ZERO EMISSIONS ISLAND KRK

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Certification Page

I, MELIS Marko, state that I am the only author and editor of the master's thesis "Zero Emissions island Krk". The master's thesis was completed in full by me from February 2011 to July 2011 under the supervision of Professor KATO Masanori of Ritsumeikan Asia Pacific University, Beppu City, Oita Prefecture, Japan. Furthermore, all the content used in this master's thesis which is not derived from my own ideas, thoughts or work is properly cited and referenced.

In Zagreb, Croatia, 1st of July, 2011

MELIS Marko

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List of Acronyms and Abbreviations

/a	per year (*lat*. per annum)
%	percent
°C	degrees Celsius
3R	Reduce, Reuse and Recycle
AD	Anaerobic Digestion
A.D.	in the year of the Lord (*lat*. Anno Domini)
BAU	Business as Usual
ca.	approximately (*lat*. circa)
CAD	Canadian Dollar
CE	Circular Economy
CEF	Carbon Emission Factor
CH_4	Methane
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
EU	European Union
EUR	Euro
FCW	Fairmont Chateau Whistler Resort
GHG	Green-House Gas
GWh	Gigawatt per hour
HBOR	Hrvatska Banka za Obnovu i Razvoj (*eng*. Croatian Bank for Reconstruction and Development)
HEP	Hrvatska Elektroprivreda (*eng*. Croatian Electro-Provision company)

HERA	Hrvatska Energetska Regulatorna Agencija (*eng*. Croatian Energy Regulatory Agency)
HRK	Hrvatska Kuna (*eng*. Croatian Kuna)
HROTE	Hrvatski Operator Tržišta Energije (*eng*. Croatian Energy Market Operator)
i.e.	that is (*lat*. id est)
km^2	square kilometer
kW_{el}	Kilowatt of electrical energy
kWh	Kilowatt per hour
kWh_{el}	Kilowatt per hour of electrical energy
LCA	Life Cycle Assessment,
LPG	Liquid Propane Gas
m^3	cubic meter
MFA	Material Flow Analysis
MFM	Material Flow Management
MSW	Municipal Solid Waste
MW	Megawatt
MWh	Megawatt per hour
O_2	Oxygen
PDCA	Plan-Do-Check-Act
RES	Renewable Energy Sources
SEEREM	South East Europe Regional Energy Market
t	metric ton
t_{CO2}	metric ton of Carbon Dioxide
UCTE	Union for the Co-ordination of Transmission of Electricity
UNEP	United Nations Environemt Programme
UNU	United Nations University

UNWTO	World Tourism Organization
VFA	Volatile Fatty Acids
WCED	World Commission on Environmental and Development
ZE	Zero Emissions

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1. Executive Summary

Island Krk in Croatia is a popular tourist destination during summer seasons. Consequently, the number of people who reside on the island soars during the summer period. This creates problems in the energy supply, the waste handling and waste water treatment during the summer months. The aim of this paper is to analyze the potential of the island Krk to become a zero emissions island and hence a "Green Tourism" destination overcoming the problems of the summer period.

The research was conducted firstly by reviewing the relevant literature followed by primary data gathering on site and secondary data gathering from other sources, such as internet. Secondly, the Material Flow Analysis was conducted for the island by analyzing the resources demand on the island in the terms of energy and water. Thirdly, a theoretical analysis was conducted with an assumption that the island would build a biogas power plant along with implementation of a modern waste management system for supplementing the energy demand and for the decrease in the waste materials during the summer.

An initial calculation led to 1,781,250 EUR as the total investments for the proposed new systems. The total consists of the following components: The cost to install one kW_{el} of biogas power plan is 2,800 EUR. For the installation of 350 kWh_{el}, this would imply the investment of 980,000 EUR. Further, the installation of the cogeneration unit matching to the same installed power would cost additional 245,000 EUR (700 EUR/kW_{el}). To have a steady production of biogas throughout the year, the collected old oils and greases need to be stored in appropriate tanks in order to be used in winter months for fermenting purposes. The installation of collection tank of this kind costs 306,250 EUR. Finally, the costs of project development and procurement of all needed permits are 250,000 EUR.

It was also noted that such new systems would contribute toward both financial savings and decrease in Carbon Dioxide emission. If such an investment is carried out on Island Kirk it is possible for the island to sustain its ever popular tourism under a term such as "Green Tourism".

Through a review of the energy supply demand situation in Croatia and the relevant legislatives, especially in view of Croatia’s imminent entry to the European Union, there are no obstacles for the island to adopt the suggested new systems. Therefore this paper strongly recommends carrying out such an investment for the island Krk.

2. Introduction

Croatia is currently in the process of becoming a full fledged European Union (EU) member. According to the most recent developments; it is going to join the EU in July, 2013. Therefore, it has to meet all the European guidelines in general as well as those regarding energy production and consumption. The government, while making the energy strategy of the Republic of Croatia has an opportunity to use the EU past and current experience. Consequently, it has developed a strategy and has established a legal framework for the promotion of Renewable Energy Sources (RES) which comply fully with the requirements of the EU. The strategy and the legislation are consisting of support mechanisms for provision of energy from RES and a feed-in tariff system for backing up the generation of electricity from RES. Further, Croatia is producing RES electricity from mainly hydropower. Solar and wind power contribution to this is minor; however, there is a great potential in these sources. In order to receive incentives, the Republic of Croatia is not counting in the electricity generated from large hydropower plants, i.e. the ones lager than 10 Megawatt (MW) installed capacity, in its RES generated electricity. If it were accounting for this generation, the electricity produced from RES would account to around 35 percent. This latter fact is interesting and, together with the implementation of new technologies and concepts can be used in a tourism strategy of a Republic of Croatia. It is a valuable benefit to promote Croatia's image as being a "green tourist" destination. One of these potential "green tourist" destinations is the island Krk.

Island Krk is one of the largest islands in Croatia and it is the most northern island in the whole area of Mediterranean. It is situated in the Kvarner Gulf of the Adriatic Sea. The island has a moderate and mild Mediterranean climate. Due to these facts, Krk has the average summer air and sea temperatures most suitable to develop its economy through tourism services. Also, the island has above average number of sunny hours per year which puts it among the sunniest parts in Europe. Owing to the above mentioned facts, Krk has a very diverse flora and fauna. In the central and western part of the island there is a vast of fertile land; therefore, the wines and olives are grown.

All the above information are leading to conclude that this island is a pearl of Adriatic Sea and that it is a imperative to maintain it as such. This is why the island's government has implemented and is still implementing projects which are preserving and will help to preserve Krk's natural beauty and which are classifying island to be a "green tourism" island. One example of these projects is a joint cleaning of beaches and sea beds organized by local tourist boards with local and foreign diving clubs. Further example is implementation of waste management on the island in the year 2005 which is the first of its kind in the Republic of Croatia. Consequently, the island is being promoted as "Eco island Krk – the cleanest part of Croatia". Further evidence that contributes in perceiving island Krk as a "green tourist" destination is the fact that it has a significant number Blue Flags, a symbol of clean beach and bathing water, flying on its beaches.

The next step in leading the island Krk in eco-friendly and sustainable tourism direction, is to develop and implement practices and technologies which will help the island in becoming a Zero Emissions Island in the terms of Green-House Gas (GHG) emissions. Only in this way, island's beautiful, and in some parts pristine nature and its tourist attractiveness will be preserved, if not enhanced. Therefore, this paper will identify and evaluate island's current state and potential, calculate the possible investments, state the problems and provide some adequate recommendations.

2.1. Problem Description

Due to its geographical position, beautiful nature and long tradition, Krk was and still is a favorable tourist destination, especially for Europeans. This is why in the peak of tourist season the number of people on the island is by ten times grater than number of people who are living there throughout the whole year. For all these visitors, an appropriate and functioning infrastructure needs to be in place. Also, there has to be an adequate number of facilities and accommodation options in order to be able to provide a proper service to each and every tourist who comes on the island.

Lots of tourists, working infrastructure and increased number of accommodation facilities are presenting a burden to the nature and to the environment. Tourists are bringing with their stay large amounts of waste on the island. These amounts coupled with the amount of waste generated by local people living there seek additional efforts to be dealt with, in the terms of capacity, technology and infrastructure. Due to the fact that it needs to be broaden and enlarged, the latter one is also presenting a problem to the environment. A vivid example of this is less agriculture land available for cultivation. The same applies for the accommodation facilities. If the local government of Krk wants to cope with the upcoming environmental pollution and increasing competition in tourism, it needs to develop and implement appropriate strategies which will tackle these problems accordingly.

2.2. Research Question

All the above information given is indicating an alarming situation which needs to be altered towards a more clean and sustainable resource management. If the local government wants to preserve island Krk's nature and promote it as a "green tourist" destination, it has to implement new sustainable concepts for its resource management. This research will analyze whether a Zero Emissions concept could be introduced and implemented on the island Krk. Furthermore, it will determine its contribution to the sustainability of the tourism sector and to the environmental protection strategy for the island Krk.

2.3. Structure and Methodology

The structure of this report is compiled out of following parts. In the introductory part, some basic information about the island Krk and about the reasons for conducting this analysis were provided. To be more exact, a brief description of the island Krk and the problems related to nature and tourism were given. Also, the research question was stated. In the next part of the paper, literature review related to the topic will be reviewed. Here, the definitions of key terms and concepts as well as a few case studies of sustainable tourism will be listed. Afterwards, attention will be brought upon the island Krk itself. This part will handle the MFA of the island, description of system boundaries, the island's resources demand and similar. In the further part of the paper, new solutions for the change in the management based on the analysis will be given. Precisely, the Zero Emissions (ZE) technologies will be stated and the tentative potential analysis with potential investment will be listed. Also, the potent CO_2 savings and overall environmental aspects will be stated. And at the final part of the paper, after discussing the next steps, current framework, strategies and objectives, an appropriate conclusion with final remarks on this topic will be provided.

The research is conducted in stages. First of all, the MFA of the whole island Krk will be undertaken. It will analyze the island's resources demand in the terms of energy and water, and similar. Also, environmental problems related to its resources demand will be listed. On the basis of this, new solutions for the change in the management will be given. Precisely, the ZE technologies coping with the waste and water management will be stated. Afterwards, the analysis of island's potential with related investment will be listed. Also, the potent CO_2 savings and overall environmental aspects will be provided at the end of the analysis. Finally, the list of new steps, current framework, strategies and objectives and final remarks will take place.

Later on in the paper it will become more obvious why clear and well structured analysis can be the only tool for the evaluation of the system. Depending upon the quality of the conducted analysis, the data collected and conclusions drawn on the basis of them can yield in undertaking sound and efficient steps towards positive system change management. In other words, if conducted properly, analysis can deliver sound and usable data. On the other hand, if conducted poorly, the information about the system will not represent its real state. Consequently, conclusions and decisions drawn upon wrong information will mostly result in undertaking wrong actions. This is why it is of the high importance to conduct this crucial segment of the research responsible and properly.

3. Literature Review

In this part of the paper, all available knowledge will be included and stated in the report. In the first part, Zero Emissions, Circular Economy and Material Flow Analysis approaches will be explained in more detail. Next, all relevant key terms and concepts, such as Material Flow Analysis, biogas production and sustainable tourism will be defined. Finally, there will be a part with descriptions of a few show cases of sustainable tourism and sustainable resources management.

3.1. Zero Emissions, Circular Economy and Material Flow Management

To have a better insight in the new approaches to a more sustainable resources management, some basic terms and concepts need to be defined. To begin with, Zero Emissions, Circular Economy (CE) and Material Flow Management (MFM) will be explained in a more detailed manner.

3.1.1. Zero Emissions

The modern way of human life consisting of mass consumption and mass production has lead to vast mismanagement of natural resources and great environmental pollution. In order to mitigate this alarming situation, a paradigm shift is needed. To this end, in 1994, United Nations University (UNU) in its headquarters in Tokyo, Japan launched the Zero Emissions concept, "designed to investigate various approaches and technological breakthroughs requisite to the creation of a new type of industrial system, lowering the unwanted dependency and developing new jobs" (Kuehr, 2007, p. 1199). The basic idea behind this concept is to minimize, if not totally cease, the production of waste. Rather, this waste could be used in other technological processes of different industries as a new raw material. Also, the aim of ZE is more efficient use of resources, regarding material and energy, in the upstream part of the production chain. This will result in less or no waste downstream of the production process. To achieve all this, a mutual collaboration and cooperation between all relevant subjects in one system or a region is required.

The phenomenon of cooperation can be best observed in the way how nature maintains a sustainable eco-system. This sustainable eco-system "is based on mutual collaboration between its constituents who serve in the roles of producers (plants), consumers (animals), and decomposers and detritivores (microbes). Hence, it constitutes the ultimate Zero Emissions system" (Zero Emissions Manual Drafting Committee, 2004, p. 3). The main objective is to alter the business as usual (BAU) approach with a new recycling based one. This new system could be achieved through mutual collaboration among all relevant subjects, such as diverse industries and different regions.

Kuehr (2007, p. 1199) further elaborates on the principle of the ZE approach:

> Also, the term refers to management standards such as Zero Defects and Zero Inventory. Together with Zero Emissions, these approaches symbolise a process of continuous improvement towards an idealised goal, improving the industrial performance in a sustainable way through a growing effectiveness coming along with decreasing volumes of wastes and harmful emissions. In the early 1980s one came to the opinion that quality or Zero Defects is an elementary prerequisite for growth and profit at the end of that decade another step was added: Zero Inventory. Through this, companies reduced the costly stock-keeping through the so-called "just-in-time" systems. These two steps found world-wide acceptance, even though flawed production and stock-keeping will never be completely eliminated. And in the mid-

1990s a new industrial triad occurred. In this, the environment as origin of the resources for production chains is regarded as an additional potential to reduce costs and maximise profit. The term Zero Emissions attracted special attention, as it is easily understandable and does not require translations into, e.g. Japanese, German, French, etc.

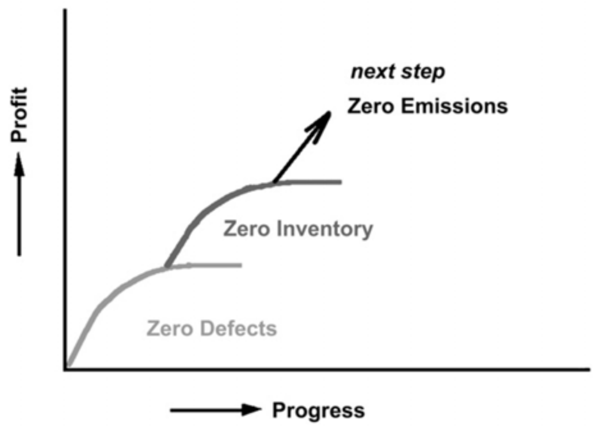

Figure 3.1. Progression model based on the industrial management concept[1]

Any complicated system cannot be changed, moreover improved over a short period of time. The same applies for the ZE concept. Therefore, achieving more efficient system requires persistent increasing efforts through a Plan-Do-Check-Act (PDCA) cycles. The Figure 3.2. shows the process with the related sub process. PDCA is "a cyclic model showing the procedure to be followed by each organization for the continuous promotion of Zero Emissions. It is a systematic and persistent approach to strengthen Zero Emissions activities and involves rotation along four steps: PLAN (setting a plan) – DO (implementation and operation of the plan) – CHECK (evaluation) – ACT (review)" (Zero Emissions Manual Drafting Committee, 2004, p. 14).

[1] Source: Kuehr, 2007, p. 1199

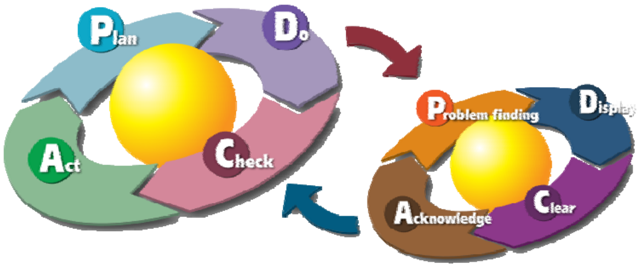

Figure 3.2. PDCA cycle[2]

To be more descriptive, the appropriate analogy will be derived. Assume that a certain company is producing a specific product. This production is connected with a generation of a certain waste. Instead of disposing this waste, as done in the BAU scenario, the Zero Emissions approach could be seen in the fact that another company would use this waste as a raw material. Than this process could be continued next to a third company, and so forth. Consequently, this would then close the loop regarding the production processes of these companies in a specific region or system. Figure 3.1. depicts one example of ZE concept.

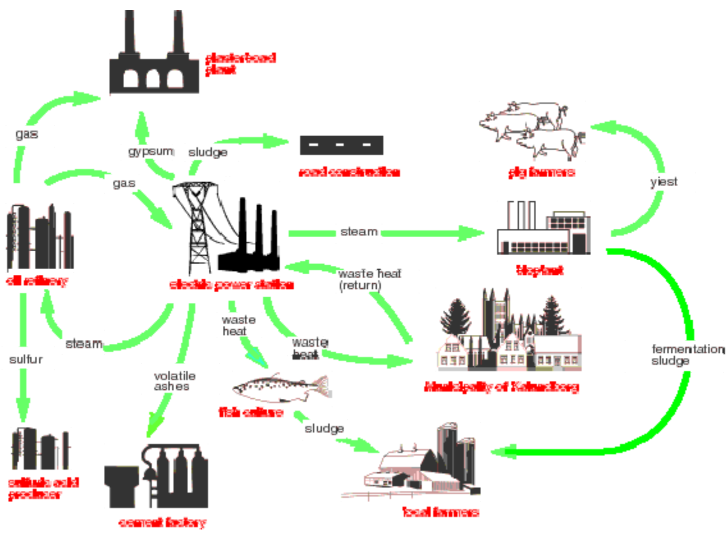

Figure 3.3. Industrial Ecosystem at Kalundborg, Denmark[3]

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[2] Source: http://www.ciephil.x10hosting.com/about.html. Retrieved May 23, 2011
[3] Source: http://newcity.ca/Pages/industrial_ecology.html. Retrieved May 23, 2011

In this example, the main parties involved are electrical power station, oil refinery, cement factory, plasterboard plant, bio plant, local farmers, municipality and others. Here, all participating parties working together have economic benefits. In other words, "participating firms each benefit economically from reduce costs for waste disposal, improved efficiencies of resource use and improved environmental performance" (Peck, n.d.). For instance, gas which is generated in the oil refining activities is being sent to the electricity generating power station which uses it for improving its electrical power production efficiency. On the other hand, electrical power station is sending its residual steam back to oil refinery in order to be used in the processes needed for refining of oil. This example brings the need of explaining the closed loop of material which could be identified as Circular Economy.

3.1.2. Circular Economy

The CE approach is based on natural flows of eco-systems. In these flows, there is no such thing as waste, because every waste material of one party serves as a raw material for the other. Furthermore, in the eco-systems only natural and renewable energies, such as solar energy, are used. In the terms of anthropogenic activities, this concept could be applied to more efficient use and reuse of input production materials coupled with as least resources losses as possible.

To make material and energy flow more efficient, circular economy approach needs to be undertaken. "A circular economy is an economy which balances economic development with environmental and resources protection. It puts emphasis on the most efficient use and recycling of resources, and environmental protection. A circular economy features low consumption of energy, low emission of pollutants and high efficiency. It involves applying cleaner production in companies, eco-industrial park development and integrated resource-based planning for development in industry, agriculture and urban areas" (UNEP, 2006, p. 1).

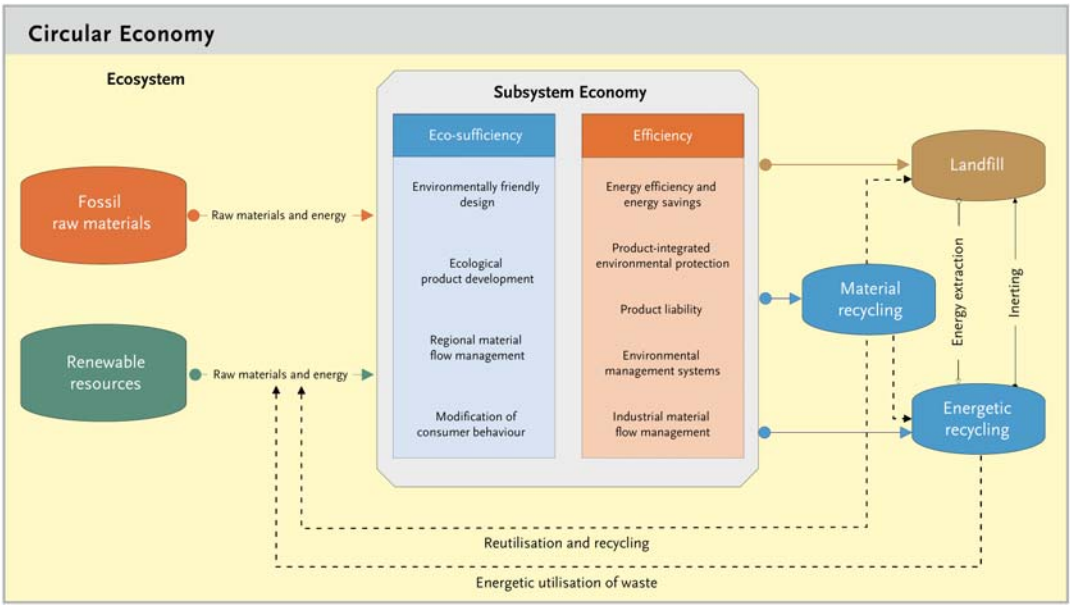

Figure 3.4. Circular Economy diagram[4]

The goals of the CE according to the Ministry of the Environment and Ministry for the Economy (2008, p. 8) are to protect the environment through the conservation of sources and sinks, to reduce the dependence of resource suppliers, to reduce costs in raw material and energy, to minimize the outflow of purchasing power, to create and maintain local jobs, to increase competitiveness, etc. The Environmental Campus Birkenfeld which is a part of Trier's University for Applied Sciences will serve as the example (Ministry of the Environment & Ministry for the Economy, 2008, pp. 12-15) how the technology and know-how in dealing with waste management can provide solutions and how the CE approach is successfully implemented.

University of Applied Sciences gets its needed energy and heat through a local heating network fed by the nearby biomass cogeneration plant. Also, renewable materials such as scrap wood, forestry waste and sawmill waste are used as fuel. Furthermore, biowaste from

[4] Source: Ministry of the Environment & Ministry for the Economy, 2008, p. 7

the district’s households is firstly used in two cogeneration plants to produce heat and electricity and afterwards fermented leftovers are turned into compost which is high in quality. German regulations enable that the electricity which is produced can be fed into the public grid. Owing to the fact that the University’s consumption of the electricity is less than generated, and the fact also entire heating demand is provided from RES, Environmental Campus Birkenfeld has been stated as a "Zero Emission University". Moreover, there is intention for the near future to include all water streams into their sustainable water management system which already uses rain water for sanitary and other purposes. This would embody separation of the water into grey, yellow and brown for the purpose of obtaining valuable nutrients. Other waste water will be treated trough the nearby wetland.

Due to the position of island Krk, in geographical as well as tourism sense, in it imperative to consider CE concept as a long term strategy when it comes to the management of the resources in that system. This approach will lead to possible cost reductions and new jobs creation, but also serve as a Krk's tourism marketing strategy in promoting the island as a "green tourist" destination.

3.1.3. Material Flow Management

The foundation on which the contemporary waste management lies is the material flow management concept. Its primary objective is to reduce and avoid waste and only if that is not possible, to reuse and recycle it. The MFM stands in opposite to end-of-pipe approach which is still prevailing in a number of systems. It could be derived that "material flow management has become an increasingly important paradigm in waste management. An essential goal of this paradigm is prioritizing waste reduction over reuse and recycling, and the latter waste management processes over secure disposal of waste residues. Separate treatment of biodegradable waste fractions (bio-waste) is a promising way to approach this goal" (Lang, Binder, Scholz, Schleiss, & Staubli, 2006, p. 101). The latter will be the stepping point of making island Krk zero emissions island.

Wagner and Enzler (2006, p. 8) define MFM, stating that "management of material flows by the involved stakeholders refers to the objective-oriented, responsible, integrated and efficient controlling of material systems, with the objective arising from both the economic and ecological sector and with the inclusion of social aspects. The objectives are determined on a company level, within the scope of the chain in which stakeholders are involved or on a national level." In other words, the MFM means optimizing resources, i.e. materials and energy of a specific system while taking in consideration certain economic, ecological and social aspects.

According to the Ministry of the Environment and Ministry for the Economy (2008, p. 9), the aspects to which MFM is oriented are:

- Integrated consideration of the entire social system (consumption, supply and waste disposal, infrastructure, commerce and agriculture, etc.) and its industrial activities
- Linking of material and energy flows intrinsic to the system and networking of the corresponding players
- Utilization of potentials intrinsic to the system (raw materials, waste materials, processes)
- Increased implementation of renewable energies and secondary fuels
- Increase of energy efficiency in the private and industrial area
- Decentralization of the energy supply

While taking in consideration that global resources are being depleted and that the world's sinks are being exhausted, MFM should be taken as a logical approach in tackling these serious problems. Without the appropriate system change, current BAU and "end-of-pipe" approaches will soon bring this already fragile system to a collapse. Material flow management combining new technologies with interdisciplinary and systematic approach can identify, analyze and realize the potential that system has. This realization of the system's potential can satisfy all three aspects, namely; economic, ecological and social, respectively. Firstly, substantial cost cuts and additional savings could be achieved if MFM approach is implemented. Secondly, scarce resources and increasing fragile environment could be preserved. Finally, additional value added in the terms of new job creation could be achieved. As could be concluded, MFM with the installation of clean technologies will be the next step towards sustainable development.

German Federal Ministry for the Environment (2009b, p. 5) states that "the key aspect of the material-flow-management approach, in contrast to traditional environmental management approaches, is the extent of the analyses involved. Along the quantitative and qualitative identification of all relevant material and energy streams, the material-flow approach also calls for determining the relevant direct and indirect costs, causal interrelationships and responsible stakeholders." To be able to successfully and fully implement MFM concept, appropriate analysis of the system needs to be undertaken. This brings into focus next key term which will be explained in more detail in next subchapter, and that is Material Flow Analysis (MFA).

3.2. Definition of other Key Terms and Concepts

In order to provide better insight in the approaches and to explain in more depth the new technologies for optimization of the resources efficiencies, the following key terms and concepts will be elaborated upon. Firstly, definition and explanation of MFA will be provided. Next, technology for biogas production will be stated and explained in more detail. Finally, sustainable tourism concept will be brought into attention.

3.2.1. Material Flow Analysis

In order to operate and to be productive, many of today's systems have high energy and material demand. Further, most of these demands are satisfied with the imports from outside the system, which generate undeserved costs. However, raw material and energy used in a system could also be generated within the system. All this could be achieved through consumption reduction, renewable energies utilization and with closing of existing production cycles. Only thing important here is to recognize this potential that a system already possesses. In order to identify, activate and realize the potential, a proper analysis of the system needs to be conducted.

In order to become better familiarized with MFA, something about its history needs to be stated. Brunner and Rechberger (2005, p. 5) state that "the first studies in the fields of resource conservation and environmental management appeared in the 1970s. The two original areas of application were (1) the metabolism of cities and (2) the analysis of pollutant pathways in regions such as watersheds or urban areas. In the following decades, MFA became a widespread tool in many fields, including process control, waste and wastewater treatment, agricultural nutrient management, water-quality management, resource conservation and recovery, product design, life cycle assessment (LCA), and others."

"The analysis of material and energy flows is widely recognized as one important and necessary step for reducing the impact of human activities on the environment" (Binder, 2007, p. 1605). In order to help preserve the environment, one way is to successfully implement MFM. The process of implementation needs to be in accordance with and based on appropriate analysis of the resources flows within the system. According to the German Federal Ministry for the Environment (2009b, p. 5), such analysis should include aspects such as:

- Waste and residual materials produced by households, industry and commercial operations,
- Wastewater, and substances resulting from wastewater treatment, such as sewage sludge,
- The many types of biomass produced in agriculture and forestry, and in landscape management, and
- The relevant fuels and energy sources, including fossil fuels, and including renewable energies such as solar energy, wind power and waste heat.

A good approach for conducting of the analysis is so called "top-to-bottom" approach. What it means is that "the analysis begins with the "large" material streams, sited on the regional level, and then moves gradually, in keeping with the relevant focuses, to lower levels, even down to individual processes" (German Federal Ministry for the Environment, 2009b, p. 5).

Material Flow Analysis is used in many fields, mainly "in a variety of environmental-engineering and management applications, including environmental-impact statements, remediation of hazardous-waste sites, design of air-pollution control strategies, nutrient management in watersheds, planning of soil-monitoring programs, and sewage-sludge management. All of these tasks require a thorough understanding of the flows and stocks of materials within and between the environment and the anthroposphere" (Brunner & Rechberger, 2005, p. 14). Also, MFA is highly important for managing the resources appropriately, especially in the analysis and planning stages. Conducted properly, MFA will identify building up or decrease in stock of resources in a certain system. On the basis of these findings, planning can be done more efficiently. Furthermore, MFA serves as a link between resources management and waste management, in the terms of final sinks and strategies for recycling and disposal.

After an appropriate analysis which will help in realizing the potential of the system, next step in which the material flows will be optimized has to be conducted. The process of optimization should consider five main aspects (German Federal Ministry for the Environment, 2009b, p. 6):

- The material and energy requirements that are behind the material streams, requirements that manifest themselves primarily in measurable consumption of the materials being studied,
- Any relevant sources, whether used or not used (= potential), of material streams,
- The technology and logistics linking potential sources with requirements (existing and available),
- Directly or indirectly relevant stakeholders,
- The financial resources required for implementation, and all planning and organizational activities required to obtain them.

The process of optimization should be based on a sound strategy which would consist of more individual business plans. The strategy and plans should be prone to continuous control and improvement, which is consistent with the PDCA principle. With the material and energy flows optimization within the system, more value added is created. This value added could be observed in all three aspects; economic, ecological and social. Precisely, costs are decreased, environment is preserved and job positions are created. The improvement in all these aspects propels the systems with its economy to more sustainable resource management.

3.2.2. Waste Management

To begin with, the term waste by itself has to be questioned. If the flow of materials in one system is sustainable; basically, there would be no waste. All the materials which can not be used in one process could be used as an input for next process. Consequently, no materials would be wasted; rather, they would all be used in the processes. Close examples of this kind of management could be found in rural areas just a few decades in the past. Unfortunately, in contemporary development of urban areas this concept is far from reality.

To date many urban areas have to cope with the constant increasing amount of every kinds of waste generated by their citizens. This is mainly because of two reasons. First of all, every major city is growing larger with every day. People are moving into the city, hence creating demand for more dwelling place. Therefore, there is a constant constructing activity present which is consequently broadening the city’s borders. Second reason is that people are starting to enjoy more the fruits of product abundance. This means that they are buying products they really do not need or that they just want to replace current good and working product with a newer and better looking one.

Next to the problem of growing amount of waste generated, large cities are faced with the fact that they are not managing their waste properly. In other words, municipal waste is either not separated at all or separated inappropriately and then dumped in the city’s landfill or incinerated. Obviously, this imposes great negative impact on the surrounding area and environment.

Brunner and Rechberger (2005, p. 17) state:

> The first signs of organized waste management appeared when people started to collect garbage and remove it from their immediate living areas. This was an important step regarding hygiene and helped to prevent epidemics. These practices were improved over the centuries. However, dramatic changes in the quantity and composition of wastes during the 20th century caused new problems. First, the emissions of the dumping sites (landfills) polluted groundwater and produced greenhouse gases. Second, landfill space became scarce in densely populated areas. Even the concept of sanitary landfilling could not solve these problems in the long run. Today, waste management is an integrated concept of different practices and treatment options comprising prevention and collection strategies; separation steps for producing recyclables or for subsequent processing using biological, physical, chemical, and thermal treatment technologies; and different landfill types. People now have the opportunity (or, in some places, the duty) to separate paper, glass, metals, biodegradables, plastics, hazardous wastes, and other materials into individual fractions.

Among other objectives of contemporary waste management, such as environmental and human health protection, resource conservation and waste reutilization and disposal, the main one is prevention of economic and ecological burden of waste to future generations. In order to achieve the latter objective, choosing the best available and the most suitable waste treating technology would not be possible without conducting appropriate MFA. It serves as a highly valuable tool which analyzes the composition of the waste on the basis of which a sound decision regarding waste treating or recycling technology to be used can be made.

3.2.3. Biogas Production

Biogas production is generated through the process of anaerobic digestion (AD). "Anaerobic digestion is a multi-stage biological waste treatment process whereby bacteria, in the absence of oxygen (O_2), decompose organic matter to carbon dioxide, methane (CH_4) and water" (Russell, 2006). Carbon dioxide and methane are the main compounds which form biogas, in the approximately 40 to 60 ratio, respectively. Biogas is a combustible gas. The left over decomposed substrate is called digestate and it is abundant with all sorts of nutrients. If containing no harmful substances, such as heavy metals, digestate can be excellent fertilizer.

This process of AD consists of a few linked stages and involves different types of bacteria. Figure 3.5. shows the simplified diagram of the process in which four main steps are displayed. The first step of AD is the Hydrolysis phase "during which the complex organic matter (polymers) is decomposed into smaller units (mono- and oligomers). During hydrolysis, polymers like carbohydrates, lipids, nucleic acids and proteins are converted into glucose, glycerol, purines and pyridines" (Seadi et al., 2008, p. 22). The second stage is the Acidogenesis stage, during which "the products of hydrolysis are converted by acidogenic (fermentative) bacteria into methanogenic substrates. Simple sugars, amino acids and fatty acids are degraded into acetate, carbon dioxide and hydrogen (70%) as well as into volatile fatty acids (VFA) and alcohols (30%)" (Seadi, et al., 2008, p. 22). During the Acetogenesis phase, all the products from acidogenesis, which can not be directly converted to methane by methanogenic bacteria, are converted into methanogenic substrates. "VFA and alcohols are oxidized into methanogenic substrates like acetate, hydrogen and carbon dioxide" (Seadi, et al., 2008, p. 23). In the last, Methanogenesis phase, methanogenic bacteria are converting the intermediate products into methane and carbon dioxide.

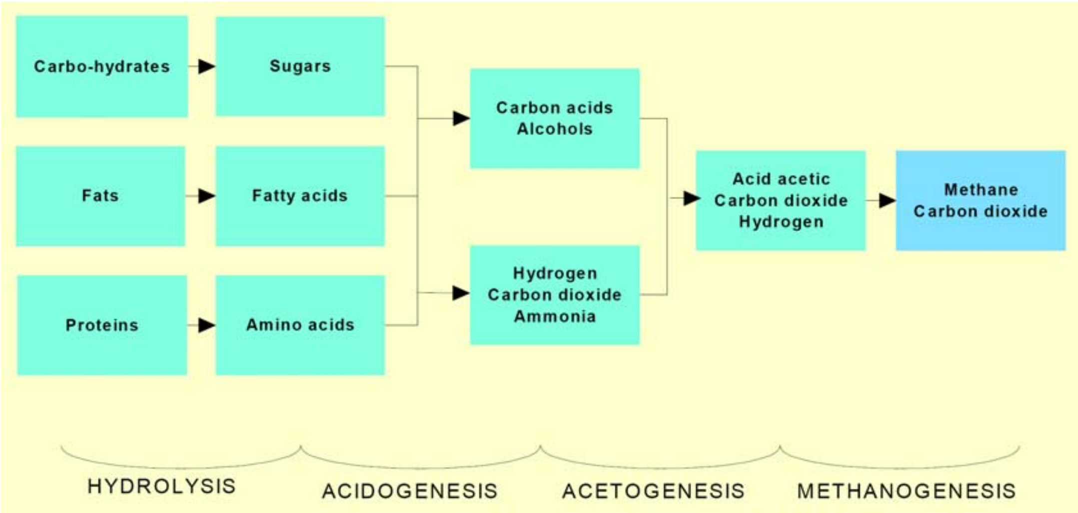

Figure 3.5. Anaerobic Digestion process[5]

It is important that the process remains continuous, i.e. that organic matter is constantly added and that decomposed mater and produced biogas is continuously removed. The duration and the efficiency of the process depend upon few parameters, such as temperature, pH-values, ammonia, etc. All this is important when planning the installation.

Biogas obtained in the above mentioned process can be used to produce electrical energy. "With a calorific value of about 6 kWh, one cubic meter of biogas is equivalent to 0.6 liters of heating oil or 0.6 m^3 of natural gas" (German Federal Ministry for the Environment, 2009a, p. 99).

For this part of the paper basic facts and figures about the biogas producing process will suffice. Later on, in the upcoming sections more detailed facts and explanations with appropriate figures and calculations will be provided.

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[5] Source: Seadi, et al., 2008, p. 21

3.2.4. Sustainable Tourism

Globalization and modern way of living made possible for people to travel the world much faster and more convenient. Moreover, the parts of the globe which are most interesting to majority of tourists are heritage sites or pristine nature. In the same time, these places are the least influenced by the global pollution and man-made environmental destruction. In order to cope with the continuous increase in both environmental pollution and growth of the tourism, the known tourism management has to be changed. Among few solutions available, managing tourism in a sustainable way is showing to be the most suitable. To grasp the understanding of the matter, definitions of sustainable tourism will be provided.

Definition of sustainable tourism is based and derived from the sustainable development concept. Sustainable development was first time defined by World Commission on Environmental and Development (WCED) in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). The same can be applied to tourism, where it needs to be sustainable in the sense that upcoming generations have to have the same or even better opportunity to experience culture and places as the previous ones did.

"Sustainable tourism in its purest sense, is an industry which attempts to make a low impact on the environment and local culture, while helping to generate income, employment, and the conservation of local ecosystems. It is responsible tourism that is both ecologically and culturally sensitive. Thus, Sustainable tourism activities have minimal impact on the environment and culture of the host community" (Institute for Tourism, n.d.).

The World Tourism Organization (UNWTO) (2004) defines sustainable tourism in the following few paragraphs:

Sustainable tourism development guidelines and management practices are applicable to all forms of tourism in all types of destinations, including mass tourism and the various niche tourism segments. Sustainability principles refer to the environmental, economic and socio-cultural aspects of tourism development, and a suitable balance must be established between these three dimensions to guarantee its long-term sustainability.

Thus, sustainable tourism should:

1) Make optimal use of environmental resources that constitute a key element in tourism development, maintaining essential ecological processes and helping to conserve natural heritage and biodiversity.

2) Respect the socio-cultural authenticity of host communities, conserve their built and living cultural heritage and traditional values, and contribute to inter-cultural understanding and tolerance.

3) Ensure viable, long-term economic operations, providing socio-economic benefits to all stakeholders that are fairly distributed, including stable employment and income-earning opportunities and social services to host communities, and contributing to poverty alleviation.

Sustainable tourism development requires the informed participation of all relevant stakeholders, as well as strong political leadership to ensure wide participation and consensus building. Achieving sustainable tourism is a continuous process and it requires constant monitoring of impacts, introducing the necessary preventive and/or corrective measures whenever necessary.

Sustainable tourism should also maintain a high level of tourist satisfaction and ensure a meaningful experience to the tourists, raising their awareness about sustainability issues and promoting sustainable tourism practices amongst them.

"The objective of sustainable tourism is to retain the economic and social advantages of tourism development while reducing or mitigating any undesirable impacts on the natural, historic, cultural or social environment. This is achieved by balancing the needs of tourists with those of the destination" (Institute for Tourism, n.d.).

3.3. Show Cases of Sustainable Tourism and Sustainable Resources Management

In this section few examples of sustainable tourism from all over the world will be provided. All the listed case studies will present material and energy utilization and undertaken actions which are enhancing their efficient use. These actions are seen in the implementation of cleaner technologies, such as better waste management, use of renewable energy sources, installation of energy saving lighting and similar. Consequently, by implementation of stated cleaner technologies and more efficient resource management, the tourist attractiveness of the listed tourism destination is growing. First, the example of Caribbean island will be presented. Next, the case study of "Sa Cova" in the Balearic Islands will be provided followed by the model of sustainable tourism from Fairmont Chateau Whistler Resort. The part with presentation of show cases will end by the example of

3.3.1. Caribbean Islands

The research reported by Fitzgerald (2005) conducted on few islands of Caribbean shown the extent of implementation of cleaner technologies by their tourism sector. Precisely, the Caribbean islands covered were Antigua, Barbados, The Dominican Republic, Jamaica, and St. Lucia. These were the findings of the research.

In all of the stated islands, the cleaner technologies measures undertaken were the use of separation and recycling of the solid and composting of organic waste. Further, in the energy field the use of energy saving lighting, such as fluorescent and low sodium pressure lights, and installation of water heaters was implemented. For the sustainable water management, the collection of rain water for irrigation purposes and the use of treated wastewater for irrigation of green surfaces were conducted.

In the majority of islands, the use of renewable energies is for water heaters. Therefore, the few islands' Governments also gave their part in greening of the tourism sector by implementing policy measures that encouraged and supported the installations of water heaters. They waived the taxes imposed on raw materials for manufacturing of the water heaters and introduced taxes for non-solar ones.

Majority of the hotels included in the research from all of the islands reported that the reasons for using cleaner technologies were to cut costs, to attract "green consumers" and to do their part in the environment preservation efforts. Also, the hotels stated that they were sharing ideas and information about clean technologies which indicates a high level of cooperation. Finally, the study indicated that all of the easy to implement and not so expensive measures undertaken are helping to sustain the Caribbean tourism industry.

3.3.2. Balearic Islands

Balearic Islands are small islands situated in Mediterranean Sea and they are a part of Spain. Furthermore, they are one of the most important tourist destinations in the world. As being small, their water and energy resources are very limited and it is an imperative to make their consumption as sustainable as possible. Moreover, on the islands a great deal of Municipal Solid Waste (MSW) is produced each year from tourist activities. If all the above stated problems are not well addressed, the tourism sector in Balearic Islands will collapse.

Fortuny, Soler, Canovas and Sanchez (2008) provided a methodology for the transition from BAU tourism to sustainable tourism in Balearic Islands. First, the appropriate analysis of the system was undertaken, focused mainly on water, energy and waste. It covered the energy and water demand, availability, waste generation and management, and similar. Based on the analysis, best solutions available were considered and plans for their implementation were provided. Finally, economic and environmental evaluation was given coupled with follow-up and review of the results.

The above methodology was applied to a country house "Sa Cova" situated on the largest of the Balearic Islands, Majorca. After an exhaustive analysis, the adequate solutions were given. First, the collection of rainwater and minimization of water consumption were proposed. Second, the installation of solar panel system and a propane boiler for the increase in energy efficiency was suggested. Finally, in the waste field, offered solutions were composting of the organic fraction of MSW and a natural reed bed filter system for wastewater treatment.

The economical and environmental impacts of proposed solutions were calculated and evaluated. The costs of the s suggested installations were around 175,000 Euros (EUR) and the payback period was around four years. "The total environmental benefit of the project was also calculated in terms of CO_2 emissions' savings compared to the same tourism enterprise but without the applied selected solutions for sustainability improvement. Thus, it was found to be 25,000 kg of CO_2/year considering the tourism occupancy level reported for the same area of the Balearic Islands where the house is located, in 2004" (Fortuny, et al., 2008, p. 867).

3.3.3. Fairmont Chateau Whistler Resort

"This case study of the Fairmont Chateau Whistler Resort (FCW) illustrates how a hotel resort is actively contributing to sustainable tourism development by striving to operate within an environmentally, socially and economically responsible framework. … The FCW is part of Fairmont Hotels and Resorts, a Canadian company that manages national and international luxury hotels. Over the past decade, this company has become a North American tourism industry leader and catalyst in ‘greening’ hotel operations." (Speck, 2002, pp. 269-270). After these few introductory sentences, it is important to state that the FCW developed and established a vision and a strategy for social responsibility. By doing this, the fundaments for achieving sustainability goals were provided.

To tackle the problems accordingly, the analysis of the system's resources flows and practices was undertaken. It revealed few priority areas, such as waste management, water and energy management, and supply chain management. Reduce, reuse and recycle (3R) concept was implemented for resource efficiency. For instance, toilet paper and tissues are made form recycled materials. Also, more efficient use of materials reduced the total waste generated. As for the water and energy management, few solutions were embarked on. The incandescent lamps were changed with fluorescent ones. The low flow taps were installed in all toilets and showers. These few easy-to-implement solutions saved up to 125,000 Canadian dollars (CAD). Finally, for managing the supplies, the traditional waxed cardboard boxes in which the meat is transported are replaced with reusable plastic totes. Only this action counts for around half of a ton of waste not ending up in the landfill annually. Also, cleaning products are procured from a supplier which specializes in industrial cleaning products that are produced to meet high ecological standards.

3.3.4. Couran Cove Island Resort

The next example is a resort which is located on the Gold Coast and Brisbane in Queensland, Australia. "Couran Cove Island Resort is built on one of the world’s few naturally-occurring sand islands, which is home to a wide range of plant communities and one of the largest remnants of the rare Livistona rainforest on the Gold Coast" (Lima & McAleer, 2005, p. 1433). Due to the fact that this resort is a part of a fragile natural environment, the planning and development of tourism activities here had to be conducted in a sustainable manner. Therefore, planning and development gave great attention to water and energy flows, waste generation and disposal, community involvement and environmental education.

The resort gets its water from the aquifer which is located in center of the island and is refilled by rainfall. In order to prevent it from being contaminated from detergents, the laundry washing is done on the mainland. To save water, low-flow water faucets are installed in showers and toilets. As for the energy, the resort uses Liquid Propane Gas (LPG) instead of diesel for its energy supply. Moreover, this generation is supplemented by wind turbines. These two solutions accounted together to a greenhouse gases emissions reduction of 70 percent. Furthermore, waste heat from LPG energy generation is used to heat the water in the swimming pool. Also, some of the vehicles in the resort are solar powered. The visitors are encouraged to monitor and control their water and energy consumption and if they over deliver, they are rewarded with the prizes, such as a free return trip to a resort.

Couran Cove's waste management is based on 3R concept. In order to reduce waste, the procuring of the supplies is done in buying-in-bulk manner to avoid excess packaging. Organic waste is reused as soil conditioner and fertilizer. In all the resort, three different types of waste bins are installed for waste separation; namely, bin for organic, recyclable and non-recyclable waste. All recyclable materials are collected and shipped to mainland for further recycling. For sewage collection, a vacuum sewer pipes are used. Then, wastewater is treated through primary to tertiary stage and afterwards returned back to system.

"Couran Cove has implemented a range of environmental and cultural educational initiatives" (Lima & McAleer, 2005, p. 1435). One example is special educational activities on sustainable tourism for schools in the community.

4. MFA of KRK

This part of the paper will handle the Krk island itself. First, the description of the system boundary will be provided. Here, some basic information such as geographical position, climate type, historical data and similar will be given. Then the demand for resources and the generation of waste will be stated. At the end, some final remarks and conclusion will be provided.

4.1. Description of the System Boundary

Island Krk, next to the neighboring island Cres, is the largest islands in the Republic of Croatia "with an area of 409.9 square kilometers" (Tourist Office, n.d., p. 5). It is the most northern island in the whole area of Mediterranean, if the small uninhabited islands near west coast of Istria and north Adriatic coast of Italy are excluded. It is situated in the Kvarner Gulf of the Adriatic Sea. Krk's location can be observed in the Figure 4.1. The administrative center of the island is town of Krk. Island has seven municipalities; Krk, Baska, Dobrinj, Malinska, Omisalj, Punat and Vrbnik. Rijeka airport is situated on the island and the island is connected to mainland by bridge of Krk which was built in the year 1980. The island has around 220 kilometers long coastline. From all the above mentioned fact, it is obvious why island Krk is such a beloved tourist destination.

Island Krk has a moderate and mild Mediterranean climate. With its average annual temperature of 14.5 °C and average summer temperature of 23 °C, the island is much warmer than it should have been according to its geographical latitude. This occurrence is mostly due to the warm sea influence. Moreover, island Krk is one of the sunniest areas in Europe with 2,500 hours of sun per year (Tourist Office, n.d.).

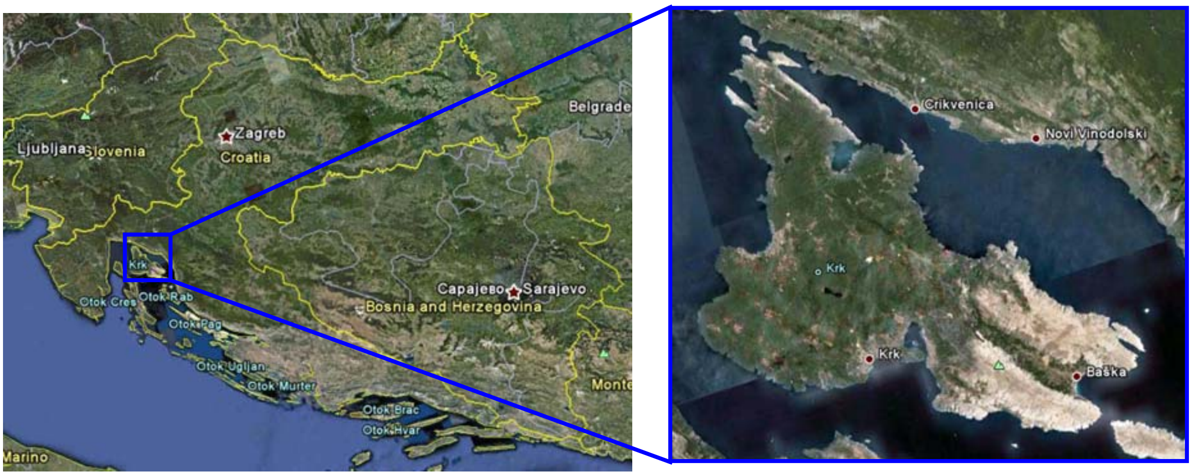

Figure 4.1. Location of island Krk[6]

The brief history of island Krk is stated in the following paragraph (www.krk-croatia.com, 2002):

> The first known settlers of the island were the Illyrian tribes of the Japods and Liburnians, followed by the Greeks in the times when Krk belonged to the Electride, i.e. Apsirtide islands, today known as the Kvarner islands. The Romans gained full control by the 9th century A.D. Meanwhile, the Croats began settling the island as early as the 6th century, and eventually became the island's major population. Christianity reached the island early. Hence, a bishopric was established in the 5th century A.D. with the town of Krk as its seat and Andrew, the first known bishop (680 A.D). The Croats settled the island in family groups that lived within castles scattered throughout the island, which resulted in a variety of Chakavian dialects. The four main dialects are known as the "cha", "che", "cho" and "tza" varieties. Towards the end of the 12th century, a powerful local family comes on the scene: the Counts of

[6] Source: Google Earth, images taken in the period from 2005-2010

> Krk, later known as the Frankopans. This was the only family coming from an Adriatic island that developed and prospered into one of the most powerful in Europe. Their origins can be traced to Vrbnik, from which they spread their power and territories to the mainland: Trsat, Bakar, Kraljevica, Crikvenica, Novi Vinodolski, Otocac, Brinje, Modrus, etc. At the height of their power they possessed territory equal to half of today's Croatia. Some counts of the Frankopan family became Croatian viceroys ("ban") with great political influence. The first Frankopan mentioned was Dujam I (1118 A.D.) and the last Fran Krsto who was executed in 1671 by the orders of the emperor and king Leopold Habsburg. The island came into Venetian possession in 1480, as the last of the Adriatic islands to fall under their reign. Count Ivan Frankopan was deceived and taken prisoner. After the fall of the Frankopan family in the 15th century, Krk witnessess many different reigns: the Venetians, French, Austro - Hungarians, Italy, Germany and Yugoslavia. Finally, after five centuries, Krk again becomes an integral part of the Croatian corpus. The Republic of Croatia was proclaimed in 1991.

As already mentioned, Krk is situated in Kvarner Gulf and therefore is a part of Kvarner area. More than 2,700 different plant species are found in this area, which makes Kvarner one of the richest in whole Croatia. "Some of the Kvarner islands (Krk, Cres, Lošinj), with more than 1,300 plant species, exceed the number of plant species found in some European countries. The richest in plant species are: the island of Krk, with some 1,500 species while in relative terms (in proportion to its surface) the island of Unije, where as much as 629 plant species grow on a surface of only 16 km^2" (The Kvarner County Tourism Office, n.d.). On the island Krk birds such as eagles, falcons, owls, hawks and many others can be found. In the terms of mammals Krk, next to island Cres and Rab, is one of the richest Mediterranean islands. Also, Krk is an island with the greatest number of reptiles and amphibians in the Mediterranean area.

"The population of the island, at the last count, was 16,402, distributed among 68 settlements" (Tourist Office, n.d., p. 5). However, when the island is in the tourist season period, the number of people residing in one moment on the island can amount more than 100,000 which can be seen from the Figure 4.2. This is a great burden for the islands infrastructure and the environment. In the month July of last year, there were 181,720 arrivals of which 171,089 is international (The Island of Krk Tourist Board, n.d.). Compared to the same period of the previous year, the increase of more than 9 percent can be observed. As for the overnight stays, in July 2010 there were 1,123,379 stays. The number of international ones was 1,058,679. The structure regarding the countries from which the tourists came from, the biggest part is Slovenia with 24.11 percent, followed by Germany (17.33%), Austria (9.90%), Czech (8.85%) and Italy with 7.27 percent (The Island of Krk Tourist Board, n.d.).

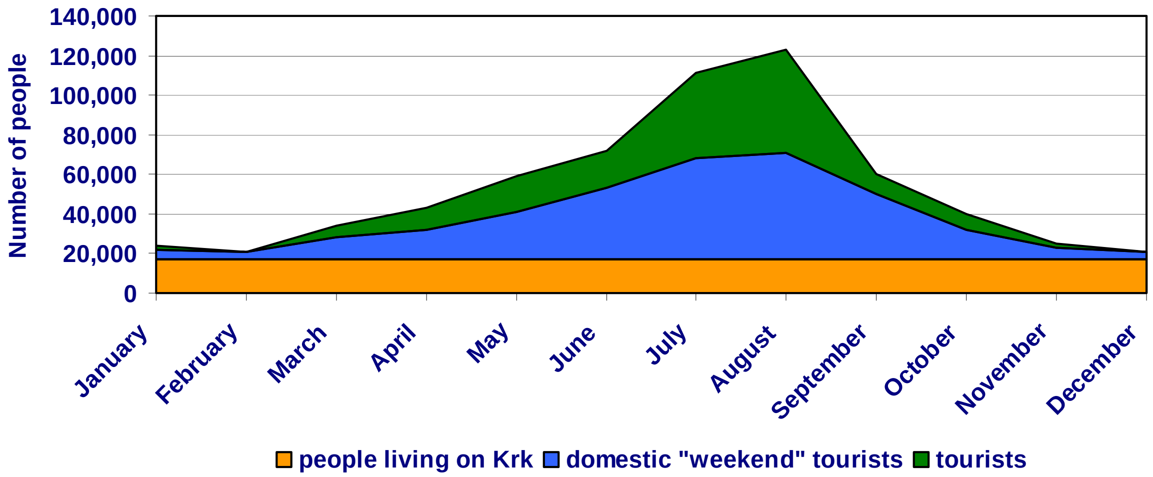

Figure 4.2. Annual guests inflow of the island Krk[7]

[7] Source: Josipovic, Knaus, Rosenthal, & Melis, 2010, p. 1

4.2. Energy Demand

The energy demand of island Krk is shown in the Table 4.1. To be more precise, the table displays the amount of low and middle voltage load electrical energy sold to the consumers. The data is shown for the year 2010 and it is stated in MWh.

January	February	March	April	May	June	July	August	September	October	November	December	Total
10,019	8,933	7,456	9,643	9,342	10,500	13,119	13,604	10,780	9,024	8,440	9,341	120,201

Table 4.1. Low and Middle voltage Electricity sold to Consumers for 2010 on Krk, in MWh[8]

From the table it can be clearly seen that the peaks of electricity demand are in high winter and in high summer seasons. The one reason could be that in winter period inhabitants are using electrical energy for the heating purposes due to the fact that there is no gas grid installed on the island. The other possible reason is that in summer season there are more people on the island due to the tourism activities which leads to the increase in electricity demand. Consequently, the demand for the electricity in the stated periods is around 10-20 percent higher then in the other periods of the year. For the year 2010, the total electricity demand of the whole Krk island was around 120 GWh (HEP: Stanic N. personal communication, May 19, 2011).

4.3. Water Demand and Wastewater Management

Table 4.2. displays the water amounts which was captured for the area of the whole island Krk in the year 2010. It has to be noted here that the amount of water sold to the consumers is approximately 21 percent lower than the figures stated in the table (Ponikve:

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[8] Source: HEP: Stanic N. personal communication, May 19, 2011

Giorgolo S. personal communication, June 27, 2011). This is owing to the fact that the table shows the amounts of water which has been captured from the natural water aquifers on the island. Therefore, the amounts of water sold to the end consumers are lees than these figures. Also, the data for water amount sold to the industries for industrial uses is also listed in the table. In the year 2010, if the 21 percent reduction is applied, the water demand for the whole Krk island was around three million cubic meters.

2010	January	February	March	April	May	June	July	August	September	October	November	December	Total
Ponikve	113,315	96,528	113,273	128,993	162,815	226,156	330,215	333,429	157,416	108,453	84,723	99,523	1,954,839
Old Baska	0	0	0	0	0	0	2,167	2,457	1,170	1,104	629	453	7,980
Baska	12,476	9,425	14,762	22,352	30,407	50,988	86,317	93,432	41,546	17,811	10,475	9,482	399,473
Paparata	658	700	1,120	1,627	1,219	2,326	5,972	5,701	1,170	1,129	802	750	23,174
Ogreni	459	375	628	837	644	733	531	210	257	447	464	473	6,058
ViK Rijeka	628	0	946	13,632	4,691	26,293	115,443	106,051	52,077	32,685	24,705	14,734	391,885
TOTAL (without industrial water)	127,536	107,029	130,729	167,440	199,777	306,496	540,645	541,280	253,636	161,628	121,798	125,414	2,783,408
Industrial water	63,717	58,090	45,142	42,209	44,460	62,458	79,502	111,448	134,304	139,664	120,130	126,295	1,027,419
TOTAL	191,253	165,119	175,871	209,649	244,237	368,954	620,147	652,728	387,940	301,292	241,928	251,709	3,810,827

Table 4.2. Amount of Water Captured for 2010 on Krk, in m^3[9]

In the Table 4.3., wastewater data for the area of Krk island is given. The data is for the year 2010 and it is stated in cubic meters. In this period, around two and a half million cubic meters of wastewater is collected and discharged. The process of collection and treatment of wastewater is as follows (Ponikve: Giorgolo S. personal communication, June 27, 2011). For the mechanical treatment, after being collected the wastewater is exposed to a fine mash. Further, sand, oils and greases are separated. Then, the wastewater is aerated. Finally, it is discharged into the deep sea. Clearly, this is far from a sustainable wastewater management.

[9] Source: Ponikve: Giorgolo S. personal communication, June 27, 2011

2010	January	February	March	April	May	June	July	August	September	October	November	December	Total
Baska	82,348	62,510	56,089	51,207	35,882	48,292	70,590	80,787	45,112	24,429	100,215	109,100	766,561
Malinska	26,732	27,301	45,696	16,297	25,105	37,330	56,416	97,606	32,590	29,007	83,264	65,062	542,406
Punat	112,560	48,514	40,699	12,131	28,607	42,800	54,131	39,194	24,635	20,497	75,783	50,947	550,498
Krk	74,838	31,035	29,758	22,125	26,908	33,448	34,949	41,461	27,259	31,274	46,518	40,014	439,587
Omisalj	21,274	6,540	11,018	10,446	8,405	7,100	6,910	7,665	6,011	8,290	13,678	15,082	122,419
Njivice	7,966	3,823	2,568	4,118	6,433	10,714	20,501	21,865	10,320	5,051	7,680	6,908	107,947
TOTAL	325,718	179,723	185,828	116,324	131,340	179,684	243,497	288,578	145,927	118,548	327,138	287,113	2,529,418

Table 4.3. Amount of Wastewater Discharged for 2010 on Krk, in m^3[10]

4.4. Waste Production and Waste Management

On the whole Krk island, Ponikve Krk d.o.o. is the only waste, water and wastewater management company. In the terms of waste, it is responsible for the collection, treatment and disposal of the municipal solid waste. Regarding water and wastewater, as can be observed from the preceding subchapter, it is providing the island services of capturing and supply of freshwater and collection and disposal of wastewater.

In the year 2005, on the island Krk the waste management system based on ecological concepts was founded. It was named "Eco island Krk". It presents the holistic model of waste management with the ability to treat all sorts of waste. Therefore, in order for this system to function, on the whole Krk area 7,000 garbage bins on 1,400 different l0 locations were placed. Furthermore, municipal solid waste is collected separately, through five different types of bins. These five types of bins are for different kinds of waste; namely, organic (bio) waste, paper, plastics, glass and other waste. Also, in the island there are seven special waste collection locations where people who live on the island can dispose of bulky house waste, such as old furniture, old electronics, car wrecks and tires, and similar. These locations are located in Omisalj, Malinska, Krk, Punat, Baska, Vrbnik and Dobrinj municipalities. Annual

[10] Source: Ponikve: Giorgolo S. personal communication, June 27, 2011

amount of waste collected on the island amounts up to 20,000 tones, out of which 12,000 tones are collected in the summer period. On the date March 31, 2010, there were total of 88 employees employed. From this figure, 53 of them were working on transportation of waste, 27 on the positions in the recycling center and waste disposal and 8 of them in the special waste collection locations. Currently, the fraction of waste which has been collected separately is around 30 percent. The central location for waste collection, treatment and disposal is Treskavac. There, the waste is treated appropriately, prepared for recycling and ultimately disposed using the most modern waste disposing methods (Ponikve d.o.o., 2010b).

Figure 4.3. displays the location of the waste management center Treskavac on the Krk island. Its central location is interesting for the logistics purposes.

Figure 4.3. Location of the waste management center Treskavac[11]

In the Figure 4.4., the amounts and structure of waste collected on Krk in the year 2009 can be observed (Ponikve d.o.o., 2010a). The amounts of waste are given in tones. The Figure 4.5. shows the structure of the same amounts of waste which were collected.

[11] Source: Google Earth, images taken in the period from 2005-2010

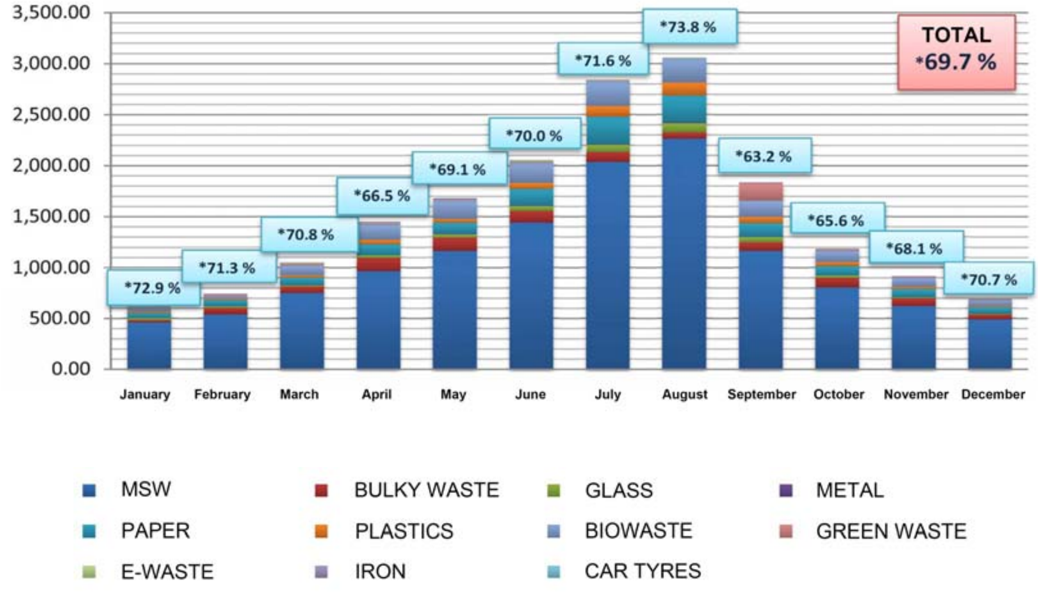

Figure 4.4. Amounts and Structure of Waste collected for 2009 on Krk, in tones[12]

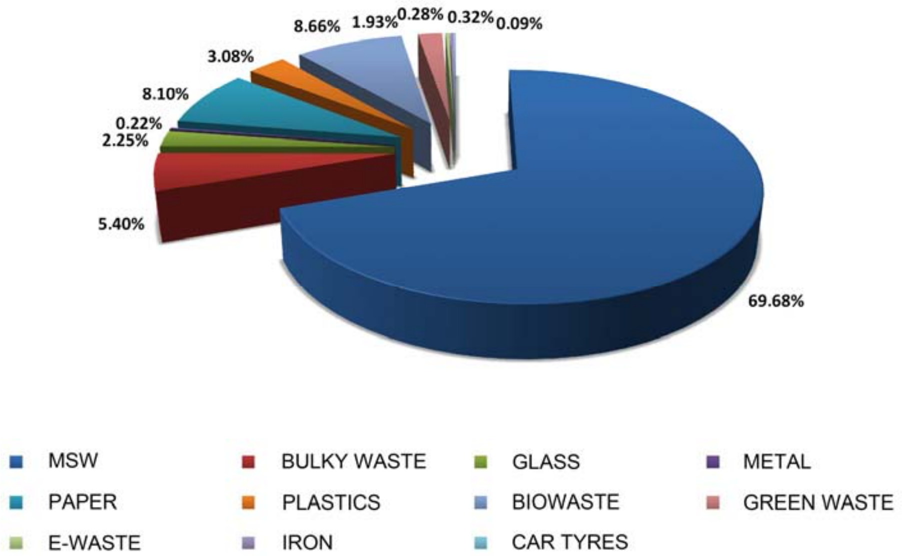

Figure 4.5. Structure of Waste collected for 2009 on Krk, in tones[13]

Additionally, on the island Krk there are a few different processing industries which are generating special waste according to their processing activities. These industries are two

[12] Source: Ponikve d.o.o., 2010a
[13] Source: Ponikve d.o.o., 2010a

fish processing industries, olive oil producing industries, wine producing industries and poultry producing company. More about the potential which could be derived from their residues will be given in the next chapter.

4.5. Environmental Problems of the System

Environmental problems of the current system are manifold. First of all, all the waste collected after being treated to one extent is berried in the landfill Treskavac. This extent of treatment could be extended with the biogas production facility which would consequently lead to a less burden on a landfill scarce space. Second, with the increased arrival of tourists on the island, there is an increase in the energy demand. This demand for energy could also be satisfied to one degree with the electricity generated from biogas plant. Third, wastewater is being discharged deep in the sea. All these problems are causing huge emissions of greenhouse gases. There are many other problems, but mitigating just these few, would bring a better situation to a system.

4.6. Conclusion

Due to all these problems mentioned above, appropriate solutions need to be implemented. Altering the system would bring many benefits. The financial savings from the reduction of costs for disposal of waste and income of sold electricity to a grid from biogas power plant are examples. Moreover, a great amount of CO_2 emissions would be decreased. Next part of the paper will list possible solutions and impacts they will have.

5. New Solutions

This part of the paper will handle the new solution which needs to be implemented in order to alter the BAU system. First, the technologies for optimum waste and water which are highly reducing the GHG's emissions will be stated. Then, the detailed analysis of Krk island's potential will be given. Afterwards, the investment needed for its implementation will be provided. Next, the amount of greenhouse gasses emissions which would be saved will be calculated. Finally, the chapter will conclude with few remarks about overall environmental aspects.

5.1. ZE Technology in Water and Waste

As mentioned in previous chapters, the technologies with efficient waste and wastewater treatment methods are available. Therefore, municipal solid waste could be treated in a manner to obtain biogas. This biogas could later on be used to drive the turbine which would ultimately produce electrical energy. Also, wastewater could be treated in a way to be clarified of all unwanted and toxic substances and ultimately be used for irrigation purposes.

Treatment of waste in order for biogas to be produced was already mentioned. Detailed figures about its generation and energy potential will be given in the next part. Here, more information about wastewater treatment will be provided.

The wastewater usually contains water from cleaning, laundry washing, food preparation, etc. After being collected, at the end of the process it is drained in the nearby river or sea. As major cities started rapidly to grow and as the population of it inhabitants significantly started to increase, more and more of wastewater is being generated. The same is happening with the increased arrival of the tourists to a specific location. Due to this increase of people in a system, industrial and hospitality activities are also increasing and consequently more waste is being produced. Therefore, it is of the great importance to introduce some kind of wastewater treatment technology to preserve the system's limited surrounding water area into which the sewage is directed.

The purpose of wastewater treatment is to remove all kinds of unwanted materials from the water before it is discharged into sea or river. These materials are organic matter, nutrients, all kinds of solids, for example plastics, than other pollutants and disease causing organisms. Wastewater is treated basically in physical, biological and chemical manner.

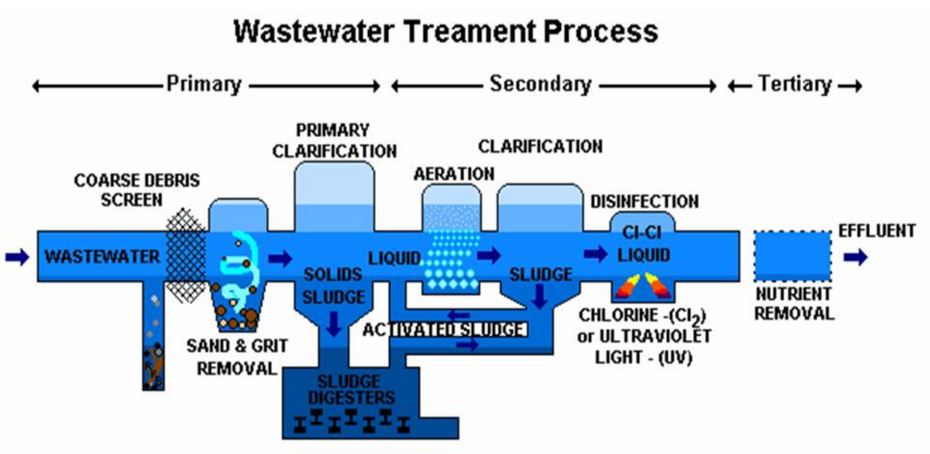

Figure 5.1: Wastewater treatment process[14]

Process of wastewater treatment is described in the Figure 5.1. It starts with primary treatment where all coarse debris that are found in wastewater, such as plastic, wood, and metal are removed. At the beginning of the process, wastewater is simply run trough parallel slanted steal bars which serve as a filter to capture before mentioned large particles.

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[14] Source: http://www.awag.org/Education/Wastewater_Treatment_Diagram.jpg, Retrieved June 17, 2011

Following operations include removal of the sand and grid and, as a last process in primary stage, separation of the solid sludge into sludge digesters where it is treated additionally.

Next is the secondary stage in which wastewater is treated biologically in order to remove dissolved organic matter with the help of microorganisms. Microorganisms are using the organic matter as food and as they are feed they are growing in size and number. In this way sludge is formed, settled out and removed as activated sludge to be treated. Last part of the secondary stage is removal of the disease causing organisms. "Treated wastewater can be disinfected by adding chlorine or by using ultraviolet light. High levels of chlorine may be harmful to aquatic life in receiving streams. Treatment systems often add a chlorine-neutralizing chemical to the treated wastewater before stream discharge" (Mancl, n.d.).

Final, tertiary stage of wastewater treatment process is the nutrient removal stage. "Ammonia nitrogen, like phosphorus is a nutrient which can promote the excessive growth of algae and aquatic plants which may disrupt the natural ecological balance of the receiving water. Nitrification is an aerobic biological process whereby nitrifying bacteria convert ammonia first to nitrite and subsequently to nitrate" (Environmental Services Department, n.d.).

Clarifying wastewater before it is discharged into nearby river or sea is beneficial in two aspects. First of all, wastewater is cleared of all unwanted substances before it is returned to water natural cycle. Secondly, from removed material sludge is obtained which can be after being appropriately treated returned to soil in order to enrich it with valuable nutrients.

5.2. Tentative Potential Analysis

The data about municipal solid waste, organic waste and biomass production from all the waste generation subjects were collected and analyzed. After a thorough analysis, exact figures about the quantity and precise information about the quality of the residues out of which energy could be generated, was obtained. On the basis of these data, the feasibility study for a biogas plant installation was conducted. The detailed findings (Josipovic, et al., 2010) based on mainly primary data collection and analysis, are as follows (the tables containing detailed data and calculations throughout the year are given in the appendices part of this paper).

First of all, the amount of organic waste which is collected by the local municipal waste collecting company generated on the whole area of the island Krk is around 1,250 tones per year. From this amount, yearly about 70,000 cubic meters of methane could be produced. Second, the two fish processing companies generate around 340 tones of organic residues per year out of which about 27,000 cubic meters of methane per year could be obtained. Third, both of the wine processing companies are producing around 300 tones per year of organic residues which yearly amount for 51,500 of methane. Further, the greenery waste residues generated from trimming and maintenance of the local municipalities' areas are accounted for 350 tones per year out of which around 29,000 cubic meters of methane per year could be obtained. Next, the olive oil producing company with its 400 tones of organic residues per year has the potential of generating 66,000 cubic meters of methane yearly. Then, the potential of methane which could be generated out of collection of waste oils and grease on the area amounts up to 300,000 cubic meters per year. Last is the veterinarian station which yearly collects up to 2,400 tones of slaughter and animal corpses waste out of which around potential 80,000 cubic meters of methane could be obtained.

When all the yearly potential methane production adds up, the figure of around 630,000 cubic meters of methane is obtained. This methane has the potential of generating 6,300,000 kilowatts per hour of energy. Out of this figure, around 40 percent of electricity could be supplied. Also, some of the generated energy could be obtained in the form of thermal energy. To be more precise, out of these renewable energy sources, around 2,100,000 kilowatts per hour of electricity and about 630,000 of thermal heat could be generated.

At this point, these figures can be compared to the whole electricity and thermal heat energy supply of the whole Republic of Croatia. For the purpose of this study, only the electrical energy will be compared and analyzed. The country's electricity supply in the year 2008 was around 18,000,000,000 kilowatts per hour (Vuk et al., 2009, p. 38). Putting it in relation to the country's whole electricity supply, the electrical energy generated from proposed biogas plant accounts for around 0.012 percent. Taken in consideration that in the Republic of Croatia there are around 8 of the same size systems with similar potential such as island Krk, if the proposed technology would be implemented in each of these systems, the total electricity generated would increase to around 1 percent of the country's whole electrical energy supply.

The last few sentences are just the rough estimate for the whole system of the Republic of Croatia. However, in the system of Krk island, the implementation of proposed technology would contribute to the energy field as follows. If the electricity which could be generated from the installation of biogas power plant is put into relation to a previous stated figure of Krk's electricity demand, the ratio of 0.0175. To be more exact, around 2,100,000 kWh of electricity which could be generated is around 1.75 percent of the total electricity demand of the Krk island. The efficacy could be enhanced even more if the heat generated from the generation of electricity is accounted for. Moreover, other renewable energy sources, such as solar and wind power could be tapped according to same principles in order for system to advance to even higher level.

5.3. Tentative Investment

For the proposed technology to operate in its optimum, it has to be noted here that the above mentioned potential implies the installation of biogas power plant and cogeneration unit with the installed power of 350 kWh_{el}. The data about the specific installation costs are taken from Josipovic, et al (2010, pp. 24-25) and are as follows.

The cost to install one kW_{el} of biogas power plan is 2,800 EUR. For the installation of 350 kWh_{el}, this would imply the investment of 980,000 EUR. Further, the installation of the cogeneration unit of the same installed power would cost additional 245,000 EUR (700 EUR/ kW_{el}). Next, to have a steady production of biogas throughout the year, the collected old oils and greases need to be stored in appropriate tanks in order to be used in winter months for fermenting purposes. The installation of collection tank of this kind costs 306,250 EUR. Finally, the costs of project development and procurement of all needed permits are 250,000 EUR. All these costs added together accumulate to 1,781,250 EUR.

5.4. Tentative CO_2 Savings

To be able to calculate the CO_2 saving which could be achieved if the proposed project would take place; few conditions need to be taken in account. First of all, the time frame for this project needs to be established. The lifetime of this project is assumed to be 20 years. Next, the Carbon Emission Factor (CEF) needs to be agreed upon. CEF needs to be considered to provide for the appropriate comparison between greenhouse gasses emissions which are emitted from the usage of the electricity from the electrical grid and from the biogas generation. Its unit is t_{CO2}/MWh. For the purposes of this study, the CEF of 0.612 t_{CO2}/MWh for the year 2010 in Croatia was taken (EBRD, 2009, p. 1). One final condition needs to be established, and that is the amount of electricity needed for the self drive of the biogas power plant which needs to be omitted from the calculation.

Having all the above conditions met, the calculation is as follows. If the assumption that the 10 percent of total electricity generated by the biogas power plant which is needed for its own operation is considered, net electricity produced during the life time of a project which is 20 years, is 38,228 MWh (Josipovic, et al., 2010, p. 30). If now CEF of 0.612 t_{CO2}/MWh is applied to this figure, the number of 23,396 t CO_{2e} is obtained. This result is interpreted as 23,396 tones of greenhouse gasses which are equivalent to the greenhouse potential of CO_2 being mitigated by implementing this technology.

5.5. Overall Environmental Aspects

It is obvious that the waste and waste problems were here from the beginning of mankind. However, only nowadays it is becoming a large problem due to the fact that the urban areas and population living in them is increasing rapidly and that the movement of people mainly for tourism purposes is growing. In a result of that, more waste is generated but also, more energy and materials are needed for the normal human functioning. Therefore, it is of the great relevance to analyze the current state of one such an area in the terms of waste generation and resource demand and try to find the appropriate solution in how to make energy and material used more sustainable. The new waste management concepts, adequately implemented, can serve as providers of a more efficient use of the scarce resources.

To make new technologies be more efficient a good management strategy has to be developed. A few methods for material recovery and energy production combined together can make the material and energy flow of one area more efficient and sustainable. This is the basic concept of a circular economy approach on which basis a new models for waste management can be build.

Nowadays, more and more municipalities and urban area are realizing the potential their region has in the terms of waste and they are willing to invest in new technologies and methods for the purpose to harvest the potential they have. In other words, they want to implement new urban waste management. On the one hand, the potential of waste is utilized and significant financial benefits are made. On the other, environment and the surrounding area are preserved as well. Only these new approaches to the real waste problems will, in the long run, result in the preservation of fragile and beautiful nature.

6. Conclusion

In this part of the paper an appropriate conclusion will be provided. First of all, a section with the list of next steps will be dealt with. Here, a brief insight in all the actions taken so far will be given. Afterwards, some suggestions and proposals for future development will be provided. Next, the current framework, future strategies and objectives regarding the use of renewable energies in Croatia will be handled. Here, all the necessary information about the energy sector will be given, such as market conditions, existing strategies and objectives, important institutions and similar. At the far end of this part, adequate final remarks will be provided.

6.1. Next Steps

This study has shown that there is a huge potential present in the system of island Krk. This potential is seen in primary the waste which is generated on the island. Study shown that the waste could be utilized in order to provide a source for a part of energy demand of the system. Consequently, by using waste as a resource, the reduction in its generation and disposal could be achieved. This would result in the decrease of the pressure on space of the only one landfill on the island, Treskavac.

First next step to take after this point is to embark on a detailed and precise feasibility study for installation of biogas power plant on the island. This would contribute to the increase of awareness of all the relevant stakeholders of the system. Here, not only people managing and living on the island are included. It embraces also the tourists which are arriving from all the places of the globe. By implementation of the new ideas and technologies, the example of how improvement could be achieved is shown. In result, bit by bit people will accept and acknowledge new solutions and provide much needed support.

After implementing proposed biogas power plant, further detailed analysis of the systems' potential needs to be conducted. It could encompass the energy potential of sun and wind, include the change in the wastewater management and similar. All this potential compared to the greenhouse gases emissions without its utilization, should be accounted for in order to attain the zero emissions island objective.

6.2. Current Framework, Future Strategies and Objectives

With the establishment of sovereign and independent Republic of Croatia in the beginning of the 1990's and after the five year war on its territory, the country started to recover both economically and politically. On the one hand, from the economic perspective, Croatia's economy had constant growth and consequently brought with it the increased demand for energy. On the other, its political strengthening led to the opening of the accession negotiations with the EU. All these factors resulted in the necessity of developing and establishing a sound energy strategy which should be in accordance with present global energy and environmental situation.

Because of its small size and low production, Croatia has been, and still is, traditionally imports oriented economy. Current global financial situation and projected future energy prices are reasons why Croatia needs to establish its own energy production. Therefore, it needs to utilize its renewable energy potential in order to become self sufficient country energy wise. Also, Croatia is currently in the process of becoming a full fledged EU member; therefore, it has to meet all the European guidelines in general as well as those regarding energy production and consumption. Furthermore, tourism is one of Croatia's most important revenue generators. It is mostly based on natural beauty, coast and sea, national parks and pristine nature. To preserve these staples of Croatian tourism, it is paramount that Croatia obtains as much of its energy as possible from RES. Also, the usage of eco friendly energy sources will reduce CO_2 emissions and contribute to establish Croatia as a "green tourist" destination.

6.2.1. Market Conditions of Electricity Sector in Croatia

To begin with, some basic figures about the electricity sector of the Republic of Croatia have to be introduced. From the Figure 6.1., data about Croatia's total electricity supply can be seen according to the source of production and import.

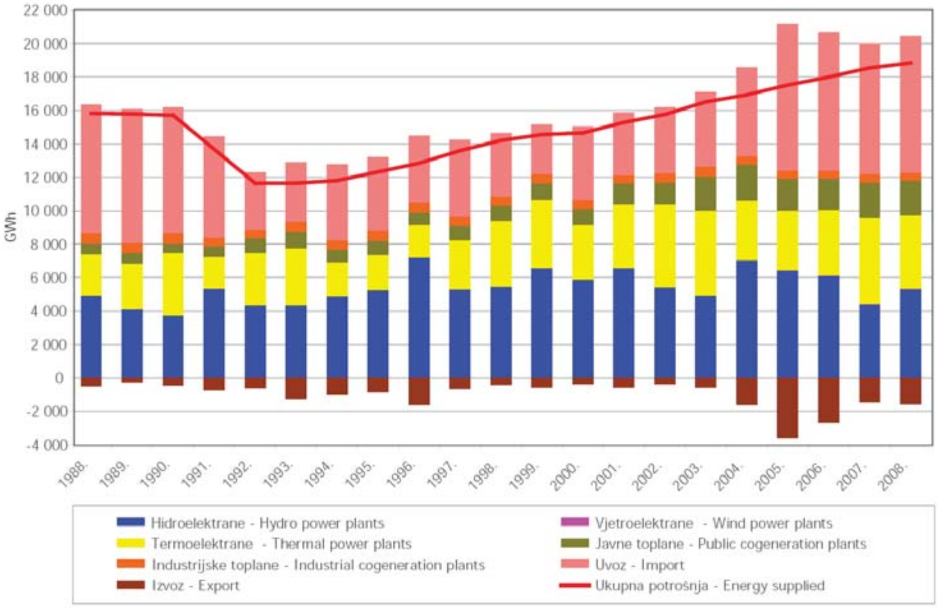

Figure 6.1. Electricity Supply in the Republic of Croatia[15]

From the Figure 6.2., the electricity consumption in Croatia can be observed. Both gross and net consumption are displayed with related transmission and distribution losses. "In

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[15] Source: Vuk et al., 2009, p. 173

2008 Croatia had the highest electricity consumption ever, with gross electricity consumption of 18,902.5 GWh and net electricity consumption of 17,196.2 GWh" (Vuk, et al., 2009, p. 38).

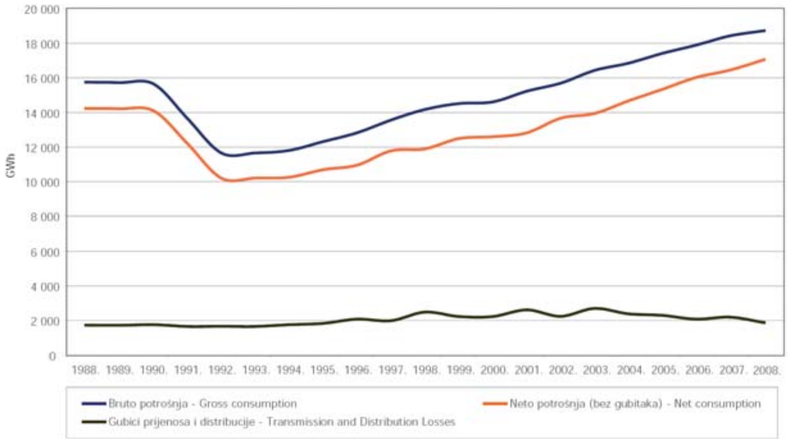

Figure 6.2. Electricity Consumption in the Republic of Croatia[16]

Electricity consumption by sectors in the republic of Croatia is displayed in the Figure 6.3. Here can be noted that service sector and households are responsible for the most electricity consumption.

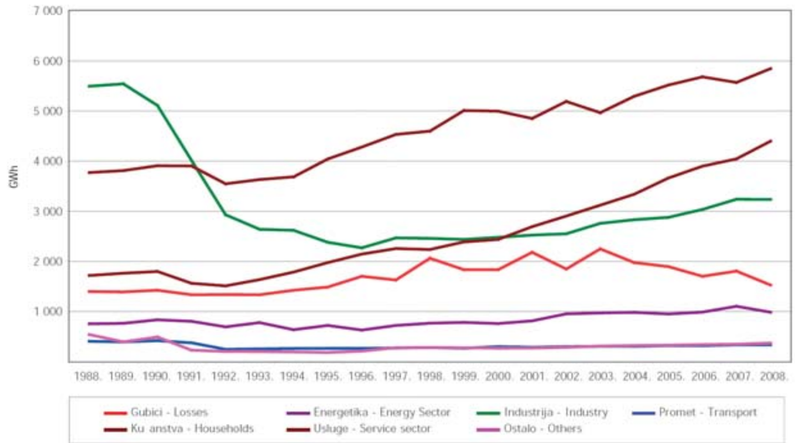

Figure 6.3. Electricity Consumption by Sectors in the Republic of Croatia[17]

[16] Source: Vuk et al., 2009, p. 37
[17] Source: Vuk et al., 2009, p. 81

Figure 6.4. gives the data about the available electricity generation capacity for the Republic of Croatia. Here can be seen that the best available electricity generation capacity is from Hydro and Thermal Power Plants.

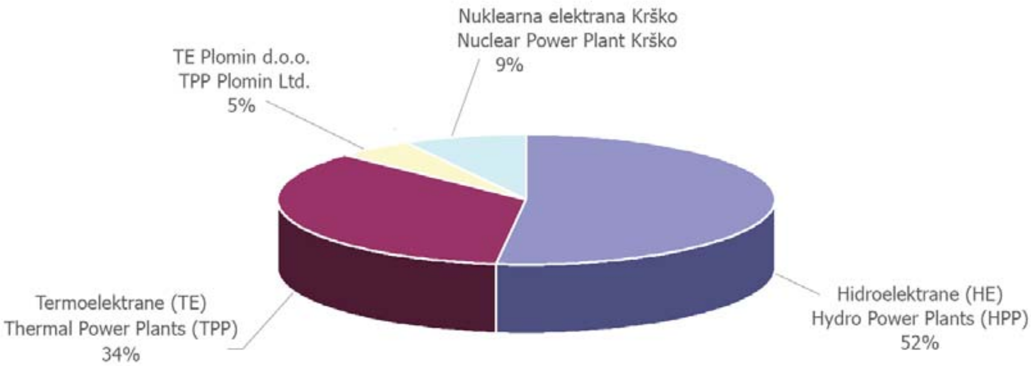

Figure 6.4. Available Electricity Generation Capacity for the Republic of Croatia[18]

From the Table 6.1., a brief summary of the electricity generation from RES in Croatia can be obtained. The total electricity generation form RES amounts up to around 155 GWh.

Vrsta izvora Type of renewable energy source	Proizvodnja električne energije Electricity generation
Sunce Solar	62.65 MWh
Vjetar Wind	39.9 GWh
Biomasa Biomass	21.1 GWh
Male hidroelektrane Small hydro	94.8 GWh
Geotermalna Geothermal	0
UKUPNO TOTAL	155.86

Table 6.1. Electricity Generation from RES in the Republic of Croatia[19]

[18] Source: Vuk et al., 2009, p. 165
[19] Source: Vuk et al., 2009, p. 204

From all these above given data, it can be easily concluded why Croatia needs to develop the generation of electricity from RES to the greatest extent possible. Due to the fact that its demand for electricity is growing and that the price of electricity will increase in the near future, it is of the highest importance to utilize the country's renewable energy potential.

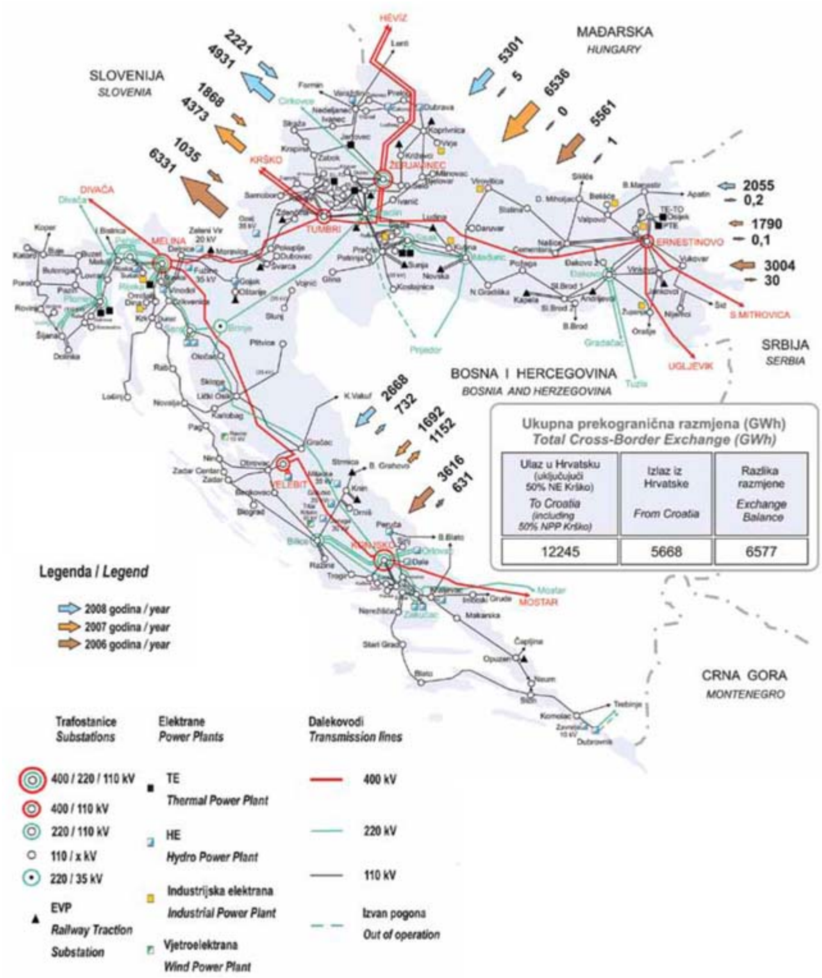

Figure 6.5. Electrical Network of the Republic of Croatia in the Year 2008[20]

Figure 6.5. displays Croatia's electricity grid with all its relevant information. It also provides the total cross border exchange with all the neighboring countries except for Montenegro.

[20] Source: Vuk, et al., 2009, p. 171

6.2.2. Existing Energy Strategies

The first and foremost important objective in Croatia's energy strategy is to fulfill the requirements of the EU relating energy sector. Croatia opened the chapter on energy in early 2008 as part of the accession process to the EU. For this purpose, it established the fundamental act governing country's energy policy and energy system; so called the "Energy Sector Development Strategy". "The Croatian Parliament, on the proposal of the Government of the Republic of Croatia, passes Energy Sector Development Strategy for a ten-year period" (Stanic, 2009, p. 4). From HROTE (2009a, p. 1/71) it can be observed that the last Energy Sector Development Strategy document was passed on October 16, 2009.

As Grewal and Ipek (2009, p. 3) rightly state:

> The main legislative changes date back to 2001 in order to help the market function properly. For instance, a new grid code has been defined, cross country capacity allocations have been drawn to a more competing environment and new rules easing the liberalization have been set out. These legislations have been also designed in line with the EU legislations with the target of full EU membership. By signing the Athens Memorandum initiated by EU in 2002 with the South East European countries, the country has been in the process of further integration with the South East Europe Regional Energy Market (SEEREM) and also outside the region. Connection of Croatia through The Union for the Co-ordination of Transmission of Electricity (UCTE) to the rest of Europe allows the country to enter into electricity trading while diminishing the imbalances between markets to some extent. The vertical and account unbundling has been completed by dividing the integrated HEP into three units: generation, transmission and distribution.

Furthermore, on July 1, 2007 the Feed- in tariff system for the generation of electricity from RES came in force after its passing by the Government of the Republic of Croatia. According to (Stanic, 2009, p. 17) this Feed-in tariff is regulated by five sub laws. These are:

(1) Regulation on incentive fees for promoting electricity production from renewable energy sources and cogeneration, (2) Regulation on the minimum share of electricity produced from renewable energy sources and cogeneration whose production is incentivized, (3) Tariff system for the production of electricity from renewable energy sources and cogeneration, (4) Regulation on use of renewable energy sources, and (5) Regulation on becoming eligible producer.

The incentive fees for electricity consumers could be summarized as follows (Stanic, 2009, p. 18). Each consumer pays an extra RES fee for every kWh spent. For the year 2008, each consumer had to pay 0.0089 Croatian kunas (HRK) per kWh, which converted to Euros is 0.12 EUR cents. This would generate a monthly increase in electricity bill for an average household of 0.27 to 0.55 EUR.

In brief, the tariff system can be observed from the Table 6.2. Note that the figures in the Table are given in HRK (in the table, next to the heading "Tariff", the abbreviation "kn" in the parentheses stands for HRK) and that one HRK equals to 0.13 EUR.

RES	**Tariff (kn)**	
	Installed Capacity **below 1MW**	Installed Capacity **above 1MW**
PV	2.10 - 3.40	-
Small Hydro	0.69	0.42 – 0.69
Wind	0.64	0.65
Biomass	0.95 – 1.20	0.83 – 1.04
Geothermal	1.26	1.26
Other	0.60	0.50

Table 6.2. Feed-in Tariff System in the Republic of Croatia[21]

[21] Source: Stanic, 2009, p. 20

6.2.3. Important Institutions in Croatia's Energy Sector

When it comes to electricity sector of the Republic of Croatia, Croatian Electro-Provision company (HEP) is one of the key institutions. Also, Croatian Energy Market Operator (HROTE) and Croatian Energy Regulatory Agency (HERA) are the two organizing, regulatory and controlling institutions. In few following paragraphs these companies will be introduced in more detailed manner.

HEP is a national electricity company which has been engaged in electricity production, transmission and distribution for more than one century. It is organized in the form of a holding company with a number of daughter companies. The parent company performs the function of HEP Group corporate management and guarantees the conditions for the secure and reliable electricity supply to customers. It has 4,000 MW of installed capacity for electricity production. Within the company there are 25 hydro power plants and eight thermal power plants fired by oil, natural gas or coal. Some of them produce both electricity and heat in a combined-cycle. Also, electricity in Croatia is produced by thermal plant Plomin, a company co-owned by HEP and RWE Power which operates a 210 MW thermal power plant, and industrial power plants and private owners of small renewable energy sources. HEP is a co-owner of Krško Nuclear Power Plant in Slovenia. HEP Renewable Energy Sources deals with preparation, construction and use of renewable energy sources such as wind, small waterways, geothermal water, etc (HEP, n.d.).

HERA is an autonomous, independent and non-profit public institution which regulates energy activities in the Republic of Croatia. HERA's obligations, authorities and responsibilities are based on the Act on the Regulation of Energy Activities, the Energy Act and other acts regulating specific energy activities. The founder of HERA is the Republic of Croatia and the founding rights are exercised by the Government of the Republic of Croatia. HERA is responsible for its work to the Croatian Parliament. Fundamental goals of regulation of energy activities are the following: (1) Ensure objective, transparent and non-discriminative carrying out of energy activities, (2) Take care of the implementation of principles of regulated access to the network/system, (3) Adoption of methodologies for determination of tariff items of tariff systems, (4) Establishment of efficient energy market and market competition, and (5) Protection of energy consumers and energy operators (HERA, 2010).

HROTE performs activities of organizing the electricity market as a public service, under the supervision of the HERA. HROTE's main responsibilities include: (1) Issuing Electricity Market Rules, (2) Registration of contractual obligations among market participants, (3) Keeping records of eligible customers, (4) Keeping records of suppliers, (5) Preparation of a day ahead market plan, (6) Settlement of balancing energy, (7) Collecting fee for incentivizing the renewables and cogeneration from suppliers and its distribution to eligible producers, and (8) Analyzing the electricity market and recommending measures for its improvement (HROTE, n.d.).

6.2.4. Strategies for Setting the Targets for RES

The strategy of the Republic of Croatia for setting the targets for electricity generated from RES can be defined as to be slanted towards the EU regulative and EU incentive funds. This can be obtained from the following paragraph (European Commission, 2007, p. 6):

> Croatia has not yet set itself a target to increase the share of electricity from renewable energy sources in total electricity consumption, but a draft regulation is expected to bring the share of electricity produced from incentivized renewable energy sources up from 0.8% in 2004 to approx. 5.8% in 2010. For the purpose of providing incentives, Croatia does not take into account RES electricity from large hydropower (capacity of 10 MW or more). However, Croatia states that if one includes large hydropower plants calculated on the basis of their ten-year average

production (6,092 GWh), Croatia's share of RES electricity in 2005 amounted to 34.7% and is foreseen to increase to 36.0% in 2010. Croatia states that due to the short time for implementing its incentive mechanism, it does not consider as realistic to define a more ambitious target than 5.8% for the share of electricity generated from incentivized RES by 2010.

Note that this screening report for energy in the Republic of Croatia was conducted few years ago. In addition to target objectives stated in the previous paragraph, the objectives for individual RES by 2020 are (Croatian Chamber of Economy, 2009, p. 10):

- 1,200 MW electricity-generating capacities in wind parks (2,000 MW by 2030)
- 140 MW electricity-generating capacities in biomass power plants (420 MW by 2030)
- 40 MW electricity-generating capacities in waste-to-energy plants (60 MW by 2030)
- 20 MW electricity-generating capacities in geothermal power plants (30 MW by 2030)
- 45 MW electricity-generating capacities in solar power plants (250 MW by 2030)
- 100 MW electricity-generating capacities in small hydropower plants(140 MW by 2030)

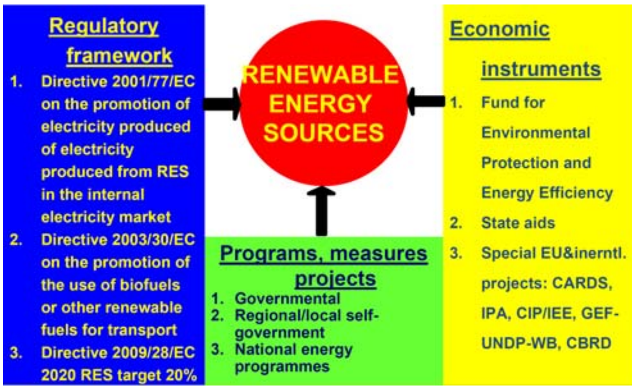

Figure 6.6. Croatian RES Policy[22]

[22] Source: Croatian Chamber of Economy, 2009, p. 15

Figure 6.6. displays all the relevant factors which are determining and influencing the RES policy in the Republic of Croatia. In that way, for the regulatory framework there are a few directives from which, one is determining the RES target for the year 2020. Furthermore, some economic instruments are stated which are backing up the policy. Also, a few programs, measures and projects are established for the implementation of the policy and they are divided into governmental, regional and national.

6.2.5. Legislation and Financing

From the Figure 6.7., institutional framework and the financing scheme can be observed. The diagram is explaining the flow of electricity and related payment in the system. The subjects are eligible producer, HEP, HROTE and consumer.

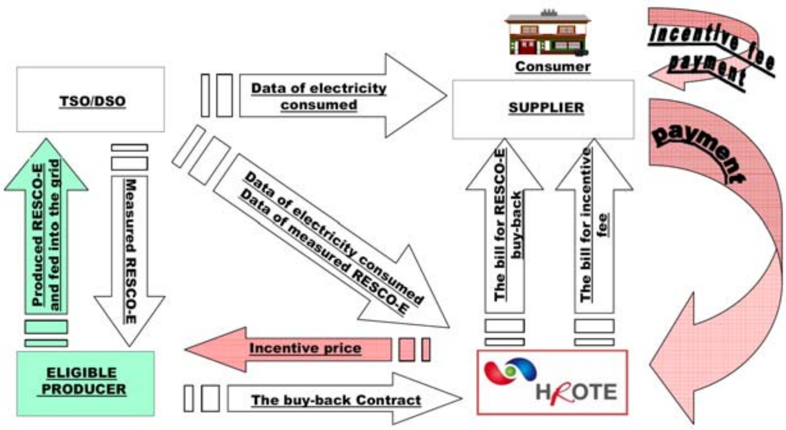

Figure 6.7. RES: Institutional Framework of the Republic of Croatia[23]

Figure 6.8. explains on the simple real example how the distribution and payment of the electricity generated from RES is conducted. The wind power plant is taken as an example for the RES for the electricity production.

[23] Source: Croatian Chamber of Economy, 2009, p. 20

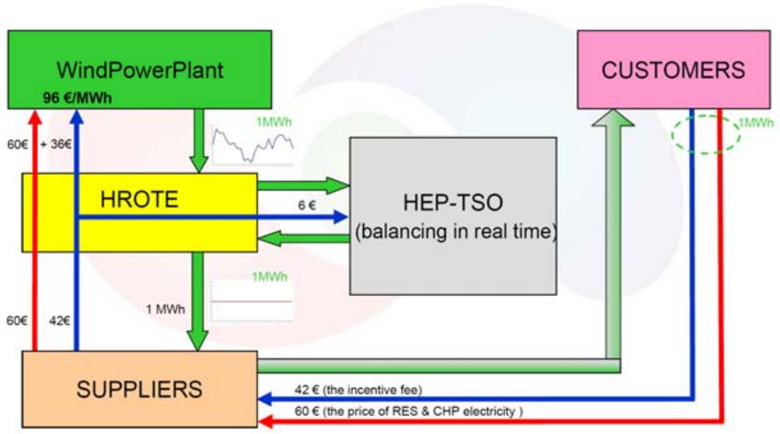

Figure 6.8. Example of Distribution of RES in Croatia[24]

From the Figure 6.9., understanding of the functioning of the economic instruments for RES in Croatia can be obtained. Particularly, the development, the investment and the operating phases are displayed.

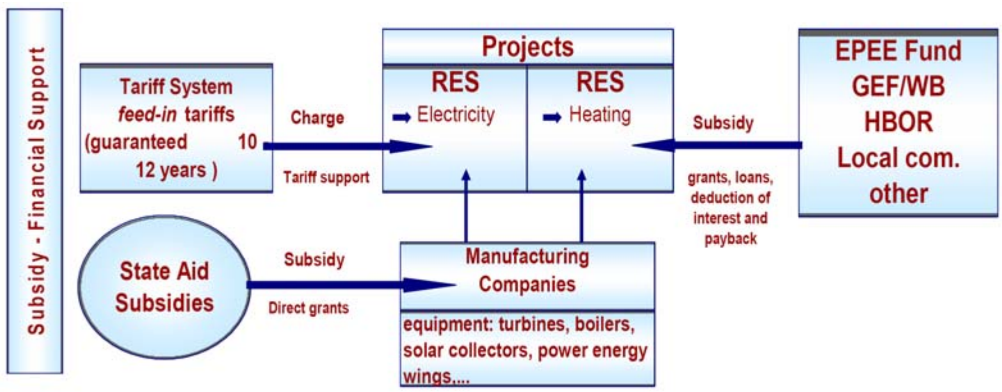

Figure 6.9. Economic Instruments for RES in Croatia[25]

The figure clearly shows that there are more factors which are necessary in order for the RES system in Croatia to work properly. One the one hand, there is a strong financial

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[24] Source: HROTE, 2009b, p. 12

[25] Source: Croatian Chamber of Economy, 2009, p. 29

support coming from the state in the terms of subsidies and the guarantee of price of the feed-in tariffs for a specific period of time. On the other, some key institutions, such as Croatian Bank for Reconstruction and Development (HBOR) with the help of local communities are also providing support. In addition, manufacturing companies are backing up the system with the provision of equipment and know-how. All this are the pillars of the sound RES system of the Republic of Croatia.

6.3. Final Remarks

In conclusion, the island Krk has a vast potential in becoming a zero emissions island. This potential could be achieved, firstly, in the will of government and all relevant stakeholders to conduct all necessary steps in implementing new solutions and technologies to utilize the resources of a system to the highest extent possible. Secondly, the systems' untapped laying resources potential could serve as a stepping stone towards sustainability concepts. Its utilization would bring manifold benefits to the system. They may be significant financial savings, new values added creation, such as more job positions, environmental preservation and similar.

Also, the framework for implementation of the new technologies, such as biogas power plant which are capable to utilize renewable energy sources' potential is crucial. As can be observed from the previous few sections, the Croatia is fully prepared to provide much needed support to these kinds of concepts and technologies. The institutions needed to monitor and control the energy sector are present with great experience. The financial incentives, such as feed-in tariffs and beneficial loans have been established. The strategies and targets set are complying with the EU objectives related to energy field and renewable energy sector.

A common knowledge is that the energy is one of the major factors in the financial structure of any economy. Therefore, it is of the great importance to make the energy sector of a country sustainable and more self sufficient. In order to achieve this, Renewable Energy Sources need to be utilized to the greatest extent possible. To this end, a necessity for the development and establishment of a sound energy strategy became an imperative.

This energy strategy should involve more decentralized approach in the generation of and meeting the demand for electricity. Towards this direction, the regions and even smaller areas should manage their resources with higher care and greater awareness in order to satisfy their energy needs. Moreover, other national strategies, such as tourism strategy should be put in compliance with the energy strategy. Working together, strategies of different field will yield better results. In relation to this, island Krk has a great opportunity which can be observed in its location and tourism activities. As explained in the previous parts of the report, Krk's unique geographical position is attracting tourists from all around the world, but especially from Europe. As a result, in the summer period there is an increased number of people residing on the island. Consequently, islands infrastructure is found to be in great stress. Therefore, sound strategies, such as modern waste management and energy generation form the renewable energy sources need to be developed and implemented. The proposed project is certainly a step towards the more efficient energy, but also the sustainable tourism strategy. Combined together, these modern approaches will help to promote island Krk as a desirable and new "green tourist" destinations.

7. References

Binder, C. R. (2007). From material flow analysis to material flow management Part II: the role of structural agent analysis. *Journal of Cleaner Production, 15* (17), 1605-1617. doi: 10.1016/j.jclepro.2006.08.017

Brunner, P. H., & Rechberger, H. (2005). *Practical Handbook of Material Flow Analysis*: Lewis Publishers.

Croatian Chamber of Economy. (2009). Legislative and Institutional Framework in the Republic of Croatia Concerning Renewable Energy Sources (RES) http://www.hgk.hr/wps/wcm/resources/file/eb019545dc3c498/2mingorp.pdf Retrieved June 14, 2011

EBRD, European Bank for Reconstruction and Development. (2009). Electricity Emission Factors Review. Milano: MWH S.p.A.

Environmental Services Department, Wastewater Services Division. (n.d.). Introduction to wastewater treatment http://www.guelph.ca/uploads/ET_Group/wastewater/Introduction%20to%20Wastewater.pdf Retrieved June 28, 2011

European Commission. (2007). Screening report, Croatia: Chapter 15 - Energy http://ec.europa.eu/enlargement/pdf/croatia/screening_reports/screening_report_15_hr_internet_en.pdf Retrieved June 14, 2011

Fitzgerald, Y. Jr. (2005). Cleaner technologies for sustainable tourism: Caribbean case studies. *Journal of Cleaner Production, 13* (2), 117–134. doi: 10.1016/j.jclepro.2003.12.019

Fortuny, M., Soler, R., Canovas, C., & Sanchez, A. (2008). Technical approach for a sustainable tourism development. Case study in the Balearic Islands. *Journal of Cleaner Production, 16* (7), 860-869. doi: 10.1016/j.jclepro.2007.05.003

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (2009a). Renewable Energies, Innovations for a Sustainable Energy Future. Berlin: BMU, Public Relations Division.

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (2009b). Zero Emissions, Recognising the potential - Optimising processes - Creating added value. Berlin: BMU, Public Relations Division.

Grewal, A., & Ipek, U. (2009). Energy policy review for EU accession countries, The case of Croatia http://www.aaee.at/2009-IAEE/uploads/fullpaper_iaee09/P_212_Ipek_Ugur_31-Aug-2009,%2022:47.pdf Retrieved June 16, 2011

HEP, Hrvatska Elektroprivreda. (n.d.). Company's Profile http://www.hep.hr/hep/en/group/default.aspx Retrieved June 15, 2011

HEP: Stanic N. personal communication (May 19, 2011). [HEP company's internal data on Electrical Energy sold on the Krk area for the year 2010].

HERA, Croatian Energy Regulatory Agency. (2010). About HERA http://www.hera.hr/english/html/index.html Retrieved June 19, 2011

HROTE, Croatian Energy Market Operator. (2009a). Energy Sector Development Strategy of the Republic of Croatia http://www.hrote.hr/hrote/dokumenti/StrategijaEnergetskogRazvoja_nn_130_2009.pdf Retrieved June 19, 2011

HROTE, Croatian Energy Market Operator. (2009b). Organization of the electricity market and renewable energy sources in the Republic of Croatia http://www.storiesproject.eu/docs/STORIES_electricity_market_model_and_RES_in_Croatia.pdf Retrieved June 20, 2011

HROTE, Croatian Energy Market Operator. (n.d.). About HROTE http://www.hrote.hr/hrote/en/about/default.aspx Retrieved June 20, 2011

Institute for Tourism. (n.d.). What is sustainable tourism http://www.iztzg.hr/en/odrzivi_razvoj/sustainable_tourism/ Retrieved June 17, 2011

Josipovic, S., Knaus, M., Rosenthal, P., & Melis, M. (2010). Preliminary feasibility study for construction of biomass power plant on the island Krk: Ponikve Krk d.o.o. - igr d.o.o. - igr AG - IfaS.

Kuehr, R. (2007). Towards a sustainable society: United Nations University's Zero Emissions Approach. *Journal of Cleaner Production, 15* (13-14), 1198-1204. doi: 10.1016/j.jclepro.2006.07.020

Lang, D. J., Binder, C. R., Scholz, R. W., Schleiss, K., & Staubli, B. (2006). Impact factors and regulatory mechanisms for material flow management: Integrating stakeholder and scientific perspectives - The case of bio-waste delivery. *Resources Conservation and Recycling, 47* (2), 101-132. doi: 10.1016/j.resconrec.2005.08.008

Lima, C., & McAleer, M. (2005). Ecologically sustainable tourism management. *Environmental Modelling & Software, 20* (11), 1431–1438. doi: 10.1016/j.envsoft.2004.09.023

Mancl, K. (n.d.). Wastewater Treatment Principles and Regulations http://ohioline.osu.edu/aex-fact/0768.html Retrieved June 28, 2011

Ministry of the Environment, Forests and Consumer protection, & Ministry for the Economy, Commerce, Agriculture and Viticulture, Germany. (2008). The Circular Economy State of Rhineland-Palatinate. Mainz: Druckerei Lindner.

Peck, S. W. (n.d.). Industrial Ecology: From Theory To Practice http://newcity.ca/Pages/industrial_ecology.html Retrieved May 23, 2011

Ponikve d.o.o. (2010a). Amounts and Structure of Waste collected for 2009 on Krk http://www.ponikve.hr/dokumenti/web-gospodarenje%20otpadom_rez2009.pdf Retrieved June 28, 2011

Ponikve d.o.o. (2010b). Waste management: Waste collection and treatment system http://www.ponikve.hr/sustav-prikupljanja-zbrinjavanja-otpada.php Retrieved June 27, 2011

Ponikve: Giorgolo S. personal communication (June 27, 2011). [Ponikve company's internal data on the amount of water captured on the Krk area for the year 2010].

Russell, M. (2006). The Basics Of The Anaerobic Digestion Process http://EzineArticles.com/328578 Retrieved June 5, 2011

Seadi, T. A., Rutz, D., Prassl, H., Köttner, M., Finsterwalder, T., Volk, S., et al. (2008). *Biogas Handbook*. Esbjerg: University of Southern Denmark.

Speck, E. (2002). The Fairmont Chateau Whistler Resort: moving towards sustainability. In R. Harris, T. Griffin & P. Williams (Eds.), *Sustainable Tourism: A Global Perspective*. Oxford: Butterworth-Heinemann.

Stanic, Z. (2009). Renewable Energy Resources in Croatia: Experience of a Croatian electricity company – HEP in renewable energy sector http://fei.rec.org/presentations/3.7_Stanic_Croatian_Electricity_Company.pdf Retrieved June 16, 2011

The Island of Krk Tourist Board. (n.d.). Island Krk tourists circulation for July 2010 http://www.krk.hr/novosti?year=2010&yearActive=yes&month=08&newsId=31 Retrieved June 21, 2011

The Kvarner County Tourism Office. (n.d.). Discover Kvarner: flora and fauna http://www.kvarner.hr/kvarner/Flora-and-Fauna_en_12.aspx Retrieved June 21, 2011

Tourist Office, Island of Krk. (n.d.). Krk Info http://www.krk.hr/en/docs/tzkrkHR/documents/46/Original.pdf Retrieved June 22, 2011

UNEP, United Nations Environment Programme. (2006). Circular Economy, An alternative model for economic development: United Nations Environment Programme.

UNWTO, World Tourism Organization. (2004). Sustainable tourism, Conceptual Definition http://www.unwto.org/sdt/mission/en/mission.php Retrieved June 13, 2011

Vuk, B., Karan, M., Vukman, S., Fabek, R., Zivkovic, S., Antesevic Maricic, S., et al. (2009). Energy in Croatia: annual energy report - 2008. Zagreb: Energy Institute Hrvoje Pozar.

Wagner, B., & Enzler, S. (2006). *Material Flow Management, Improving Cost Efficiency and Environmental Performance*. Heidelberg: Physica-Verlag, A Springer Company.

WCED, World Commission on Environmental and Development. (1987). *Our Common Future*. New York: Oxford University Press.

www.krk-croatia.com. (2002). History of island Krk http://www.krk-croatia.com/eng/povijest.htm Retrieved June 21, 2011

Zero Emissions Manual Drafting Committee. (2004). *Zero Emissions Manual, Realizing a Zero Emissions-based Regional Community*: United Nations University Zero Emissions Forum Booklet.

8. Appendices

In the appendices part, tables with various calculations are provided. Table 8.1. displays biomass and biogas potential on the area of Krk island. Table 8.2. shows the final calculations of the total biogas potential and energy which could be derived from it.

Institution	Gas Potential	Gas Yields
RO-trade (fish processing industry)	Methane content: ca. 55-75% Yield: 50-200 m^3/t	=35 t/a * 125 m^3/t * 65% =2,844 m^3 /a
	Biogas Volume	4,375 m^3/a
	CH_4 - Potential	2,844 m^3/a
Krajani d.o.o. (fish processing industry)	Methane content: ca. 55-75% Yield: 50-200 m^3/t	=300 t/a * 125 m^3/t * 65% =24,375 m^3 /a
	Biogas Volume	37,500 m^3/a
	CH_4 - Potential	24,375 m^3/a
Katunar (wine processing industry)	Methane content: ca. 65% Yield: 260 m^3/t	=80 t/a * 260 m^3/t * 65% = 13,520 m^3 /a
	Biogas Volume	20,800 m^3/a
	CH_4 - Potential	13,520 m^3/a
Hotel Baska	Green residues: Methane content: 60% Yield: 175 m^3/t	= 30 m^3 * 175 m^3/t * 60% = 3,150 m^3/t
	Biogas Volume	5,250 m^3/a
	CH_4 - Potential	3,150 m^3/a
Tos Punat (olive oil producing industry)	Methane content: 55% Yield: 300 m^3/t	= 400 t/a * 300 m^3/t * 55% = 66,000 m^3/a
	Biogas Volume	120,000 m^3/a
	CH_4 - Potential	66,000 m^3/a
Poultry farming	Methane content: 60% Yield: 40 m^3/ m^3 (manure)	= 400 m^3/a * 40 m^3/ m^3 * 60% = 9,600 m^3/a (for manure)
	Biogas Volume	16,000 m^3/a
	CH_4 - Potential	9,600 m^3/a
Agricultural association (wine processing industry)	Methane content: ca. 65% Yield: 260 m^3/t	= 225 t/a * 260 m^3/t * 65% = 38,025 m^3/a
	Biogas Volume	58,500 m^3/a
	CH_4 - Potential	38,025 m^3/a

Institution	Gas Potential	Gas Yields
veterinary station Rijeka	Slaugther residues: Methane content: 55% Yield: 60 m^3/t	= 2,400 t/a * 60 m^3 * 55% = 79,200 m^3/a
	Biogas Volume	144,000 m^3/a
	CH_4 - Potential	79,200 m^3/a
IND-EKO	Grease: Methane content: 60% Yield: 650 m^3/t Cooking oil: Methane content: 55% Yield: 350 m^3/t	= 150 t/a * 650 m^3/t * 60% = 58,500 m^3/a = 25 t/a * 350 m^3/t * 55% = 4,812 m^3/a
(oils and grease collecting company)	Biogas Volume	106,249 m^3/a
	CH_4 - Potential	63,313 m^3/a
ECOOPERATIVA d.o.o.	Grease: Methane content: 60% Yield: 650 m^3/t Cooking oil: Methane content: 55% Yield: 350 m^3/t	= 350 t/a * 650 m^3/t * 60% = 136,500 m^3/a = 175 t/a * 350 m^3/t * 55% = 33,687 m^3/a
(oils and grease collecting company)	Biogas Volume	288,749 m^3/a
	CH_4 - Potential	170,188 m^3/a
KEMIS TERMOCLEAN d.o.o.	Grease: Methane content: 60% Yield: 650 m^3/t Cooking oil: Methane content: 55% Yield: 350 m^3/t	= 150 t/a * 650 m^3/t * 60% = 58,500 m^3/a = 25 t/a * 350 m^3/t * 55% = 4,812 m^3/a
(oils and grease collecting company)	Biogas Volume	106,249 m^3/a
	CH_4 - Potential	63,312 m^3/a
Organic waste	1,262 t/a	=1,262 t/a * 100 m^3/t * 55% = 69,410 m^3/a
(collected by Ponikve d.o.o.)	Biogas Volume	126,200 m^3/a
	CH_4 - Potential	69,410 m^3/a
Greenery waste (silage: -12% storage loss)	351 t/a	= (351 t/a *88%)* 172 m^3/t * 54% = 28,689 m^3/a
	Biogas Volume	53,128 m^3/a
	CH_4 - Potential	28,689 m^3/a

Table 8.1. Biomass and Biogas potential on the area of Krk island[26]

[26] Source: Josipovic, et al., 2010, pp. 18-19

Total Biogas Volume	1,087,000 m^3/a
Average	90,583 m^3/a
Standard deviation from average	25%
Total CH_4 Potential	631,625 m^3/a
Average	52,635 m^3/a
Energy content	6,316,250 kWh
Annual operating hours	8,000 h
Average electric installed capacity	276 kW
Electricity generation	**2,134,471 kWh**
Electricity surplus	**1,921,024 kWh**
Average thermal installed capacity	434 kW
Heat generation	**896,478 kWh**
Heat surplus	**627,535 kWh**

Table 8.2. Total Biogas and Energy potential on the area of Krk island per year[27]

Next two figures are displaying the availability of biogas potential throughout the year. Figure 8.1. displays amounts of biogas available according to months in one year. Due to the tourism sector and agricultural activities (harvest of olives and grapes), the amounts of biogas fluctuate during a year period. In order to assure that the production of biogas will occur relatively even during a year, it has been assumed that the collected potential from old oils and greases would be stored in appropriate tanks and used in winter months for fermenting purposes. This evenly spread production of biogas is shown in the Table 8.2.

[27] Source: Josipovic, et al., 2010, p. 20

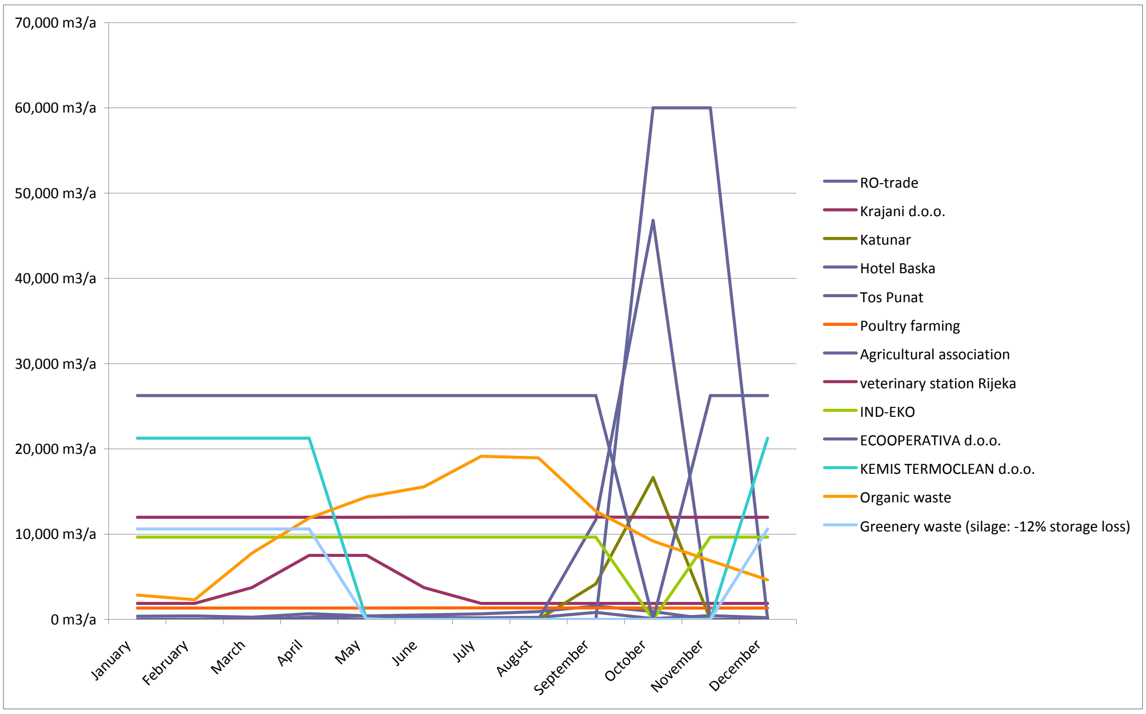

Figure 8.1. Biogas potential on the area of Krk island during a year[28]

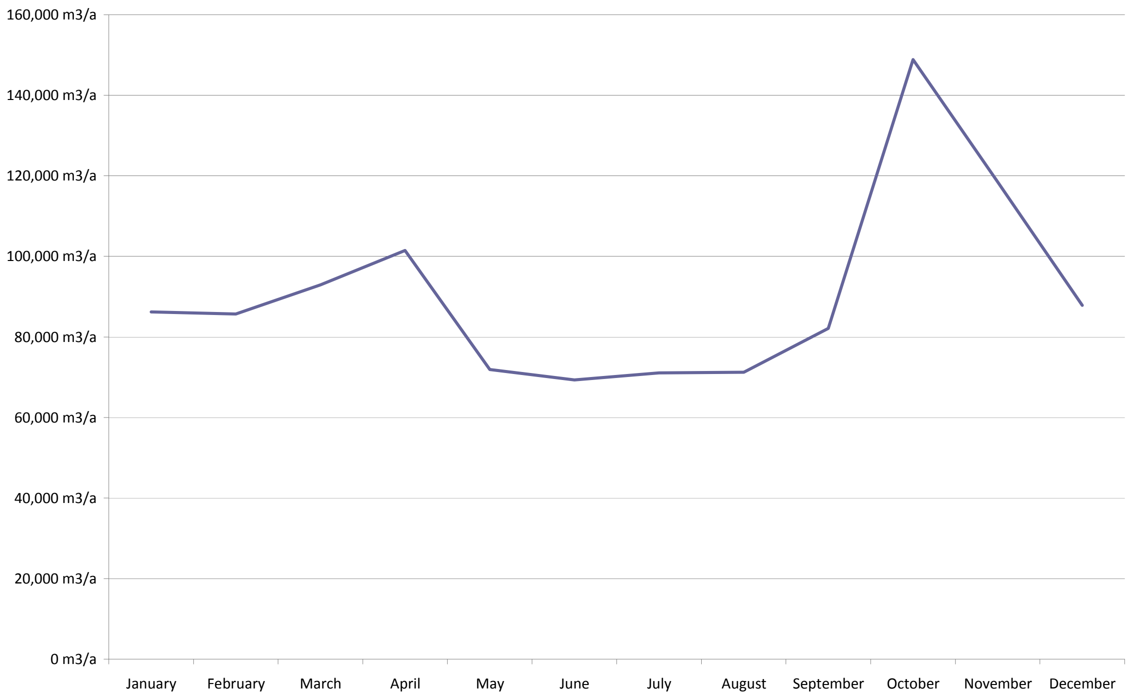

Figure 8.2. Optimal distribution of biogas amounts on the area of Krk island during a year[29]

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[28] Source: Josipovic, et al., 2010, p. 21
[29] Source: Josipovic, et al., 2010, p. 22