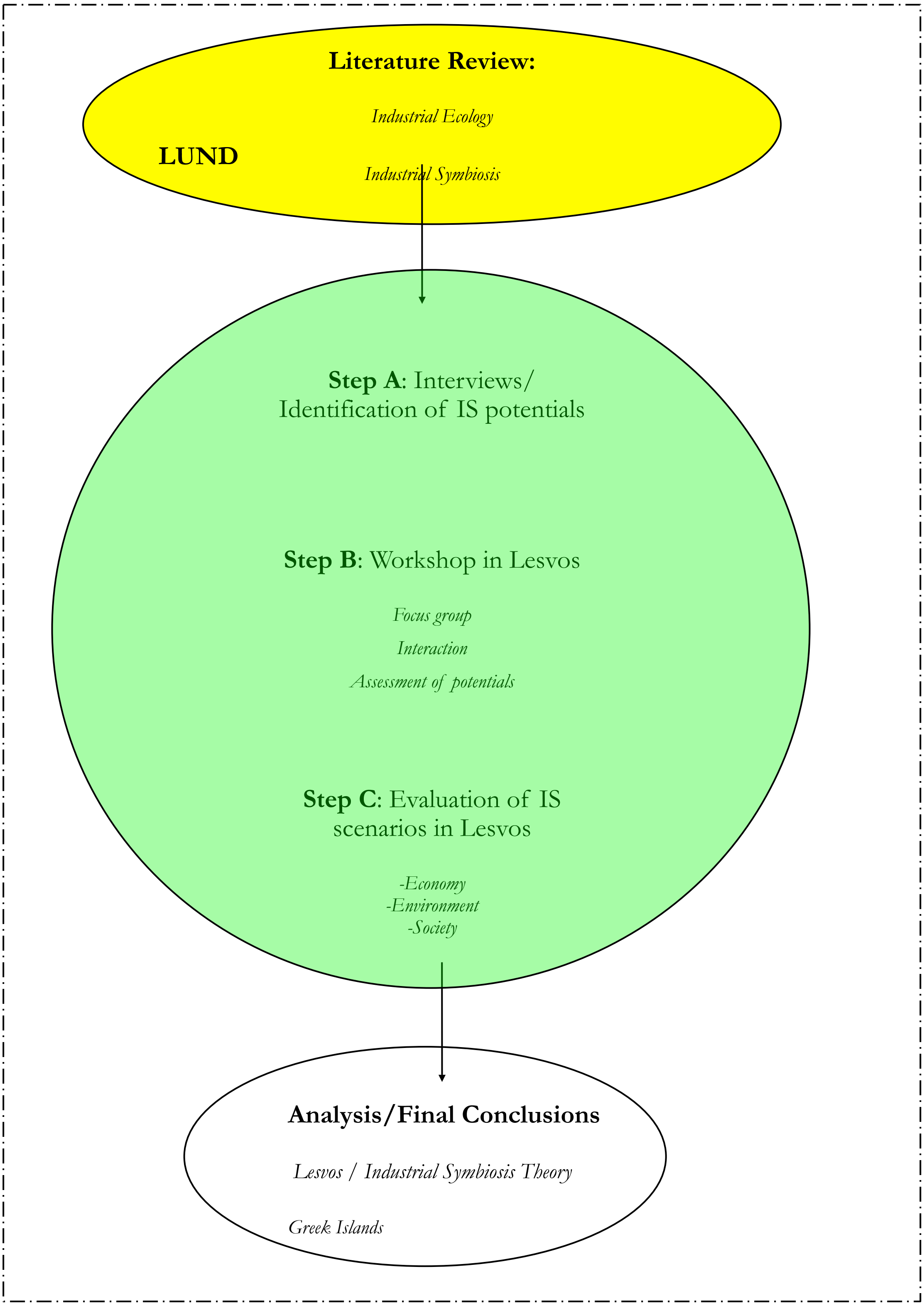
2. *What are the specific conditions on a Greek Iisland and specifically in Lesvos that are affecting the IS-concept? Where are the barriers towards the implementation of IS schemes?*

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

1.4Methodology

The methodology that is followed for the current research is described in the Figure 1.1. As it is obvious, the research is divided in three major sections: The **preparatory** phase, the **onsite** research and the **analysis** of the findings that lead 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



1.4.1 Preparatory Phase

During this phase of the research that was held 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.

1.4.2 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 new pioneer ideas. The conducted workshop was part of this effort where many representatives from the local industry, university and municipalities were invited. Primary data were collected from interviews and observations on site.

Since the researcher tried to ignite the interest towards the IS tool by providing necessary data and information, while at the same time this was beneficial for the better understanding of the IS tool for himself, the research has partially the characteristics of a case study, and those of an action research.

Action Research is one of the concepts that have lots of definitions available 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 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 in several steps**: Step A**, which was the collection of data through interviews with local actors that can play a determinant role in the evolution of the potential synergies in the island. Some of them 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, 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*: 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 the freedom to the environmental authorities to decide and give permission for projects. Therefore it is necessary to obtain a clear and high standardized route of connection so that targets of this research and further opportunities are assessed.

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

Basically, all the big Lesvian industries are identified after conducting several interviews with some "big" players of the economic local scheme. After the comprehension of the production processes of each industry, potential synergies are 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.

Furthermore, the data collected from the initial interviews, is 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 towards 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 are 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, that workshop was an introduction to a future engagement.

During **step C** (last phase of research), the results of the workshop were evaluated. The most attractive cases of synergies that will arise through the workshop were held for further development. After the development of different scenarios of IS, an assessment and analysis took place, based on barriers that may arise, benefits for the actors and the local economy, and finally a suggested framework of igniting each project and transferring the scenario into practice.

Evaluation / Analysis Phase

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

- Firstly, to the overall feasibility: How possible it is for this synergy to evolve. Is it cost effective and if so, what is the outlook for payable 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.

1.5Scope 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 favourable for the 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 not another research for the current issues neither in Lesvos Island, nor in any other Greek territory (at the time that this report is being written), the research will begin from scratch, mapping the local industrial system and then proceeding to the identification of possible synergies and or similar.

It is crucial to mention that also "synergies with software"[3] 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 the environment with significant benefits.

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

In fact, the results extracted, must come under some skepticism. The research period was three months and in any case a safe result is difficult to be drawn, 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 more or less similar characteristics of local economy: Basically islands that do not rely heavily on tourism and they present a sort of industrial variability, based on the agriculture sector.

Finally no lower 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.

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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.

1.6Thesis Structure

The second chapter gives a brief idea of some 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, status of economy and other similar variables. After that, in chapter four, the identified potentials are presented. This presentation is followed by an assessment for each potential synergy (chapter 5). Chapter 6 incudes conclusions and personal observations of the author while in the last chapter (Chapter 7) recommendations for future thinking are available.

2Sustainability Concerns and Tools

It was until recently when humans had to manage with an upcoming problem: The unlimited extraction of sources together with the 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 with 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 carrying capacity. Another misconception that has to be avoided is the difference of 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 towards 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 are the most common:

- 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 of regenerating 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).

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

2.1The 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 be also considered isolated. The level of isolation depends on its remoteness from the mainland. However, even in our days that transportation is quicker and reliable the cost for connecting the 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 from 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 tremendous and it seems that this enhances the dependence of the island towards fossil fuels. Waste management is also limited, considering the well defined space (island's area) and the use of land.

Proceeding, 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 in a rate that endangers future assimilation;

2. Renewable sources should be used with rationality, allowing for the system to regenerate the appropriate amount 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, society systems have to come to terms with those 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 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 up-mentioned categories are also applicable to any kind of region; not only remote islands. However it should be always 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 by any means 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 in a much more obvious 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 ecosphere and regional systems is much more intense, always in comparison with other region that do not present characteristics like remoteness from mainland and so on (Wallner H. 1994).

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

The trade system that is operating in islands is another special characteristic that can be attached to the island's 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 from the mainland(Mihalakakou G. 2001). Resource security is always an issue at 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 the 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 our days that 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 they have. Islands can be considered as closed systems, depending on their level of remoteness from mainland or other islands. This characteristic can become a barrier towards importing heavy fuels, electricity and other goods that the local economy can not 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 land available on the islands (Chertow 2004).

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

2.1.1 Island Sustainability

Before entering the concept of sustainable islands there is a need to clarify what a sustainable community/region is. However, it is easy to understand that the definition of sustainable regions is not altered from the main definitions of sustainability apart from putting the concepts into a more specific geographic scope and to the locality 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 effect to islands are more noticeable than in other mainland regions. Some of the 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 comes to terms with the Brundtland's report 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).

[5] Islands in this case are not parts of land surrounded by water but areas that may 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.

Information and level of communication with other "islands" is affecting 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, taking also in consideration informational, cultural, capital share, while the latter takes under 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. Division of the system 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. In this way strong foundations for the 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, political situation, 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 towards sustainability (that are already 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).

2.1.2 Main Concerns for Island Sustainability

In order to assess the possibilities towards sustainable islands, there is an excessive 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 the 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 the 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 higher in cases (islands or remote mainland regions) where on the 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 concerning the availability of water masses. Moreover, as mentioned above the climate type can also play a determinant role towards water supplies.

- Biodiversity: Many animal 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 proved to be a barrier towards environmental sustainability.

- Waste: Waste seems always to be a problem towards environmental sustainability, and this is worsened by the constraint land that by definition in an island exists. 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 be applied. The energy issue seems to be the same in all remote islands and sometimes in remote mainland regions. In order to generate 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 on oil price have measurable impacts on small economies, and this seems to be the case in an island prospective. This fact in connection with the higher price per produced energy unit (due to smaller scale of production) together with the impotence 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, digging deeper, it appears that there are some extra factors that can be a barrier towards islands' sustainability. These factors can be:

- 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 towards development. Established ways of linking regions (mainland to islands) seems to be a temporary solution, when the circumstances allow[6].

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[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.

- Unemployment: Inhabitants of islands have to seek for 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. Actually, unemployment rates seem to be higher than those in the mainland (Koroneos C. 2003).

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

2.2Towards more efficient systems

During the past decades, and after a series of crises, the need to recreate more efficient systems was born. As mentioned above, several tools were created and evolved 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 them.

2.2.1 Industrial Ecology (I.E)

"*Industrial ecology, is another concept and field of study without a single agreed upon definition*" (Mirata 2005). The first wide 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 reminding 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 world in the future, a four-fold increase in agriculture, energy use, and industrial production is necessary, if the majority of people will need to have a better housing, diet, transport and other services than today (Ausubel 1992).

The traditional concern of ecology is interactions of the 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 available 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 waste are used as an input (or a resource) for other organisms, part 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 at the Scientific American magazine 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, part of the industrial ecosystem.

In 1997, Erkman in a historical view of Industrial Ecology, adds in 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".* Else, *"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 eventhough 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 are they related with the biosphere;
- It emphasizes the connection between human activities and nature;
- It takes under consideration the technological evolution and its potentials 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 the 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 severall connections between natural world and technological society generates the idea of 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 into 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).

2.2.2 Industrial Symbiosis

In general, the term of symbiosis is used to describe a natural relationship available in the 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 that there is no specific agreed definition (Mirata 2005). Thus, further down, the two most common definitions available in the literature will be indicated. 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, ex-manager of one of the key companies in the case of Kalundborg Denmark, IS is:

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

Marian Chertow, the guru of Industrial Symbiosis (IS) earlier in 2000, gives 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 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 that are 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).

Cooperations 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 presents to have a strong dependency on the degree of reliability of each member.

Learning issues and know how transmitting is another very common characteristic that comes 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 not homogenous group is recuired (Boons F.A.A 2001).

The main focus of IS is the exchange of both tangible and intangible resources. Resources like energy, 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 contribute 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 being 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 is the need for minimizing the generated waste, or changing the consumption patterns and generally any 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 can be 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 in order to create incentives for the actors to participate into an IS network. This attractiveness as stated by Mirata, can be quantified both in monetary and non monetary terms. The economic incentives are straightly depending on direct costs, transaction costs, 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 economical incentives may be. In addition some non monetary benefits can arise from the operation of the IS networks. These can be the image of the actors (through the enhanced environmental concern), the 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 the 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 under 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 a 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 pioneer solution towards the unsustainable attributes of a region and especially of a Greek island, eventhough 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 supporting 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 to 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 then 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.

3Lesvos Island

3.1 Generic Information

Lesvos Island is situated on the North East side of the Greek territory (*see image 1)*. It is the third biggest Greek island and the seventh biggest in the Mediterranean Sea, covering 1 630km^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 while 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 at the island (Thermi, Gera gulf, Polichnitos, Eftalou, Lisvori) producing hot water (nearly 95°C)[7].

[7] Data retrieved from 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 finally to products like ouzo, 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.

3.2Main Industries

The industrial system in Lesvos is based mainly on food/ agricultural products and beverages. As seen there is an industrial diversity in 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 are presented:

Table 3.1: Amounts of domestic products in 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 sub sectors in the Lesvian territory: Olive oil production and dairy processing. An extensive presentation is available in the following paragraphs:

Olive oil production

Olive oil is the basic Lesvian product. Twelve million olive trees exist at the island, while the mean annual olive oil production varies around 20.000 tons. According to statistics, 10-15% of the olive oil production is being bottled under big manufacturers and exported to the rest 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 in the international market.

The excellent quality of Lesvian oil is an immediate result of the traditional ways of cultivation. It is worthy mentioning that no pesticides residues were ever found in the olive oil samples, because of the very well organized network, ran by the local administration that spreads the pesticides only at 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]

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

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 at the parts of the chain where inputs and outputs exist. Following down a scheme of the olive oil extraction, is presented:

Figure 3.2: Inputs and Outputs, olive oil extraction

Energy coming mainly from sun and from nutrients at the soil, together with water and amounts of pesticides and fertilisers are the main inputs of the process and can be found at the olive grove. Going on, the olive fruit is collected and transported to the olive mills, where the olive oil is extracted. Part of the prunings is given to the local farmers and combusted mainly for heating purposes, during 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 olive oil is collected, while from the second one waste are gathered for further treatment. Olive oil is refined, packed, labelled and sold either to the local or to the international market. As seen at 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, 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 alter dramatically depending on the used technique of extraction. So, by using other methods of olive oil extraction that require initially the extraction of the pit from the olive fruit, there is also olive pulp generated[9].

The OMWW is heavily organic and has to be treated before disposed at 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 have to be initially pre-treated[10] with lime before disposed at the Lesvian natural environment (Halvadakis C.P. 2004).

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

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

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 taking place by smaller industries that are using a series of chemical substances (like hexane).

Cheese production

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

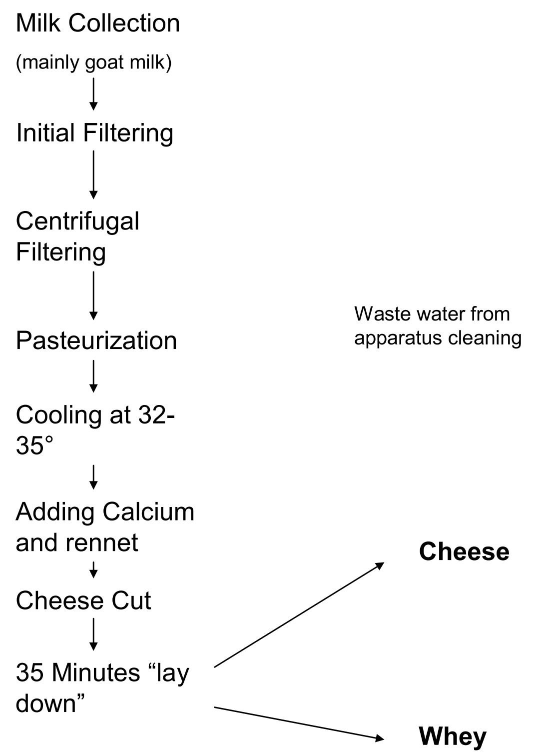
The main types of cheese produced in Lesvos, are the well known Feta cheese (soft cheese), the yellow cheese (also known as "kasseri") and finally the yellow cheese matured in olive oil ("olive oil cheese"). Almost 150 tons of milk are being processed on a daily basis on Lesvos island (Thimelis I, interview). As a result, according to the Lesvian Chamber of commerce, 40 000 tons of the up mentioned 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 in the local environment.

It's 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 bigger. The rest comprises 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 is being significantly compromised by the different kind 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 with not so many details and facts recorded. After conducting several interviews with some of the big milk producers, the following production flow was created:

[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 transshipment stations from where it is then being transported to the cheese producer. If the amount of the milk exceeds the capacity that the producer can handle daily, then it is being cooled and stored. Else it is directly canalized 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 being used in order to allow to 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 being cast and then sold to the market. Considering the amounts of generated whey, there is not a specific use of this product in Greece, therefore it is being dumped in streams and other natural ecosystems.

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

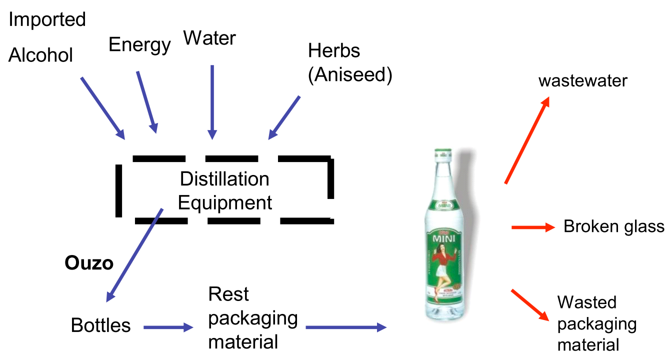
Ouzo Production

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, as until today, covers 50% of the total Greek production. Only 15-20% of the local production is being sold and consumed within the island's territory. The rest is exported in Athens (capital of Greece), Thessalonica (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 and this gives reasons for not having numeric data available, concerning the amounts of inputs that the ouzo production process has.

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 it is distilled. For this purpose extensive needs for energy 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 is being bottled in glass bottles, then 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 big capacities is the production of the "Kalloni Sardine", which is treated in a traditional way, maintaining in that way high levels of sustenance. Kalloni Sardine is basically exported in the other Greek Territories. Worldwide exports are not considerable at the current time. However, numeric data with national exports are 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 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). In details the animal is transported to the local slaughter house, where it is initially examined by the veterinarian (who is assigned by the municipality). After the necessary tests the animals are driven at 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) have 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 200kg per cow and 8kg per sheep are being 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 enough 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 in the island is provided together with the necessary amounts of imported fuels from the mainland.

The energy plant is situated almost 2km northwest from Mytilene central. 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 the autumn (with a small peak again on December). This peak is probably based upon the number of tourists that attend every year the island.

Table 3.2: Total Energy Production in Lesvos and fuels

Year	Total Production (MWH)	Diesel (Tones)	Crude Oil (Tones)
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 rise year by year, provoking a raise at 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 interested to see that eventhough 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 in the Aegean University, the RES cover 11% of the energy demands of the island.

3.3Main Challenges

The main challenges that Lesvos Island seem to face towards environmental sustainability can be summarized as in following:

- 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, a fact that is deteriorated during extensive dry periods. Water system breakdowns are quite often though, generating problems for the locals (irrigation problems) and for tourism.

Energy Shortage: Connection to the energy grid of 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 responsible to cover the needs for the whole island, is not enough. Blackouts are scheduled on a daily basis in order to serve critical areas (like hospital, schools and so on). At the same time, a new energy plant is planned to be built in the next ten years, but still 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, 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 big debate was ignited concerning the location of the sanitary landfill that has been planned to operate since 2004 and no recycle collection points exist on the island. The problem is even bigger, when thinking that the space for waste landfilling is already limited because of the island's 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 lots of other smaller towns in Lesvos do not take any care at their disposals. The case of Andissa (a city almost 60km western of Mytilene) that all the municipal waste water are disposed in the nearby pond is a great example. Lots of smaller offshore villages are literally dumping their waste at the sea without any further concern. 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 facing at the time being. Implementation of tools like IS and IE, that have as a prime target to minimize the use of raw materials and through a more efficient system with smaller waste generation, will be assessed in the Lesvos Island case and then to Greek islands with similar characteristics.

[12] NIMBY: Not In My Back Yard

4Industrial Symbiosis in Lesvos Island

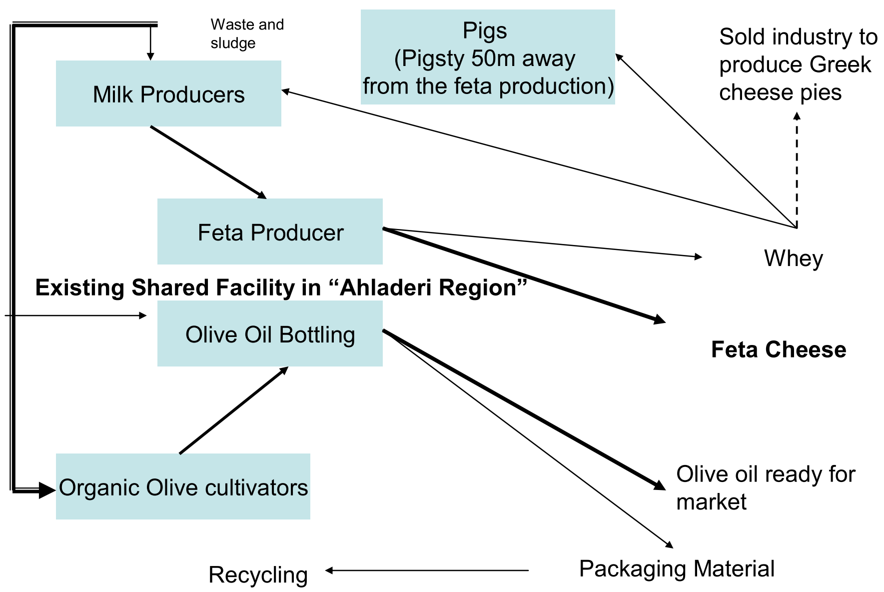
In the following paragraphs, four synergies, involving different sectors of the Lesvian commercial activities are presented. Each one of them is selected based on the geographical proximity in the island, on the availability of data, on willingness of the managers to participate in the research and finally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

4.1The existing case of IS in Lesvos: The case of "Terra Aiolica"

Terra Aiolika is a company which is located inside the Simadiri farm. Terra Aiolica, managed by the owner Mr Andonellis, is producing feta using biological methods and raw materials which are exported both nationally and internationally. At the same time, organic olive oil is being bottled and labelled at the site and then promoted at 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 are at present time inserted into different production procedures.

Further down, 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 is entering the process in order to cover the daily needs of the company (around 1500kg of daily). Milk is delivered on site by the milk producers or collected from specific "gathering points". Almost 25% of the milk is used to create feta, while the rest 75%

[13] It is referred 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 to the environment by continuously improving the operational procedures.

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 the animal needs in a percentage that can reach 90% (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 being collected, dried down to a certain level of humidity and 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 at the company, labelled and bottled and finally put at the market. Packaging material that is not appropriate for use is recycled and then re-enter the process.

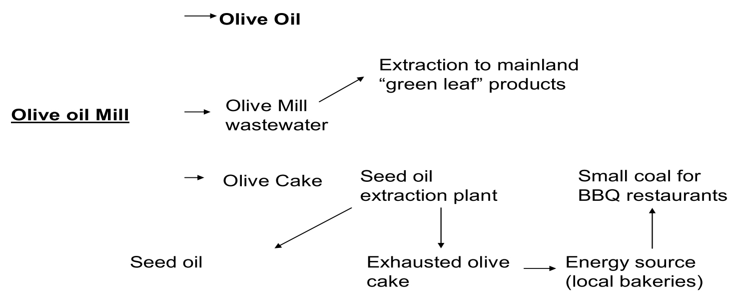
What it seems really interested is the fact that the owner and manager of the company managed to persuade a small network of farmers and milk producers to use only specific raw materials feeding the animals, in order to provide organic milk for the cheese production. "*I helped them by guiding them on 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).

4.2The 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 now called exhausted olive cake) seems to be an excellent energy carrier. In the past days, 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 in nearby area from the seed oil extraction plant.

The combustion of exhausting olive cake leaves ashes and a small residue (resembles a 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 time being, 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 amount of ashes, need for big storage facilities) can be outreached (Andonellis Interviews). Moreover, the level of synergy depends on the proximity of the cheese producers from 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 be sold in the market, was discussed. This idea exists already and some of the big financial Lesvian actors are trying to estimate the feasibility of the project. Since everything is in a very initial level, nobody was willing to give more data either concerning the amounts of wastewater generated or any other information concerning the upcoming synergy. Eventhough this synergy is at very primary 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). Actually the dry olive skin can be either sold to cattle breeders or when the olive production is large, sold to the industry for further use.

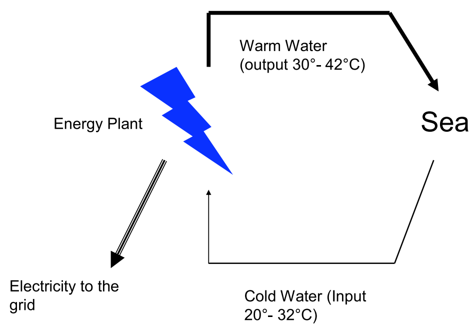
A schematic of the "olive oil" synergy is presented further down. The potentials synergies are marked with dashed lines:

Figure 4.3: The olive oil current and potential use

4.3The Ouzo – Energy plant symbiosis case

As mentioned in section 3.2, the energy plant is situated at a close proximity from Mytilene city and only some meters from the sea shore. There are extensive needs for cooling agents, and at the moment the plant uses big amounts of sea water passing through heat exchangers, cooling down the engines. The plant needs 4-5,5 m^3 of sea water per hour to cover the consumption. Temperature of seawater input varies, starting from 20°C during winter, reaching 32°C during summer. After the water passes through the warm equipment its temperature may be increased up to plus 10°C from the input temperature, reaching 27°C -30°C during winter and even 40-45°C during summer time (Katsanis A. Interview). At the end of the process, the warm sea water is discharged via pipes into the gulf (see Figure 4.4). As easily understood the energy plant wastes huge amounts of heat every day by discharging them into the sea.

Figure 4.4: Current Water Input and Output in 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 1000tn of ouzo annually, 300 tons of liqueur and 800 tons of vodka annually, which are shipped and sold both nationally and internationally (Kouzinoglou A. Interview).

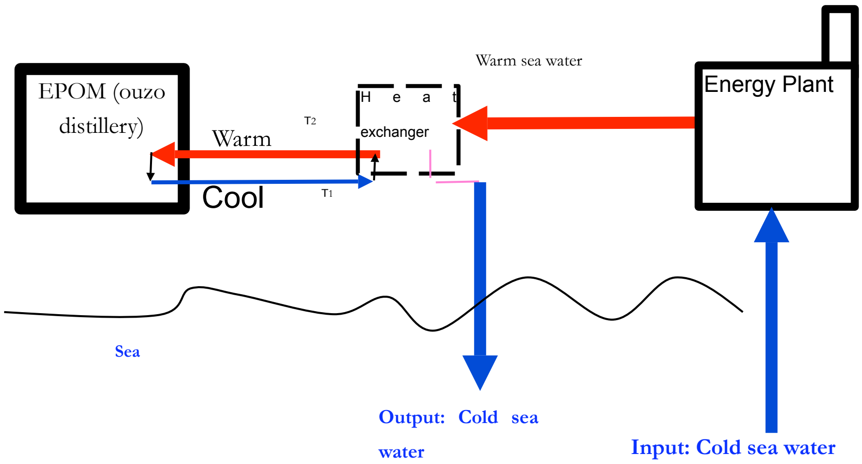
Due to the nature of the products, extensive amounts of energy and warm water are required. Water is used for the main production of ouzo, for cooling the apparatus and finally for cleaning purposes. Water that is used directly for the ouzo production has to be pre-treated (certain level of ions have 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 by the local energy plant. A big percentage of the operational costs are dedicated for purchasing light and gas oil and there is a need to minimize these costs (Kouzinoglou A, Interview) to become more cost effective.

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

Hearby enters the potential synergy. The nearby energy plant, situated in walking distance from EPOM industry, wastes heat through warm waters that are being disposed at 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 at a temperature around 15°C. Keeping the dixies at a temperature (that varies from 30-45°C) by using the heat from the warmed up sea waters can have as an immediate result considerable savings in petrol since less energy is need to bring them in 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:

Figure 4.5: Schematic representation of 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 equivalent in order to estimate how much oil the company will save. Two scenarios are taken under consideration: At the first scenario – which will take place during winter times- temperature of sea water will be 32°C while at the second scenario water temperature will be around 42°C (summer period).

For the calculations, the following assumptions will take place:

- Initially, the temperature of the dixies are 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 around 7-10%;
- The warm water flow is estimated around $5m^3$ per hour (for 8 hours which is the daily shift);

- The energy plant will be in the specific 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:

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 of the sea waters is around 4.2 kJ per kg and degree temperature[15]. After converting the volume of $5m^3$ into mass, by multiplying with the average sea 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 around 1.110 kWh (or else 4GJ per day). Since one ton of oil equivalent can provide 10.465kWh per hour when combusted (Haralambopoulos, Interview) and a 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, following the upmentioned assumptions and calculations the company will gain 79,5 € on a daily basis. Here it is crucial to mention that the savings are totally depending on the oil price and of course on the temperature difference, which means that the savings are going to be considerably bigger during summertime.

The investment cost for this project appears not to be significant. Due to the geographical proximity of the two plants, which is estimated around 60 meters, cost for insulating piping is low not exceeding some hundreds of euros, while at the same time a pump with $6\text{-}7m^3$ hourly capacity costs around 200 euros (Strupheit, 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

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

that day, the distillery will generate profits that can be accounted around 25.000 euros annually.

Table 4.2: Investment and payoff figures

Distillery – Energy Plant Symbiosis	Initial Investment Cost	Daily Savings(in €)	Annual Savings (in €)	Payoff period (operating Days)
	2.500	79,5	25.000	33

Another symbiotic relation that is under consideration for developing 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 at approximately 4 270 euro per year. This estimation is done under the current price per purchased m^3.

Table 4.2: Cost of purchased water for secondary procedures

Purpose of use	**Amounts in Cubic Meters (m^3)**	**Cost per Cubic Meter (euro)**	**Total euro per process (m^3)**
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 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.

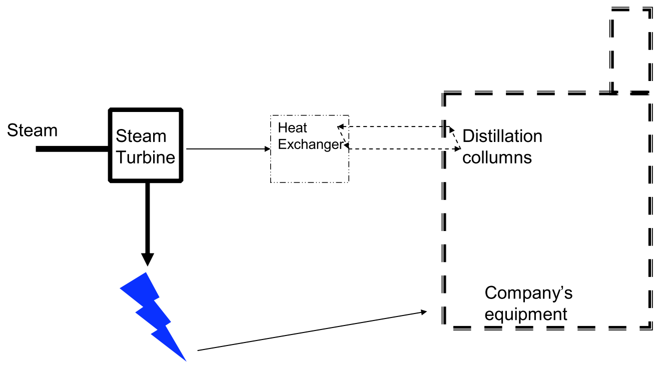
Table 4.3: Warm Water In/Output at the Energy plant

	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	11680	13870
Maximum Water Input	5,5	44	1320	16060	

Warm water coming from the energy plant during storage facilities 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 reminded that the energy plant works 24 hours a day, so there is a continuous usage 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 that do not have quality requirements) with the sea water, then the profit is estimated around 3.660 euro annually, while the savings for cooling purposes is estimated around 250 euro annually.

There is another potential synergy that can be developed between the energy plant and the ouzo distillery and 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, while the rest (steam of lower temperature that does not carry enough energy to spin the turbine may be used (through heat exchangers) for passing from 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 be bigger. Finally it shall always be taken under consideration the fact that the energy plant will operate at the specific site only for the future 8-10 years (Katsanis, Interview).

Going deeper in the assessment of this synergy was difficult at the specific time period of the research however the idea exists and shall be taken under serious consideration from the managers of the distillery.

4.4The "Bio-Slaughter"

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

When the animal is examined by the local veterinarian is entering the slaughter house, where the main product is the meat. Apart from that, as declared by the EU legislation, the biohazardous waste are combusted and the rest of the waste is being dumped either in organized landfills (where possible) or just at local dumps.

However the organic non hazardous waste can be used with 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 technologies exist in the European market that can provide with the appropriate apparatus and know-how the slaughter houses managers. The biogas, always depending on the generated amounts can be used firstly to cover the needs of the abattoir and after that in order to be used as 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) at the local farmers. A schematic representation of the symbiotic chain is available furtherdown:

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 at that region. In a close geographic proximity from the slaughter house (around 40km) there is a cheese production facility. The cheese producer already uses as energy carrier natural gas, mainly to cover heating needs (pasteurization, cooling down 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 Eressos-Antissa greater region.

There are examples worldwide that pursue these types of symbiosis 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 at 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 into the local market[17].

[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

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 derive from the environmental impact assessment of Kalloni slaughterhouses, and are dated to the year 2006.

Table 4.4: Amounts of slaughtered animals and waste in 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 slaughter house of this capacity can generate there is a need to take some assumptions:

- The amounts of animals slaughtered are 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 years;
- The wastes put into the anaerobic digestor are firstly hygienised so that the fertilizer will not include any pathogenic micro-organisms destroying the crops and the feasibility of the symbiotic project.

Greece, presents specific variables that may determine the amounts of generated biogas. Temperature and climate conditions may be considerable variables towards 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 by benchmarking.

A small scale pilot project took place in Rural Ghana, exploiting the waste from the slaughter houses, managed to generate almost 10 m^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 around 38°C with the average pH ranging around 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 important, and every six months there is a need to open the digestors' doors and remove scum from the interior. It is worthy to mention 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 the same –more or less- environmental conditions like Lesvos Island: Temperature varies from 26°C in the winter to 39°C during summer in Ejura, when in Lesvos the average winter temperatures can vary between 17°C - 21°C. Summer temperatures can reach even higher levels from the Ghana example varying from 33°C - 42°C. Secondly the amounts of generated waste from the slaughter houses are really near 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 can be accounted to almost 100 tons 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 of purifying biogas[18]. Applying this biogas to the Andissa cheese production facility, will substitute a big percentage of use of natural gas 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) around 50€ for the producer. It is obvious that with a reasonable price both parts of the symbiosis may be have a significant profit: The 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 porterage can be bigger 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. One may be only sceptical about the initial investment cost, since the equipment was installed six years ago on Ghana (2001) thus a small price change must be expected.

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

Table 4.5: Generic results of the bio-abattoirs

	Waste not disposed at the environment (kg)	Generated Biogas (m^3)	Fertilizer (kg)
Daily	365,7	10	100
Monthly	10 971	300	3000
Annually	132 000	3650	36500

4.5The 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 around 15.000 tons. 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 for the animals' diet nutrients (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 be also used as a material input to the previous mentioned synergy, where it can be entered in 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.

5Analysis 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 followings:

- 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 mistaken.

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

- The future of synergy. What are the estimations for the duration period of the synergy and how it can evolve over time?

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

5.1The 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. 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 towards their effect to 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 the Lesvos case, 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 kg.

However, substitution and use of olive pit will require the construction of silos, big enough to be able to cover the supplies for a certain period. Therefore there might be a need for extra space near the cheese factory facilities plus and this might rise 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 (were 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. Quantifying at the present time the benefits for the olive producers is not a safe action to be taken. Provisions for the price of the olive pit are not safe at all 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 be seen. 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. This fact is quite severe having always in mind the amounts of waste generated after the olive oil extraction (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 to mention 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. Eventhough the system is supposed to be closed –which means that no hexane is escaping at the environment or the product, there are data (like annual purchase of hexane) proving leaks of hexane into the products. Thus, bypassing it will mean fewer emissions at the air, no hexane at the olive oil and a safer environment. Less fossil fuels will be combusted and fewer emissions are going to be released in 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 at the atmosphere and inserted at the local ecosystem (Kouzinoglou, Workshop) and secondly it leaves lots of ashes in the combustion chamber that need to be taken care. Proper organization and framework can give a solution at 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" at 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 finally is used as proposed in order to produce cosmetics and others, then less organic waste will be disposed, giving a brilliant solution to the main problem that occupies lots of regions that their economy is based on the olive oil extraction. However, strict management shall organize the operation of such industries in Lesvos, so that they follow common environmental patterns, ensuring that environmental degradation will be kept away from the future results of 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, 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 need a transition period, through which they will try to adopt the new products (i.e cosmetics based on OMWW) to their needs and if the new products do not enter the market together with extra incentives, for the customers to test them, then the symbiotic circle may broke creating negative spin off effects for the future of the whole synergy "Olive oil – Energy".

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

The implementation of the synergy in the Lesvian community can face several problems. Firstly as mentioned also in the workshop, legislation and bureaucracy is a big constraint that a hypothetical project will face. It appears that there is a strong difficulty to organize 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 didn't 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 out 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 pit 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 attempt.

Table 5.1: Positives, Negatives and Neutral points of Olive-Energy synergy.

	Environment	**Economy**	**Society**
	(+)Less waste from OMWW dumped at the environment.	(+)Cheaper Source for cheese producers	(+) Job potentials
	(+)No hexane at the environment.	(+)More income to olive oil producers	(+) New, natural products.
	(+)Full symbiotic cycle. (+)Substitution of fossil fuels	(+)Innovative Solutions	(o) Transition period for adopting the new products
Olive – Energy Synergy	(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. Eventhough the constraints are not unsolvable, 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.

5.2The 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 available further down:

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 is only 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 combustions gases emitted at the atmosphere, promoting in that way sustainability and environmental quality. Another benefit that this synergy will arise is the fact that the ouzo distillery can use the up-mentioned 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 islands' development for local products aiding at a less energy demanding distillation and at the same time they do not disturb the marine ecosystem by dumping cold and not warm water.

Society: There is no direct employment creation through this synergy between the energy company and the energy creation. 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, private owned. The owner may not agree for the installation of underground pipes crossing his land (Katsanis, Interview). Secondly, there is always a big difficulty trying to combine private owned companies with state owned. 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 only 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 up-mentioned period. However the benefits appear to be still considerable.

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 process 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 does 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

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

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's water grid and water shortage is a common feature, especially during summer. Costs and benefits of this alternative cannot be quantified in this study. However, it is suggested that in future it could be done promoting local sustainability by pioneer techniques.

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

Table 5.2: Evaluation of Ouzo Distillery – Energy Plant Symbiosis

	Environment	Economy	Society
Ouzo Distillery – Energy Plant Symbiosis	(+)Less warm water at 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	

5.3The Bio-abattoirs

This synergy is less concrete than the rest proposed in the previous sections. There is no coherent story concerning this part, however the implementation of this new – for the Greek actuality - idea, may ignite more synergies based on the exchange of biogas that can be used for multiple reasons. Specifically for this case, 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 be benefited by 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 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 soon will be the case that the European Union will start fining the EU countries that do not comply with the directive 91/689/EC that does not allow the organic waste to be dumped at the 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 slaughter house 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 slaughter houses 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 smell, rodents and intense pollution of underground waters, are only some of the characteristics that exist in 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 necessity for monitoring and recording details during the operational period that can affect the quantity of the generated biogas. In addition a contract with a transportation company shall be signed, for the frequently transportation of the biogas at the cheese producer 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 is on 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 at the environment (Kardaras, Interview). Furthermore the mayor, (also manager of the slaughterhouse), most likely because of an extreme work load especially during summer period, presented not to 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

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

feasibility study can be made in order to estimate amounts of generated biogas and in general if the synergy with the Antisa cheese producer is feasible. In addition, there was a lack of willingness to help gathering any possible data from the manager, who can present another obstacle when trying to persuade this part 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 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 seem really attractive. However, 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 case of anaerobic treatment of waste can be used firstly to cover the regional needs for energy and then, if the amounts are considerable, even extract it to other regions of the island. Finally it is quite clear that the importance of these types of synergies is more strengthened for an island perspective that is not connected to electricity grid of the mainland. In the table 5.3 the results of such a synergy are summarized and classified according to their effect to the environment, society and economy.

Table 5.3: Evaluation of 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	

5.4The Cheese symbiosis

As explained in chapter 3, there are several potentials that are included in the cheese process chain and 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 the savings are going to be considerable. These savings, under the appropriate management and investment plan can lead to 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 that 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 at 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 at 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 tons annually less whey.

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 at the environment were exceeding the limit set by the Greek authorities. The operational forbiddance of this factory is leading to another major problem: There is not any demand for supply 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 in the island. In this case, both the milk producers and the employees of the cheese producers will be benefited.

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) denied 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 prerequisite to lead these synergies to success.

On the second hand, the implementation of an action framework that would set the foundations for an IS scheme (as mentioned above) would require devotion from all participants and people working for the specific industry appear to believe only in solutions with obvious results only in the short term. 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 the whey into the environment, the former can also enjoy savings either from installation of treatment facilities or from governmental fining.

Table 5.4: Evaluation of the Cheese Synergy.

	Environment	**Economy**	**Society**
The "Cheese" synergy	(+) No ecosystemic degradation	(+) Savings for pig farmers	(+)No end in milk processing in Lesvos
	(+) Less chemicals at 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)	

6Discussion

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 scepticism before any conclusions are drawn.

6.1Observation - 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 really sceptical towards the implementation of the IS tool and almost all of the times 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 medium companies. Questions like "what will the manager of this scheme win" or "who ensures us that the operational manager will act for our benefit" were part of a common dialogue that had to explain that all participants in a theoretically implemented IS project will be benefited 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 denied giving any data from their production processes even after the researcher's guarantee that these data would have been used only for academic purposes. A generic phobia towards university representatives was dominating the research period and industry representatives were opened 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 non positive position of other cheese producers towards IS. The whey issue was flammable topic that no cheese producer wanted to speak about, being afraid for the future of his company. Their argumentations for this denegation was sometimes out of any logic thinking since the asked data were available and so, retrieved by other means like taxation records or similar.

Another main observation was made: When information or data were asked on behalf of the researcher by somebody that was part of the local community in any way, then the interviewees were outstandingly more opened 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 asked 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 them.

Therefore part of the obstacle could have been born down if a "messenger" was hired for this purpose: To approach the industries representatives and communicate the IS tool, while presenting 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 new comers (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 of the Aegean university was made in order to link the olive oil producers in order promoting 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 the expected. Generally speaking, the collaboration issue was a point that was criticised almost in 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 raised even when the researcher was mentioning 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 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. To a great surprise, the responsible of public relations, informed that the managers would not appreciate to be interviewed for the purposes of the IS assessments in Lesvos.

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

It was a surprise to the researcher the fact 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 require that the environmental performance of the product or service is continuously improving, this could explain why the level of acceptance the new idea of IS was higher than the rest industrial actors in Lesvos. However, even in that case, the synergy remained part of a theoretical future development, eventhough the profits seemed to be considerable.

From the above 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, are operating and producing in a certain way over the past 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 confrontation is the same.

It has to be stressed that especially in the case of a remote island, traditions are conserved more intensively compared to a city in 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 be the explanation towards deny for change.

Another observation that the researcher did while assessing the IS potentials in Lesvos Island, had to do with the current implemented environmental policy and frameworks. It is a fact that there is a strong gap there. 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, thus 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 of emitting a certain amount of whey at the environment, but the actual generated amount that is disposed at 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 at 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 them 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.

6.2Answers to the Research Questions

As mentioned in the first chapters, the main scope of this research is to assess how applicable is the IS tool 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 sustainability in an island and especially in the case of the Greek Islands?*

IS and IE concepts are assessing synergies and collaborations, with primary targeting on minimizing the use of raw materials and secondly on minimizing the amount of generated waste through a more efficient production process. Concepts like re-use and recycle 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, that none of them 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 big amounts of fossil fuels to cover their needs. More efficient systems will mean less dependence on fossil fuels and on the other hand less emission to the local environment (as a result of the fewer combustion processes). Moreover, reuse of energy (such as 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, make the use for 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, benefiting 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 presents to have lots of possibilities in an island's 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 be always a major issue in the Greek actuality. Lack of trust towards the organizers and the managers of the scheme, makes people that have adopted the idea of "idea-killing" even more difficult 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. Especially in the cases of an island, where the "closed" type of society does not allow privacy and the "vendettas" are becoming 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 proved that in Lesvos Island case, the implementation of the existing legislation is a major issue. Even if the legislation framework exists and seems to cover every possible gaps its implementation is the one creating the error. Due to the closed type of society (i.e. there are not enough new people with fresh ideas mixed in

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's grid apart from the telecommunication grid. Therefore they are totally depending on imports of fuels, products and others from the mainland, thus 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 to promote 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 risen. Less raw materials will mean either a bigger profit (keeping the prices at the same levels as at the pre – IS implementation era, or smaller profit but much more competitive in the markets (lowering down the 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.

Furtherdown 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: 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 and so on) and finally, if specific methods of olive oil extraction are used then a possible synergy with the animal breeders may rise. (For more details see chapter 4).
- Cheese producers' synergy: Reuse of generated whey in different ways. Firstly covering the daily nutrition needs for pigs. Secondly to produce giza and finally to "replicate" the Norwegian idea of mixing it with cream to create the Messe Ost.
- The Bio-slaughter synergy: Anaerobic digestion of organic non marketed slaughtering residues to produce biogas that can be transported to Andissa cheese producer. The specific producer is already using natural gas mainly for to pasteurize the milk and for heat purposes.
- Ouzo distillery-Energy plant synergy: Synergy between the private 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 position the distillery needs energy to preheat the distillation equipment before the process starts. In this way the savings for the distillery will be big, and at the same time the state owned energy plant can create a more ecological image in the society, without damaging the local environment.

It seems that there is enough potential in Lesvos Island. 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 new 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 in a very small scale. There is no sanitary landfill at the moment, a big amount of illegal dump sites exist, no recycling exists extensively in the island, while at the same time environmental awareness of the locals are 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 payoff 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 at the natural environment, better use of raw materials, more efficient systems, better consuming systems with reuse and recycle ideas) putting another stone towards environmental sustainability.

7Final Recommendations

A number of potentials were assessed, linking the main industries in Lesvos and in Greek Islands with similar characteristics like the level of remoteness, the type of industry and the dependence on the mainland. In order to achieve the triple sustainability (environmental, social and economical) and according to the personal observations that the author did, while researching the Lesvos Island case, some recommendations that may aid are presented further down:

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 the waste management in any case. In this way big amounts of waste are disposed at 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 any 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 present to have low level of trust towards non Lesvian people even if those appear to have a genuine interest towards the local development. For 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 trustful for 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 synergy, 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 raised. Perhaps each department shall communicate in a more extensive way any programs and researches to the society. In this way, locals may understand and comprehend the benefits of the existence of an academic institute at a region, enhancing their level of trust. University researchers are not connected at any way with tax offices, police departments or similar, this is why, the industry representatives must be willing to present a thorough picture of their business with exact data and figures. Moreover since university is the source of "know-how" when the appropriate level of trust is achieved, then the academia representatives must start heading towards being the coordinating body in the future implementation of an IS scheme. University has easier access and acceptance 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.

It is totally respectable that especially in remote islands people preserve their traditions, language. However, it was observed that locals follow a specific way of operating, and this way in the majority of the up-mentioned cases is not taking into consideration the technological evolution and generally new up to date pioneer ideas. There is a strong need for the local actors (and especially the most powerful) to understand that the current positive result of a process now, 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 look in the long term future of the island is vital in order to be able to overcome the possible difficulties that will jeopardize the sustainable development.

In the case that an IS scheme will be implemented then 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 decide 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 agrees 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 think how these synergies can be communicated in other Greek island, since there is such a level of 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 with Lesvos (like Samos, Chios and so on) belong luckily to the same prefecture. Thus it could be the case that personnel responsible for the regional development of each prefecture can communicate the IS tool, by showing successful examples in other examples. It might also be the case 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 ignited (and here enters the

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

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

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 will be created on the island for new comers to stay, work and transmit their knowledge and experiences in the islands' actuality.

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

These are some recommendations that will help promote sustainable development and were assessed through a three months period that the researcher spent in Lesvos Island. The replicability in other islands with similar characteristics cannot be questioned since data show similar observations as those made in the Lesvos case. However, apart from the up-mentioned, personal responsibility and engagement from the locals may "make or break" an IS synergy!

Industrial symbiosis is not the panacea towards sustainable development of the Greek islands. As shown above it presents deficiencies and attributes that must be taken under serious consideration before implementing it. However it is a solution that will recognize the unsustainable attributes of the Greek islands 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.

Bibliography

Ausubel, J. H. (1992). "Industrial Ecology: Reflections on a colloquium." Proc. Natl.Acad. Sci USA **89**: 879-881.

Boons F.A.A , B. L. W. (1997). "Types of Industrial Ecology: The problem of coordination." Journal of Cleaner Production **5**(1-2): 79-86.

Boons F.A.A , B. M. (2001). "Stretching the Boundary: The possibilities of flexibility as an organizational capability in industrial ecology." Business Strategy and the Environment **10**: 115-124.

Brown, C. (1997). Towards Sustainable Islands, Approaches to Attaining Agroecosystem Sustainability in the Carribean and the Pacific Islands. Tropical and Subtropical Agriculture Research. Orlando, Florida.

Buhagiar, V. (2006). Sustainable Development and Building Design in Malta. Faculty of Architecture and Civil Engineering, University of Malta **MSD:** 10.

Buhler-Natour C., H. F. (1999). "Criteria for sustainability and their application at a regional level: the case of clearing islands in the Dubener nature park (Eastern Germany)." Landscape and Urban planning **46**: 51-62.

Chertow, M. (2000). "Industrial Symbiosis: Literature and Taxonomy." Annual Review Energy and Environment **25**: 313-337.

Chertow, M., DeschenesP.J (2004). "An island approach to industrial ecology: towards ustainability in the island context." Journal of Environmental Planning nd Management **47**(2): 201-217.

Chertow, M. R. (2007). "“Uncovering” Industrial ymbiosis." Journal of Industrial Ecology **11**(1): 11-30.

Chtouris Sotiris, P. D. (2002). The Ouzo of Lesbos: The aroma and taste from the crossroads of the East and West. Hellenic Foreign Trade Board. Athens.

DiMaggio Paul J., W. W. P. (1983). "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields." American Sociological Review **48**(2): 147-160.

Doikos P., K. P. (2002). "Strategic Environmental Development - Course Description."

Domac K., R. K., Risovic (2005). "Socioeconomic drivers in implementating bioenergy products." Biomass and Environment **28**: 97-106.

E.D. Aklaku, K. J., K.Obiri-Danso (2006). "Integrated Biological Treatment and Biogas Production in a Small-Scale Slaughterhouse in Rural Ghana." Water Environment Research **78**(12): 2335-2338.

Ehrenfeld J.R. (2007). "Would Industrial Ecology Exist without Sustainability in the Background?" Journal of Industrial Ecology **11**(1): 73-84.

Erkman., S. (1997). "Industrial Ecology: A historical View." Journal of Cleaner Production **5**(1-2): 1-10.

Frosch, R. (1992). "Industrial Ecology: A philosophical solution." Proc. Natl.Acad. Sci USA **89**: 800-803.

Frosch R., G. N. (1989). "Strategies for Manufacturing." Scientific American **3**(261): 144-152.

Goodland, R. (1996). "Environmental Sustainability: Universal and Non-Negotiable." Ecological Applications **6**(4): 1002-1017.

Goodland R., D. H. (1996). "Environmental Sustainability: Universal and Non-Negotiable." Ecological Applications **6**(4): 1002-1017.

Gronkvist Stefan , P. S. (2006). "Driving forces and obstacles with regard to co-operation between municipal energy companies and process industries in Sweden." Energy Policy **34**(1508-1519).

Halvadakis C.P., N. M. (2004). Olive Processing Waste Management. Athens, Elsevier.

Haralambopoulos D.A., F. P., Safos M., Kovras H. (2001). "The structure of residential energy use on a North Aegean island: The town of Mytilene." Energy(26): 187-196.

Herbert, P. (1991). Tal och fakta om energi. Stockholm, Ångpanneförningen.

IEA (2005). Biogas in Society. I. B. T. 37.

Jeffrey C., B., Luloff A.E. (1999). "Toward an interactional approach to sustainable community development." Journal of Rural Studies **15**: 377-387

Koroneos C., M. M., Moussiopoulos N. (2003). "Multi-objective optimization in energy systems: The case study of Lesvos Island, Greece." Renewable & Sustainable Energy Reviews(8): 91-100.

Lifset, R. (1997). "Relating Industry to Ecology." Journal of Industrial Ecology **7**: 1-2.

M. Minhalma, V. M., D. Queiroz, Maria Norbert de Pinho (2007). "Optimization of Serpa Cheese whey nanofiltration for effluent minimization and byproducts recovery." Journal of Environmental Management **82**: 200-206.

Maltin, M. (2004). Industrial Symbiosis and its Alignment with Regional Sustainability Exploring the Possibilities in Landskrona, Sweden. IIIEE. Lund, Lund University. **MSc:** 80.

Masters, J. (1995). "The history of action research." Action Research electronic reader(University of Sydney).

Mihalakakou G., S. M., Kovras H. (2001). "Energy design investigation for the Greek area of the North Aegean Sea." Renewable Energy(24): 171-183.

Mirata, M. (2004). "Experiences from early stages of a national industrial Symbiosis programme in the UK: Determinants and coordination challenges. ." Journal of Cleaner Production **12**: 967-983.

Mirata, M. (2005). Industrial Symbiosis. A tool for more sustainable regions? IIIEE. Lund, Lund University. **pHd:** 245.

Mirata M, E. T. (2004). "Industrial Symbiosis networks and the contibution to environmental innovation: The case of Landskrona industrial symbiosis program." Journal of Cleaner Production **13**: 993-1002.

Mirogianni, A. (2006). Women cooperatives in Lesvos: "Comparison with big private companies under the framework of local sustainable development". Department of sociology. Mytilene, Aegean University. **MSc**.

Oxford, D. (2003). Oxford Advanced Learner's Dictionary. O. U. Press, Oxford University Press.

Schwarz Erich J., S. K. W. (1997). "Implementing nature's lesson: the industrial recycling network enhancing regional development." Journal of Cleaner Production **5**(1-2): 47 -56.

Scott W. Golla., R. G. (2007). Keeping ethanol production green. Pollution Engineering

Shih Henry., S. T. (2007). "Utilization of waste heat in the desalination process." Desalination **204**(464-470).

Silveira., S. (2005). Bioenergy-Realizing the potentials. London, Elsevier.

Starlander, J. E. (2003). Industrial Symbiosis: A Closer Look on Organisational Factors A study based on the Industrial Symbiosis project in Landskrona, Sweden. IIIEE. Lund, Lund. **MSc:** 111.

Stefan Gronkvist, P. S. (2006). "Driving forces and obstacles with regard to co-operation between municipal energy companies and process industries in Sweden." Energy Policy **34**(1508-1519).

Stuart, E. K. (2006). "Energising the Island Community: a Review of Policy Standpoints for Energy in Small Island States and Territories." Sustainable Development(14): 139 -247.

Taleghani G., K. A. S. (2005). "Technical-Economical analysis of the Saveh biogas power plant." Renewable Energy **30**: 441-446.

Tsobanoglous George., T. H., Samuel A. Vigil. (1993). Integrated solid waste management. New York.

Wallner H., N. M. (1994). "The concept of sustainable islands: cleaner production, industrial ecology and the network paradigm as preconditions for regional sustainable development." Journal of Cleaner Production **2**(3-4): 167-171.

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

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Appendix

On July 31st at the facilities of the department of Environment of the Aegean University, situated in Mytilene, a workshop under the title "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.

Find furtherdown a list of the participants:

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