UNIVERSITY OF PERAEUS

INDUSTRIAL ADMINISTRATION AND TECHNOLOGY

MSC AT ENERGY AND ENVIRONMENTAL MANAGEMENT

BIOGAS

A BUSINESS CASE FOR THE INSTALLATION OF A BIOGAS UNIT AT THE ISLAND OF POROS

THESIS

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2015

ΑΦΙΕΡΩΣΗ

Στην οικογένειά μου

Σύνοψη

Το έργο αφορά ένα επιχειρηματικό πλάνο για την εγκατάσταση μιας μονάδας βιοαερίου στο νησί του Πόρου στην Βορειοανατολική Πελοπόννησο, στην Έλλαδα. Σκοπός είναι η συλλογή και η επεξεργασία των οργανικών στερεών αστικών απορριμάτων της νήσου του Πόρου αλλά και του οικισμού του Γαλατά, μια μικρή πόλη απέναντι από το Πόρο σε απόσταση μόλις 400 m. Από την επεξεργασία αυτή των απορριμάτων, σκοπός είναι η παραγωγή βιοαερίου και κατ’επέκταση η παραγωγή ηλεκτρικής ενέργειας για κατανάλωση στην τοπική κοινότητα. Παράλληλα, η μονάδα θα παράγει και Compost, ένα είδος λιπάσματος με σκοπό τη πώλησή του στις τοπικές φάρμες του νομού Αργολίδος.

Έγινε έρευνα για όλα τα απαιτούμενα κόστη, όλες τις απαιτούμενες αδειοδοτήσεις, τους δυνατούς τρόπους χρηματοδότησης του έργου και όλα τα πιθανά έσοδα. Έγινε εκτενής ανάλυση των δεδομένων και υπολογισμός της καθαρής παρούσας αξίας. Τέλος, έγινε και μια ανάλυση για τους πιθανούς κυνδίνους που εμπεριέχει μια τέτοια επένδυση.

Abstract

The project is a business plan about the installation of a biogas unit at the island of Poros in northeastern Peloponnisos, at Greece. The aim is the collection and the elaboration of the organic municipality solid wastes of the island of Poros and the town of Galatas, which is located across the island of Poros in a distance of 400 m. From the elaboration of the wastes, the aim is the production of biogas and the production of electricity for the local community. Moreover, the unit is able to produce Compost, a fertilizer with the aim to be sold in the local farms at the county of Argolida.

A research was developed for estimating all the costs, all the demanded permits, the possible ways of financing the project and the probable income. In addition, it was developed an analysis of the data and the calculation of the net present value. At last we developed a risk assessment for all the possible hazards, which consume an investment like this.

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1. Executive Summary

The biogas unit developers are seeking a preferred equity investment of approximately 200.000 € for the SMARTFERM UNIT IN POROS project. The project is an energy production unit which will produce clear energy using the municipal solid wastes as a fuel (biogas) of the island of Poros and the village of Galatas at Peloponnisos in Southeastern Greece. The installation of the biogas unit can take place either at the island of Poros or at the Galatas village. The project will be also financed by debt providers who will contribute approximately 200.000 € and from the European commission who will subsidize 600.000 € by the LIFE programme. The total funds will be used to complete all project phases, which consist the equipment purchase and it's installation, plans and permits.

Project Financial Summary	
Total Development Cost	1.000.000 €
Subsidy	600.000 €
Equity investment	200.000 €
Senior Debt	200.000 €
PROJECT NPV	966.476,7 €
PROJECT IRR	28%

Concept

The aim of the project is to produce electrical energy from a biogas unit by converting the organic municipal solid wastes of Poros and Galatas into biogas. The unit can produce also Compost a fertilizer coming from the organic wastes which is a key material in organic farming.

The Opportunity

The energy produced by biogas can be sold to the public power corporation of Greece for 220 € per MWhr. Furthermore the Compost is estimated to be sold for 50 € per tone. There is no other way to treat the municipal wastes in the area, which are usually transported to Athens for treatment.

Site Location

Poros is a small Greek island-pair in the southern part of the Saronic Gulf, at a distance about 58 km south from Piraeus and separated from the Peloponnese by a 200 m wide sea channel, with the town of Galatas on the mainland across the strait. Its surface is about 31 km^2 and it has 4.000 inhabitants. Poros is a popular weekend destination for Athenian travellers.

Galatas, is a town located in the eastern part of the Peloponnese peninsula, Greece. It is the seat of the municipality of Troizinia, which belongs to the Islands regional unit and has 2.200 inhabitants. It is situated on the coast, opposite the island Poros, across a 400 m wide strait. It connects to the island of Poros with water buses and ferry boats.

Deal of the project

The equity investors and the municipal authority of the area will form a partnership, under which the local authority will continue to fund the collection and transportation of the municipal solid wastes to the area in which the investors will proceed with the elaboration of the wastes. The capital structure will be 60 % subsidy, 20 % equity and 20 % debt. The loan interest will be 5,5 % and the profits will be shared to the investors only.

2. Concept of the project

2.1. Description of the business case

The aim of the project is the installation of a biogas unit, which will convert to biogas the municipal solid wastes (M.S.W.) of the island of Poros and the small town of Galatas. The biogas is going to produce electrical energy which will be sold to the local area. The amount of the M.S.W. that won't be converted to biogas will be able to be converted to Compost.

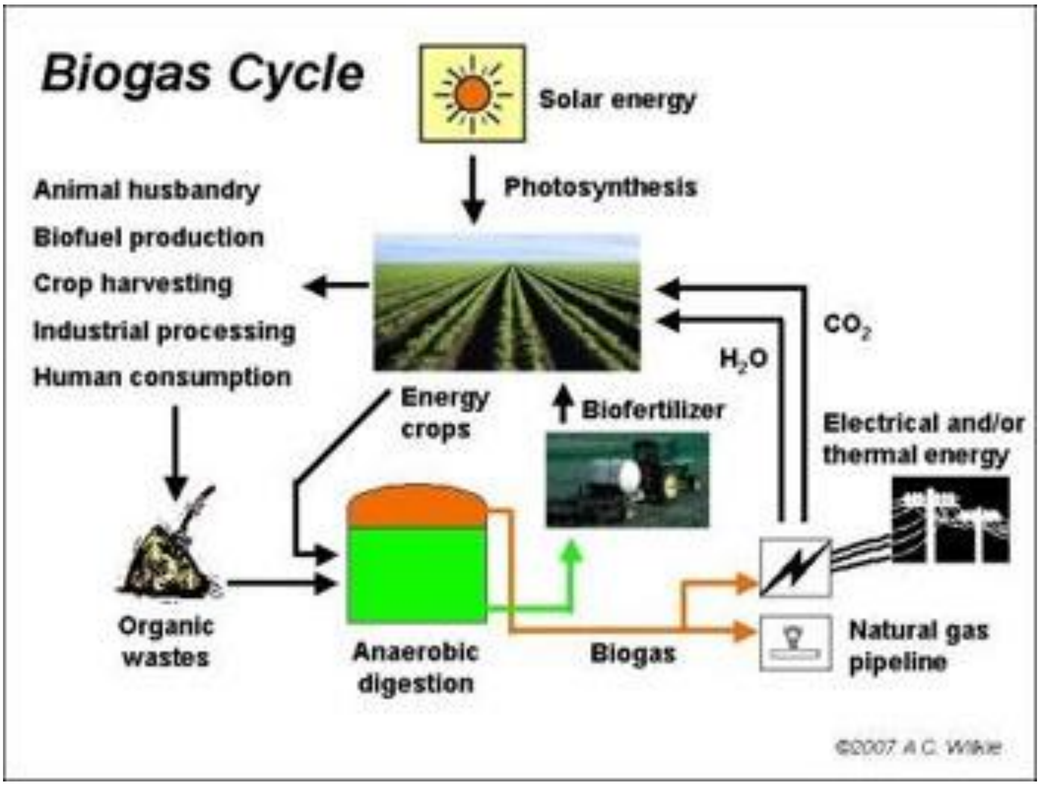

Figure 2.1: Biogas Cycle

In the local area for which this business case was made, doesn't exist a facility which can elaborate the M.S.W., and the wastes are usually sent to Athens for treatment. So an agreement that could be achieved with the local authorities, is that they will continue to fund the collection of the wastes and the transportation to the location of the biogas unit.

The biogas unit can be installed either on the island of Poros or at the outlands of Galatas. The island of Poros is connected with the main electricity grid of the whole country, which means that the produced electricity can be transported to the island immediately. Moreover there will be the advantage that there won't be any losses during the transportation of the electricity.

The chosen unit to install is the SMARTFERM unit of Eggersman Anlagenbau, a german corporation. The Smartferm unit is a semi-mobile, small-scale dry anaerobic digesting system designed to process and treat the organic fraction of municipal solid waste to recover energy and reduce the volume of solid waste that must be landfilled. The Smartferm unit can produce 100 kW from 5000 tones per of M.S.U. per year. Except from the biogas and the electricity the smartferm unit can produce Compost a fertilizer which can be sold to the local farms at the area of Galatas or at the area of Argolida's state nearby. The area needed for the specific unit is small at about 278 m^2, and the time for completing the construction is 20 working days. We have to mention that the zerowaste energy corp. invested to build a smartferm unit at Monterey in 2012, and the construction began in mid-September and was completed by mid-December. The start up began in January 2013.

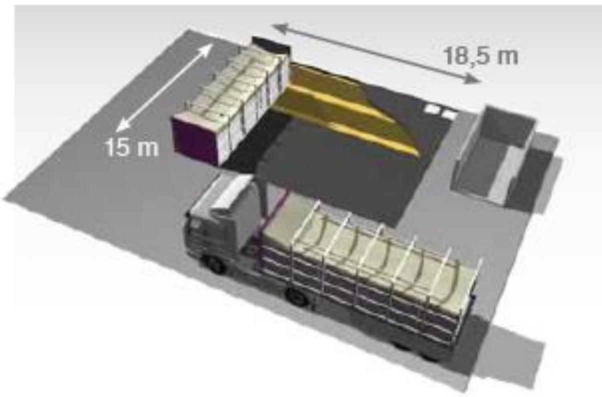

Figure 2.2: The needed area for the SMARTFERM unit.

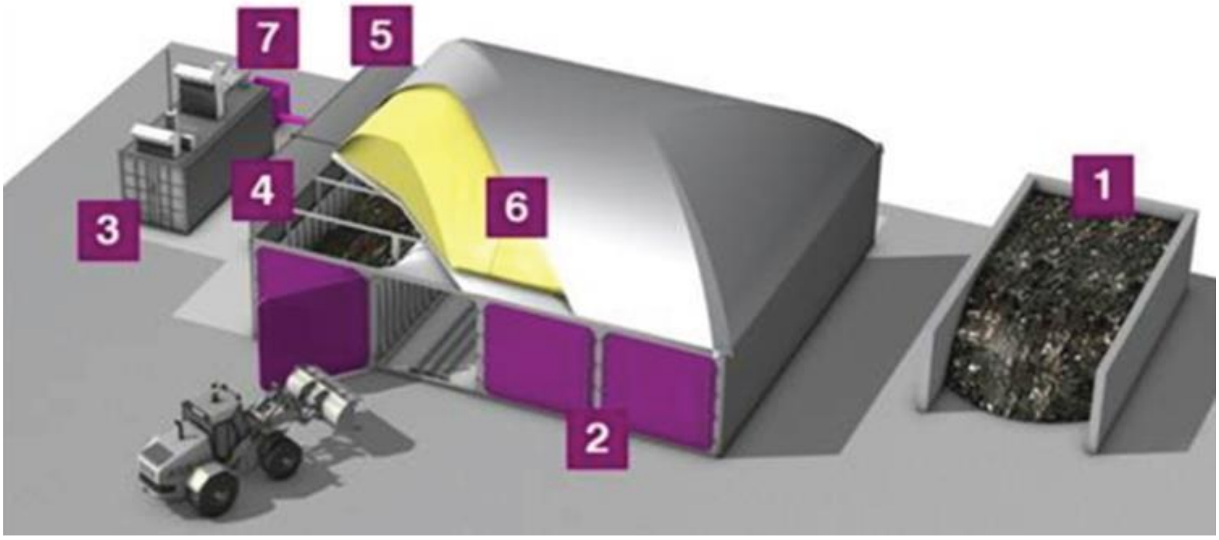

Figure 2.3: Site Plan of the SMARTFERM unit. 1. Input Storage, 2. Dry fermenters, 3. Biogus CHP, 4. Mechanical Box, 5. Electrical/Control Box, 6. Biogas Storage, 7. Biofilter

At last, the electricity is going to be sold to the public power corporation of Hellas. The biogas units are getting to a feed in tariff program and it will be cost 220 € per MWhr. The compost is estimated to be sold for 50 € per tone.

2.2 Existing technological equipment

Waste-to-Energy (WTE) or energy-from-waste is the process of generating energy in the form of electricity and/or heat from the incineration of waste. In the U.S., some cities primarily in the northeastern and mid-Atlantic, burn part of their municipal solid wastes. Hemmed in by major population centers, landfill space in these areas is at a premium, so burning wastes to reduce their volume and weight makes sense. Combustion reduces the volume of material by about 90 percent and its weight by 75 percent. The heat generated by burning wastes has other uses, as well, as it can be used directly for heating, to produce steam or to generate electricity.

In 1885, the U.S. Army built the nation's first garbage incinerator on Governor's Island in New York City harbor. Also in 1885, Allegheny, Pennsylvania built the first municipal incinerator. As their populations increased, many cities turned to incinerators as a convenient way to dispose of wastes.

These incineration facilities usually were located within city limits because transporting garbage to distant locations was impractical. By the end of the 1930s, an estimated 700 incinerators were in use across the nation. This number declined to about 265 by 1966, due to air emissions problems and other limitations of the technology. In addition, the popularity of landfills increased.

In the early 20th century, some U.S. cities began generating electricity or steam from burning wastes. In the 1920s, Atlanta sold steam from its incinerators to the Atlanta Gas Light Company and Georgia Power Company.

Europe, however, developed waste-to-energy technologies more thoroughly, in part because these countries had less land available for landfills. After World War II, European cities further developed such facilities as they rebuilt areas ravaged by war.

The use of municipal waste combustion for energy in the U.S. is not common; the nation had only 87 such facilities in 2007 and has added several more today, while Europe has more than 430 such facilities. By the 1990s, after the tax credits extension of 1986 finally ended, fewer waste-to-energy plants were built. Figure 2.4 shows the generic process of converting waste to energy.

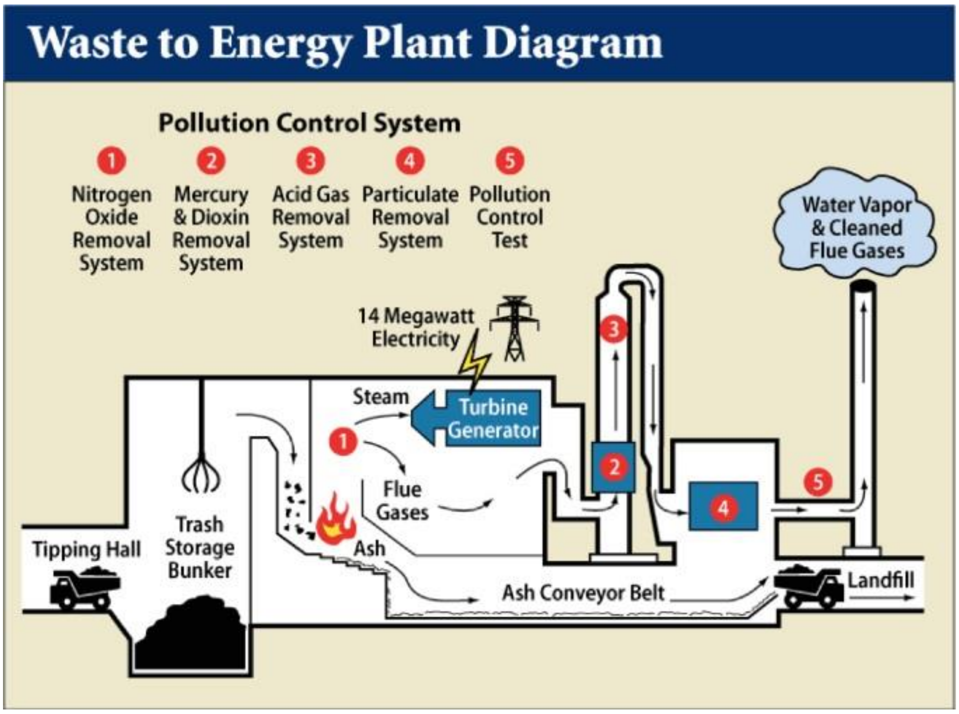

Figure 2.4: Typical WTE diagram.

Recently in the U.S. WTE has been deemed a Renewable Energy source. According to the EPA the definition of Renewable Energy - "Renewable Energy is energy obtained from sources that are essentially inexhaustible, unlike natural gas, coal and oil, of which there is a finite supply." According to the Department of Energy (DOE) – "Renewable energy sources include: wood and other biomass, solar (Photovoltaic and Thermal), wind, geothermal, wastes [Municipal Solid Waste (MSW), Refuse-Derived Fuel (RDF), Landfill Gas (LFG)] and any other sources that are naturally or continually replenished." By definition, the DOE describes renewable energy as a "non-deplete-able source of energy."

Technologies

The technologies described in this paper all produce energy, we will not address pure incineration or other means of reducing municipal solid waste that does not produce energy. We will also not address the Non-Thermal Technologies (Anaerobic Digestion, Landfill Gas, or Hydrolysis and Mechanical Biological Treatment.

The purpose of this paper is to provide a technical evaluation of the available technologies and provide an indicative cost estimate ranges associated with each.

The technologies we reviewed are as follows:

- Thermal Technologies
- Direct Combustion (Mass Burn and RDF)
- Pyrolysis
- Conventional Gasification
- Plasma Arc Gasification

As mentioned earlier we did not evaluate the Non-Thermal Technologies.

Thermal Technologies

Direct Combustion Mass Burn and Refuse Derived Fuel

As mentioned above Mass Burn facilities have been in existence for decades and as the technology reflects it literally burns/combusts everything, leaving only noncombustible material. There are over 100 of these facilities operating in the U.S. and considerably more in Europe and Asia. Refuse Derived Fuel (RDF) is the process of removing the recyclable and noncombustible from the municipal solid waste (MSW) and producing a combustible material, by shredding or pelletizing the remaining waste. There are only 19 RDF facilities in the U.S., but as energy prices climb and landfill permitting gets more difficult there may be an increase in the number of these facilities. Figure 2.5 are B&W's rendition of typical Mass Burn and RDF technologies.

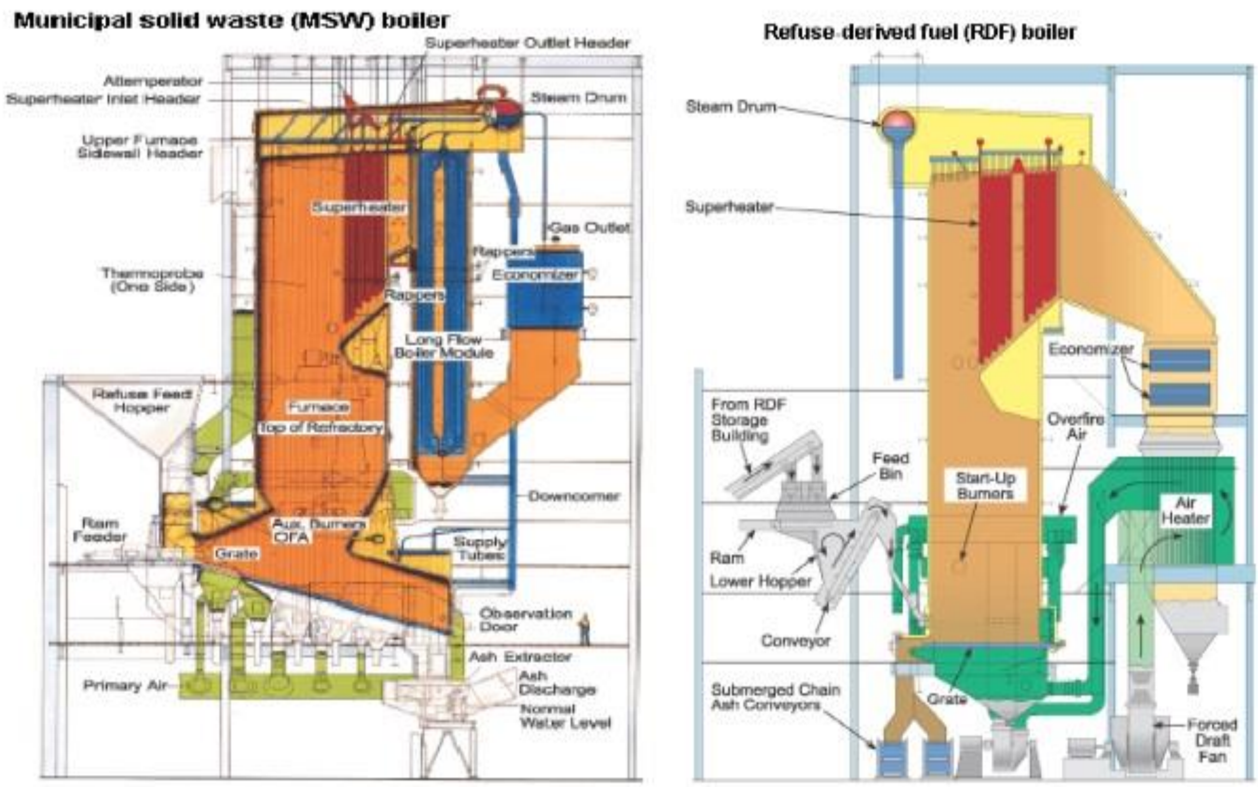

Figure 2.4: At left is pictures a mass burn technology and at right an RDF technology.

Pyrolysis

Pyrolysis is the thermo-chemical decomposition of organic material, at elevated temperatures without the participation of oxygen. The process involves the simultaneous change of chemical composition and physical phase that is irreversible. Pyrolysis occurs at temperatures >750°F (400°C) in a complete lack of oxygen atmosphere. The syn-gas that is produced during the reaction is generally converted to liquid hydrocarbons, such as biodiesel. Byproducts from the process are generally unconverted carbon and/or charcoal and ash.

There are various types of Pyrolysis technologies ranging from carbonization to rapid or flash type systems. Table 2.1 below shows the different types and comparisons of the process conditions and major products.

Technology	Residence Time	Heating Rate	Temp. (°C)	Products
Carbonization	hours - days	very low	300 - 500	Charcoal
Pressure Carbonization	15 min – 2 hours	medium	450 - 550	Charcoal
Conventional Pyrolysis	hours	low	400 - 600	Char, oil, syn-gas
	5 – 30 min	medium	700 - 900	Char, syn-gas
Vacuum Pyrolysis	2 – 30 sec	medium	350 - 450	Oil
Flash/ Rapid Pyrolysis	0.1 – 2 sec	high	450 - 650	Oil
	<1 sec	high	650 - 900	Oil, syn-gas
	<1sec	very high	1000 - 3000	Syn-gas

Table 2.1: Pyrolysis Technologies – Process & Major Products

Figures 2.5 shows the process flows for the fast and rapid pyrolysis processes that are being offered commercially. We are aware of small modules operating throughout the world, but to our knowledge there are no systems operating at large industrial sized.

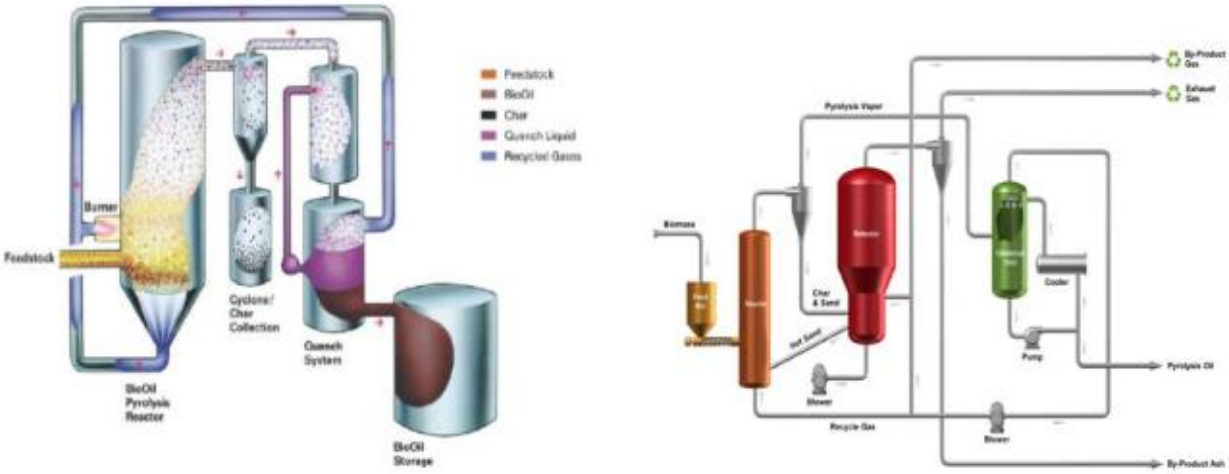

Figure 2.5: At left is pictured a fast pyrolysis process and at right a rapid pyrolysis process.

Conventional Gasification

Conventional gasification is defined as the thermal conversion of organic materials at temperature of 1,000 °F - 2,800 °F (540 °C – 1,540 °C), with a limited supply of air or oxygen (sub-stoichiometric atmosphere). This is not combustion and therefore there is no burning. Gasification uses a fraction of the air/oxygen that is generally needed to combust a given material and thus creates a low to medium Btu syn-gas.

Although more mature than other processes, it does require complex systems, such as gas clean up equipment.

The U.S. Department of Energy's (DOE) Worldwide Gasification Database shows that the current gasification capacity has grown to 70,817 megawatts thermal (MWth) of syn-gas output at 144 operating plants with a total of 412 gasifiers. The database also shows that 11 plants, with 17 gasifiers, are presently under construction, and an additional 37 plants, with 76 gasifiers, are in the planning stages to become operational between 2011 and 2016. The majority of these plants—40 of 48—will use coal as the feedstock. If this growth is realized, worldwide capacity by 2016 will be 122,106 MWth of syn-gas capacity, from 192 plants and 505 gasifiers. This data base does show that there are gasifiers operating on both biomass and waste. Figure 2.6 shows two basic types of gasifiers, a fluidized bed gasifier and char combustor and a typical slagging gasifier.

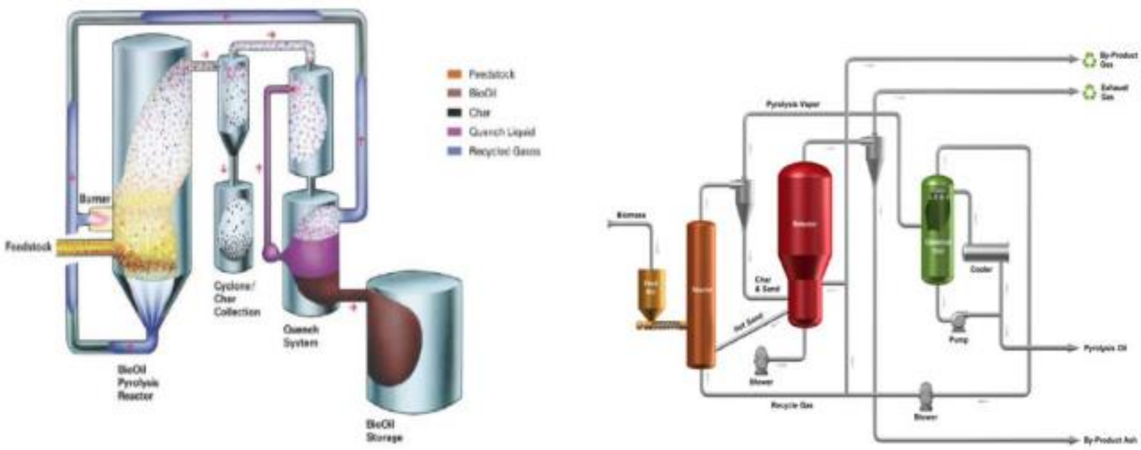

Figure 2.6: At left is pictured a fluidized bed gasifier and at right a slagging gasifier.

Plasma Arch Gasification

Plasma Arc gasification is the process of that utilizes a plasma torch or plasma arc using carbon electrodes, copper, tungsten, hafnium, or zirconium to initiate the temperature resulting in the gasification reaction. Plasma temperature temperatures range from 4,000 °F – 20,000 °F (2,200 °C – 11,000 °C), creating not only a high value syn-gas but also high value sensible heat. The technology has been used for decades to destroy wastes that may be hazardous. The resulting ash is similar to glass that encapsulates the hazardous compounds.

The first Plasma Arc unit began operation in 1985 at Anniston, Alabama. The unit used a catalytic converter system to improve gas quality and the gasifier was designed to destroy munitions. The second system began operation in 1995 in Japan followed by the third system in Bordeaux, France, both design for MSW. There are other operating systems in Sweden, Norway, the UK, Canada, Taiwan and the U.S., Japan has added nine more since 1995. All of these are small in size but have the ability to scale up, using multiple units. Figure 2.7 shows a couple of current systems available on the market and both can be employed to reduce waste and generate clean electric energy.

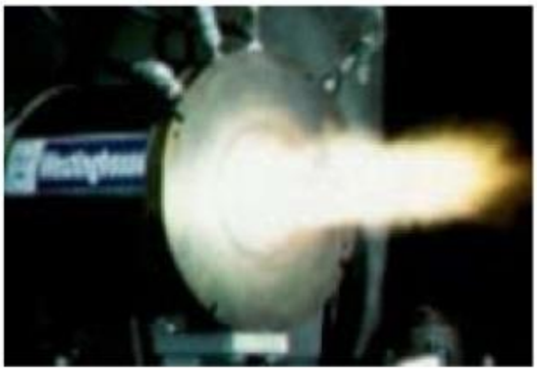
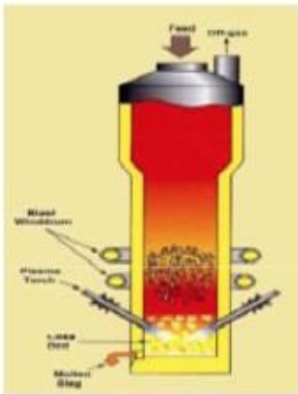

Figure 2.7: At left is pictured a typical plasma arc and at right a plasma arc gasifier.

The advantage of the Plasma gasification is the high temperature that minimizes air pollutants well below those of traditional WTE facilities. At the elevated temperatures, there is no odor, and the cooled off gas has lower NO_X, SO_2 and CO_2 emissions. The solid residue resembles glass beads [1].

2.3 Equipment chosen to be installed

As mentioned in the 2.1 paragraph the equipment that was chosen to installed for the project is the SMARTFERM unit of Eggersman Anlagenbau corporation.

SMARTFERM is a semi-mobile, small-scale dry anaerobic digesting system designed to process and treat the organic fraction of municipal solid waste to recover energy and reduce the volume of solid waste that must be landfilled. The space-efficient, pre-fabricated, scaleable modular system is capable of processing between 4,000 and 20,000 tons per year, depending from the number of existing dry anaerobic digesters that are going to be installed. Operating costs are low and are offset by harvesting high quality compost and biogas that can be converted to power or fuel (CNG) from waste materials. SMARTFERM can be installed in a short time, without extensive construction measures and with minimal space requirements for the direct production of electricity and heat are required. On a surface of approximately 18.5 x 15 metres the four fermenters can be installed in container design within around 20 days.

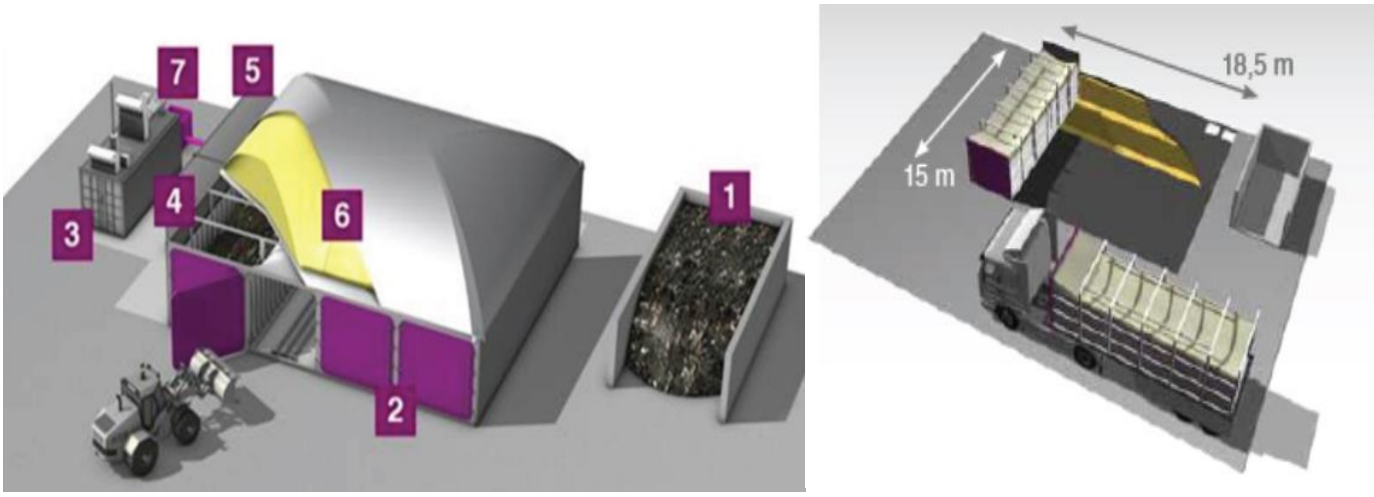

Figure 2.8: Smartferm unit plan 1. Input Storage, 2. Dry fermenters, 3. Biogus CHP, 4. Mechanical Box, 5. Electrical/Control Box, 6. Biogas Storage, 7. Biofilter.

The basic SMARTFERM unit system includes 4 x 40' dry anaerobic digesters, which can convert 5000 tones per year of organic solid wastes to 100 kW electrical power or to 3.000 btu per tone of biogas. The digester dimensions are 40 m (L) and 12 m (W). The specific system is estimated to elaborate up to 6000 tones of organic solid wastes per year. Moreover is able to produce 75 kW-115 kW of electricity annually, depending on the volume of the organic wastes produced by the installation area during a year.

The basic system is also able to produce 2.200 tones of Compost per year from 5.000 tones of organic wastes per year.

The SMARTFERM can be operated mesophilic (approx. 38 ºC) or thermophilic (approx. 55ºC). A hygienisation can also be integrated in the process[2].

Figure 2.9 Components of the SMARTFERM unit

The SmartFerm AD facility includes the following four major process phases described below:

1. *Supply Air and Aeration* — Once the organic wastes are loaded into a digester, a hatch door is closed using a gas seal to ensure that biogas cannot escape. Each digester contains an in-floor aeration system, which is activated once the door is sealed. This aeration system pumps air from outside into the organic waste to help create aerobic digestion conditions that self-heat the material to designed process conditions for the first 12 hours. A mixture of oxygen and methane is potentially combustible so the chamber air is purged to remove any remaining oxygen before the anaerobic cycle commences.

2. *Percolate Cycle*—Under anaerobic conditions, the waste materials are sprayed with conditioned process water containing thermophilic microorganisms (percolate) that begin the decomposition process and produce biogas. This percolate is pumped in a closed loop between the digesters and the heated and insulated percolate tanks located beneath the digester units. Percolate continues to be sprinkled on the waste materials for approximately 20 days, causing the production of biogas. Percolate is collected in a drainage system, screened for solids and pumped back into a percolate tank where it is recharged with thermophilic organisms. Process control instrumentation ensures proper control of the percolate tank and regulation of percolate temperature.

3. *Biogas System*—Biogas from each digester is pumped to the percolate tank to obtain a rich, homogenized biogas, then pumped to a roof-top, doublemembrane storage bladder. The stored biogas is then combusted in a power plant or compressed into natural gas (CNG) for future uses.

4. *Exhaust Air*—On the 21st day of processing (and before the digester doors are opened) ambient air within the digester is collected in an

exhaust piping system. Low quality biogas (less than 20 percent methane) is combusted and the digester air is transferred to a biofilter for treatment [3].

2.4. Area context

Poros is a small, volcanic little island of great beauty. It is very close to Athens Greece, and is a popular summer resort to both Greeks and foreigners. Many Athenians have summerhouses there, which can be noticed in the weekends, since the island livens up a lot then.

The island's name means narrow strait, and is separated from the Peloponnese and the picturesque town of Galatas by a 370 meters canal. The town of Poros is build on the small peninsula of Sferia mainly on the small hill overlooking the port. Towards Mikro and Megalo Neorio you will find marinas for yachts and boats. The tourist season starts already from the middle of April as the island is very near to Athens and is ideal for day trips.

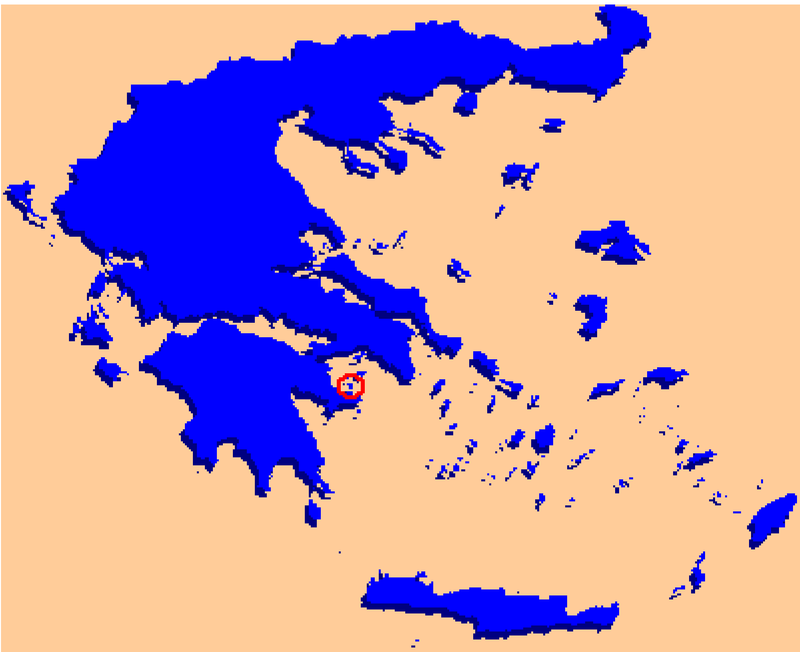

Figure 3.1: Location of the island of Poros and the town of Galatas in greece

The domestic population of the island is estimated to be 4.000 people, a number that increases significantly during the tourist season, and at weekends when many travelers from Athens arrive for a small trip. During the tourist season the number of the population can reach the 20.000 people.

The island of Poros is close to the port of Piraeus, about three hours with the ship, and one hour with the high speed boat. It's connection with the town of Galatas is being with ferry boats in less than 5 minutes.

Figure 3.2: View of the island of Poros from the town of Galatas

The town of Galatas, is at Peloponnese exactly in the opposite of the island of Poros as mentioned earlier. The town of Galatas has less population than Poros, about 2.200 people a number that increases too during the weekends and the tourist period. However the population does not have the same increase with the island of Poros, because most of the visitors prefer to stay in the island of Poros instead of the Galatas town. That's why the maximum increase is estimates to 4.400 people.

The municipality solid wastes of Poros and Galatas are sent to Athens for elaboration, because in the area does not exist a facility that can treat the wastes of the area [4],[5].

Figure 3.3: Map of Poros

3. Market Analysis

3.1. Legal background

Greece is supporting the use of biogas with different legislations. In Greece there are several laws which provide the legal basis for using biogas. The first law concerning renewable energies including biogas was the Law 1559/1985 in the year 1985. After that several more laws followed.

Feed-in tariff system:

Law 3851/2010, «Acceleration the Development of RES to Combat Climate Change and other provisions regulating matters which fill in the competence of the Ministry of Environment, energy and Climate Change» entered into force on June 2010 to amend the current legislation on renewable energy sources and particularly Law 3468/2006 [9].

Among other, law 3851/2010 sets new and higher feed-in tariff system based on the form of biomass (there are different prices according to biogas source, namely 220 €/MWh for biogas emanating from biomass - organic remnants of animal farming and of agricultural processed remnants and refuse - with installed capacity of d3MW and 200€/MWh for the same type of biogas plants but with installed capacity of >3MW). This is a key driver for attract higher interest on biogas exploitation schemes as the guaranteed market price was increased more than 2 times. Furthermore, the energy produced from biogas, providing the investments are realised without the use of government subsidy, is priced on the basis of the prices of the law 3851/2010, raised by 15%.

Power Purchase Agreements have a total duration of 20 years.

- **Law 2773/99**: Part of this law was the introduction of the so called "Electricity generation licence". This licence was the first licence concerning renewable energies directly and nowadays has still to be obtained first for each project in the field of renewable energies.
- **Law 3010/2002**: This law was the first law based on the Directive 97/11/EC which was implemented by the European Union.
- **Law 3423/2006**: The so called "Efficiency cogeneration of electricity and heat" law was following. This law consists of three main aspects:

  a) Simplifying the licencing procedure

  b) New pricing system for electricity

  c) The national renewable energy target of 29% electricity production in 2020
- **JMD 49828/2008**: This law includes general criteria to exclude some areas or land used for biogas exploitation schemes.
- **Law 3428/2005**: The so called "Liberalisation of the Natural Gas Market" law allows the feed-in of bio-methane in the national gas grid. However, certain quality requirements concerning the bio-methane have to be fulfilled. This law is based on the named targets of the Directive 2003/55/EC which was implemented by the European Union in the year 2003.
- **Law 3734/2009**: This is the so called "Promotion of cogeneration of two or more useful forms of energy" law. This

law transposes the Directive 2004/8/EC into the national legislation of Greece.

One more fact that has to be mentioned is that biogas projects are free taxed projects.

<u>Present permitting procedure:</u>

The first step in the permitting procedure for a biogas plant in Greece is to obtain the so-called Electricity Generation Licence (production licence). The present permitting procedure for a biogas project in Greece is shown in Figure 3.1.

The complete permitting procedure in Greece is shown in the Table 3.1. This includes aspects such as the name of the needed permit, the responsible authority, needed time for obtaining the permit, and possible costs and the validity of the permit [6].

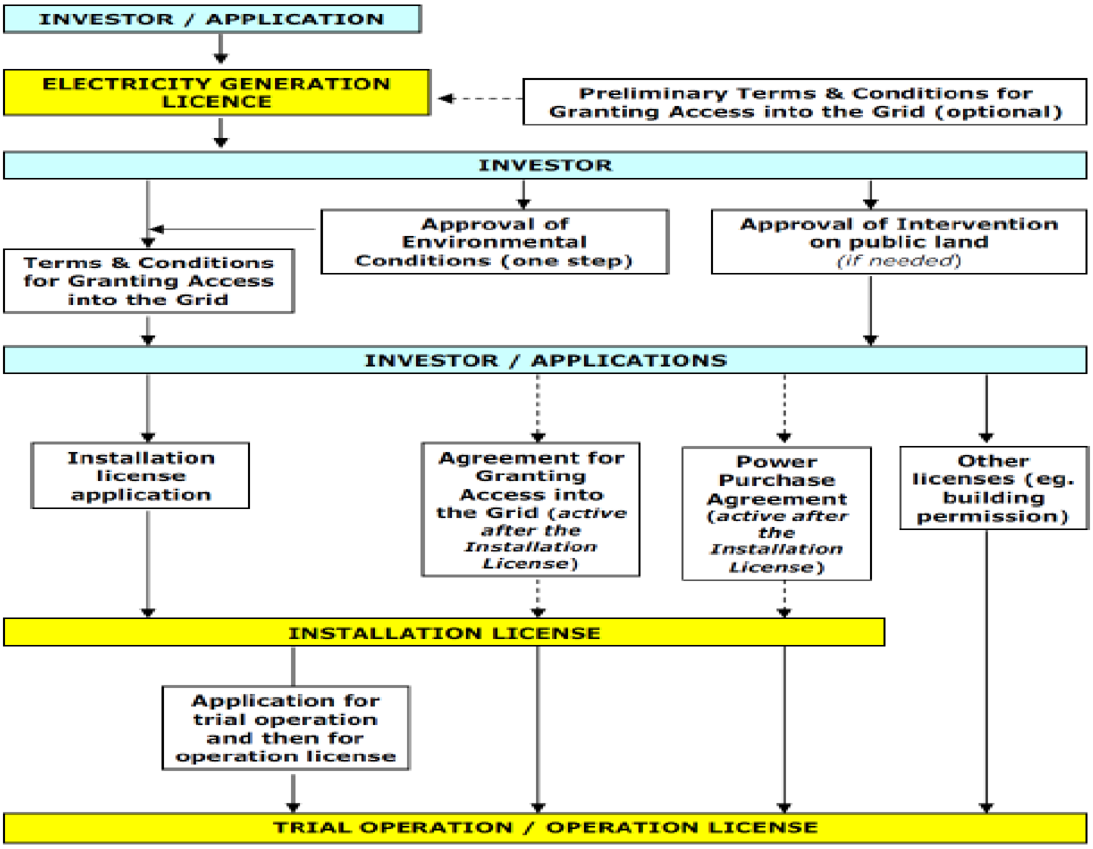

Figure 3.1 Permitting procedure for a biogas project in Greece.

Table 3.1: Needed permits for a biogas project in Greece

Name of permit	Responsible authority	Time till obtaining	Validity
Electricity Generation Licence	Regulatory Authority for Energy (RAE)	2 months	25 years (can be prolonged 25 more years)
Connection offer	Managers grants	4 months	4 years
Approval of Environmental Conditions	Respective region	4 months	10 years (can be prolonged 10 more years)
Installation licence		45 days	Permanent
Operation licence	Centre for Renewable Energy Sources and saving Environment C.R.E.S		20 years (can be prolonged 20 more years)

3.2. Production of the solid wastes of the area

Because of the lack of information by the local authority of Poros and Galatas, about the volume of the municipality solid wastes, a research was made in order to determine the amount of solid wastes for the next twenty years, a time period over which we are going to examine this business case.

A research was made about the production of the solid wastes of the whole country over the past years. For this investigation it was found that all the cases that need to know the production of the solid wastes in Greece, use the data of a research that was made by the regional waste management (R.W.M.P.) plans in 2006, in which was determined the total solid wastes of the year in every area in Greece for 2001, the production of solid wastes of 2001 per person in each area of Greece, the percentage of growing of the wastes for the next twenty years, and the characteristics of the solid wastes.

Therefore, data of researches was taken into account by both the municipality of the island of Poros and the world tourist organization (UNWTO), in order to determine the fluctuation of the population of the local area.

Although, both the island of Poros and the town of Galatas reside in the province of Attiki administratively, they belong to the province of Peloponnisos geographically. This is why we used the data of Peloponnisos in order to determine the volume of the solid wastes of the area.

According to the research by the (R.W.M.P.), the people of peloponnisos produced 1,093 kg/per person/per day in 2001. By their research they accomplish to determine a rate of growth for the solid wastes of Peloponnisos at 2% per year. Now the business case assume that the project will be ready to start working in 1 January of 2016 [7]. Thus, we can calculate the production of every person per day for the year of 2016:

$$1{,}093 \cdot (1{,}02)^{15} = 1{,}471\ kg/person/day.$$

As it was mentioned in the previous chapters, the local population of Poros is 4.000 people [4]. However, the island of Poros doesn’t have a steady population during the year because of the tourists who visit the island during the summer. Moreover the population increases significantly from april by 5.500 people, according to the research of the municipality of Poros [5]. This happens because the island is very close to Athens and many people (especially retired from work) are going to the island where they own country houses for the half of the year (april-september). Based on the same research the increase of the population grew during the high season period (July-August) in 2009 by the greek tourists that arrive on the island at approximately 11.000 people. The foreign tourists where 5.000 people in 2009. According to this research the number of the greek people that arrive in the island of Poros is not changing during the years, so we can assume that this numbers will be the same in 2016 at the baseline of this project. In the opposite, the number of the tourists that arrive in Greece and finally at the island of Poros has grown in the average by 10% every year since 2009, according to the world tourist organization [8]. By doing the calculation the number of the tourists that is expected to visit the island of Poros during the high season of the summer in 2016 is 8050 people.

Having determined the change of the population in every month for the island of Poros the amount of the municipality solid wastes can be determined.

Production of M.S.W. by the local people:

$$4.000\, persons \cdot 1{,}471\ kg/person/day \cdot 30\, days/month \cdot 12\, months/year \cdot 10^{-3} = 2118\, tones$$

Production of M.S.W. by the increase of the population in the period from April to June:

$$5.500\, persons \cdot 1{,}471\ kg/person/day \cdot 30\, days/month \cdot 3\, months/year \cdot 10^{-3} = 728{,}2\, tones$$

Production of M.S.W. by the increase of greek tourists in the high season period from July to September:

$$11.000\,persons \cdot 1{,}471\ \ kg/person/day \cdot 30\,days/month \cdot 3\,months/year \cdot 10^{-3} = 1456{,}4\,tones$$

Production of M.S.W. by the increase of foreign tourists in the high season period from July to September:

$$8.050\,persons \cdot 1{,}471\ \ kg/person/day \cdot 30\,days/month \cdot 3\,months/year \cdot 10^{-3} = 1066{,}2\,tones$$

In total: $2118 + 728{,}2 + 1456{,}4 + 1066{,}2 = 5.368{,}8\,tones$

For our project we need to determine the amount of the M.S.W. that are organic. According to the research of R.W.M.P. 50% of the total M.S.W. are organic [7]. Therefore the project's wastes input from the island of Poros are:

$$\frac{5.368{,}8\,tones}{2} = 2684{,}4\,tones$$

After the determination of the volume for the wastes of Poros, the volume of the wastes for the town of Galatas had to be determined. As mentioned in the previous chapters the local population is 2.200 people. During the period from April to September we assumed that the population of the town is doubled. The specific assumption was made because most of the tourists (greek and foreign) target the island of Poros for their vacations. In the town of Galatas usually visit tourists who either couldn't find accommodation in the island of Galatas or searching for a cheaper accommodation than those in the island of Poros.

Production of M.S.W. from the local people of the town:

$$2.200\,persons \cdot 1{,}471\ \ kg/person/day \cdot 30\,days/month \cdot 12\,months/year \cdot 10^{-3} = 1165\,tones$$

Production of M.S.W. during the period between April to September:

$$2 \cdot 2.200\, persons \cdot 1{,}471\ \ kg/person/day \cdot 30\, days/month \cdot 12\, months/year \cdot 10^{-3} = 1165\, tones$$

Total Organic M.S.W. of the town of Galatas:

$$\frac{1165 + 1165}{2} = 1165\, tones$$

At last, the total organic wastes for the year 2016 where determined:

$$2684.4 + 1165 = 3.849{,}4\, tones$$

and every year there is going to be an increase by 2%.

Year	Organic M.S.W. (tones)	Year	Organic M.S.W. (tones)
2016	3.849,4	2026	4.692,4
2017	3.926,4	2027	4.786,2
2018	4.004,9	2028	4.882,0
2019	4.085,0	2029	4.979,6
2020	4.166,7	2030	5.079,2
2021	4.250,0	2031	5.180,8
2022	4.335,0	2032	5.284,4
2023	4.421,8	2033	5.390,1
2024	4.510,2	2034	5.497,9
2025	4.600,4	2035	5.607,8

Table 3.2: Final determination of the organic M.S.W. in the Area of the project.

3.3. Conclusions, findings, recommendations

Strengths/Opportunities

- The location of the project site, in which there is no facility for elaborating the M.S.W.
- The feed in tariff system that consists biogas units, and can quarante steady and big revenues every year, 220 €/MWh
- The price of the Compost (50 €/tone), which can be sold to the local farms of the area.

- The demand for <<clean energy>> which is growing in Europe.
- The big subsidy which is offered by the European commission from the life project (60% of the total cost).
- The low cost for the chosen unit (SMARTFERM) and the quick time needed to be instanled.
- The low operation cost needed for the unit to operate.

Constraints/Challenges

- Lack of specific biogas legislation.
- Relatively negative public perception, experience and awareness about RES in general and biogas projects.
- Long lasting bureaucracy during the permitting procedure.
- Lack of properly working energy networks and public grids.
- Lack of experienced staff (skilled with knowledge about biogas) in the administration of the public authorities in the field of biogas.

In conclusion the market analysis shows that the area of the project can be a profitable investment, due to the lack of a unit that can elaborate the M.S.W. in the area. Moreover the feed in tariff system can provide standard revenues in the life time of the project. The ability of the unit to produce also Compost can add more revenues to our case. The European commission makes the finance of the project easier with the life project.

The bottlenecks are the long lasting bureaucracy for the permitting procedure, a problem that exists for any cases in Greece, and the lack of experienced staff in Greece [6].

4. Financial Analysis

In this chapter is going to be an analysis from which the Net present value will be determined. At first the ways of financing are going to be presented. Then, the determination of the overall costs will take place. At last, this chapter will close with the calculation of the NPV.

4.1 Methods of Financing

In the executive summary was mentioned the funding from the European commission via the life project. The LIFE programme is the EU's funding instrument for the environment and climate action. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value.

The LIFE 2014-2020 Regulation (EC) No 1293/2013 was published in the Official Journal L 347/185 of 20 December 2013. The Regulation establishes the Environment and Climate Action sub-programmes of the LIFE Programme for the next funding period, 2014–2020. The budget for the period is set at €3.4 billion in current prices.

The LIFE programme will contribute to sustainable development and to the achievement of the objectives and targets of the Europe 2020 Strategy, the 7th Union Environmental Action Programme and other relevant EU environment and climate strategies and plans.

The 'Environment' strand of the new programme covers three priority areas: environment and resource efficiency; nature and biodiversity; and environmental governance and information. The 'Climate Action' strand covers climate change mitigation; climate change adaptation; and climate governance and information.

The programme also consists of a new category of projects, jointly funded integrated projects, which will operate on a large territorial scale. These projects will aim to implement environmental and climate policy and to better integrate such policy aims into other policy areas.

The new regulation also establishes eligibility and the criteria for awards as well as a basis for selecting projects. The programme is open to the participation of third countries and provides for activities outside the EU. It also provides a framework for cooperation with international organizations.

In June 2017, the European Commission will carry out an external and independent mid-term evaluation report and by December 2023 it will complete an ex-post evaluation report covering the implementation and results of the LIFE Programme.

The co-financing rates of the programme are:

- 60% co-financing during the first multiannual work programme (2014-2017)
- 55% co-financing during the second multiannual work programme (2018-2020)

Supposing that our project can start up during the first period, we assume that the substitution percentage which can be given for the Smartferm project is 60% [13].

The second way of funding is by lending. According to the center for renewable sources and saving (CRES), the greek banks are interested in loaning projects for renewable energy with law interest rates, between 5-6 %. Some of the banks offer specific loans for biogas projects. Moreover they are interested in loaning either corporations or self-financing projects. They are willing to allow a grace period for biogas projects, but these depends from the type of lending and the investor's reliability. The banks require an equity investment about 20-25 % of the whole capital cost followed by a full financial plan, more funding sources (subsidy), operation plan and a legal basis. Usually the negotiation for the loan lasts about 4-6 weeks, but for some projects more time is required [14].

Some of the considered hazards by the banks for funding biogas projects are:

1. Changes in legislation for RES (non-stable framework)
2. Lack of experience by the investors
3. Ensured raw material (by contracts)
4. The existing technologies for biogas (there are many unproven technologies)

The basic conditions for the greek banks in order to offer a loan for biogas projects are:

1. A full-grown business plan
2. Presentation of licenses
3. Proven technologies
4. A good financial capacity by the investor
5. Ensured raw material
6. A reasonable cost
7. Equity funds

The last part for completing the capital cost is the equity funding or the seeking investors for the implementation of the SMARTFERM project.

4.2. Estimated Costs

In this section was made a research in order to estimate all the costs of the project. This estimation was made according to other biogas projects from US, Europe and Greece.

At first we assumed an interest rate at 5.5 % for a loan of 200.000 €, with a payback of 10 years. Then an effort began to determine the total capital cost. The problem in that determination was the difference between the European and the USA's costs.

The capital cost according to some projects in the USA was much bigger than the European projects. In some projects Zero Waste energy announced a total Capital cost of 2.000.000 € or 20.000 €/kW for the installation and start-up of a Smartferm unit in California [3],[11]. Thus, the cost for an American corporation should be bigger considering that the Smartferm unit is produced in Germany. The problem was that it wasn't possible to find financial data about a Smartferm project in Europe (or in Greece). That's why it was considered a general cost for biogas projects in Europe for the estimation of ours project capital cost. The average capital cost for a biogas project in Europe is 4.500 €/kW, and some projects in Greece had a capital cost of about 5.000 €/kW [10],[12]. Considering the law operation cost that the specific unit offers and the fact that the purchase of the components for the unit is being with a corporation from an EU country, the capital cost was balanced between those costs, but closer to the Greek referred cost. So at last the total capital cost was considered at 10.000 €/kW or 1.000.000 €. In the table 4.1 we can see a Conceptual plant estimation. By the life project a subsidy cost is able to be obtained at 600.000 € (60 %), and supposing that a private investor is able to invest 200.000 € (20 %), a loan could be given of 200.000 €.

Item	Cost
Digester Components (Leachate collection slab, gas collection bag, heating elements, gas piping, etc.)	410.000 €
Building Superstructure	235.000 €
Engine Generator Set	80.000 €
Improved Base for Foundation	85.000 €
Mixing Platform	40.000 €
Biofilters	40.000 €
Food Storage Pad	20.000 €
Electrical Interconnection	30.000 €
Design, Permitting Support and Fees	20.000 €
Contingency	40.000 €
Total	1.000.000 €

Table 4.1: Conceptual plant estimate [3].

The next step was the estimation of the operational cost. In this determination the problem that appeared was the same with the capital's cost, the deference between the European and the US financial data. As long as the US market, the operational cost is being set at 2.400 € /kW. The greek market sets the operational cost at 630 € /kW for biogas units between 1-2 MW electrical output. In order to decide a number for this project's operational cost, we used the same logic with the capital's cost. The operational cost should be between the US's and the European's but a little bit closer to the last one. At last the operational cost was estimated at 1.300 € /kW or 130.000 €.

That number includes Annual Capital Repair and Replacement and the employee's payments. In table 4.2 the staff needed is shown.

Employee	Number Hired	Job Description
Security Guard	3	Guards the digester, tanks, and equipment 24 hours a day. Refills Tanks for customers. Checks digester operation status.
Laborer	5	At the start of each batch, employee will collect the organic waste in carts and bring it back to the digester. At the end of each batch, employee will clean out the digester, and put the fertilizer into packages to be sold.
Manager/ Salesmen	1	Manages and directs the laborers to make proper adjustments for each batch. Directed by the expert to adjust operation parameters. Also, sells the fertilizer.
Expert	1	Tests and verifies operation parameters. Directs the manager to adjust operation parameters.

Table 4.2: Employee details [15].

4.3. Calculation of N.P.V.

The last part of the financial analysis is the calculation of the Net Present Value. The total costs were analysed in the previous section. At start we have to mention again that there are no taxes paid for biogas projects, which means that there is no need in calculating depreciation.

The total electricity produced (kWhrs) depends from the amount of the wastes, whose the yearly numbers were calculated in the 3.2 section. We have to mention that 5000 tones of M.S.W./year are being converted to 100 kW of electricity. If the amounts of M.S.W. are more or less from the number above we assume that the electrical output changes in a linear way, as long as it ranges between 75-115 kW. The revenues from the electricity are 0,22 €/kWhr. The capacity factor of the unit is 90 % which corresponds to 7884 hours operating per year.

The amount of the Compost produced according to the technical information of the Smartferm unit is the 40% of the total M.S.W. collected. The commercial value of the Compost is assumed at 50 €/tone [10],[11].

The total yearly revenues are going to be given by:

$$(0{,}22\ €/\text{kWhr} \times \text{Energy production}) + (50\ €/\text{tone} \times \text{Compost production}) =$$

$$= \left(0{,}22\ € \,/\, kWhr \times \frac{(Yearly\ amount\ of\ M.S.W.)}{(5000\ tones)} \times 100\ kW \times 7884 hrs\right) + (50\ \ € \,/\, tone \times 0{,}4 \times Yearly\ amount\ of\ M.S.W)$$

At last in order to calculate the discount rate of the project a 25% was consumed as a cost of equity. Thus, the discount rate was calculated:

$$i = (percentage\ of\ subsidy \times 0) + (percentage\ of\ equtity\ funds \times 0.25) + (percentage\ of\ loan \times 0.055) =$$
$$= 0{,}6 \times 0 + 0{,}2 \times 0{,}25 + 0{,}2 \times 0{,}055 = 0{,}061 = 6{,}1\%$$

At the table 4.3 below, the calculation of the N.P.V. is pictured.

BIOGAS UNIT: SMARTFERM

Cost of Capital	
Total	1.000.000 €
Subsidy Cost	600.000 €
Private Equity	200.000 €
Loan (5,5% interest rate)	200.000 €

Year of project	Year	Amount of wastes (tn)	Energy production (KWh)	Compost production (tn)	Revenues		Discount rate (6,1%)	Expenses				Net Cash flow
					Yearly	Present Value		Operating	Loan Reimbursment	Yearly	Present Value	
0	2015											- 200.000 €
1	2016	3.849,4	606.973,4	1.539,8	210.522,1 €	198.418,6 €	0,943	130.000,0 €	21.100,0 €	151.100,0 €	142.412,8 €	56.005,8 €
2	2017	3.926,4	619.112,9	1.570,6	214.732,6 €	190.751,2 €	0,888	130.000,0 €	21.100,0 €	151.100,0 €	134.225,1 €	56.526,1 €
3	2018	4.004,9	631.495,1	1.602,0	219.027,2 €	183.380,0 €	0,837	130.000,0 €	21.100,0 €	151.100,0 €	126.508,1 €	56.871,9 €
4	2019	4.085,0	644.125,0	1.634,0	223.407,8 €	176.293,7 €	0,789	130.000,0 €	21.100,0 €	151.100,0 €	119.234,8 €	57.058,9 €
5	2020	4.166,7	657.007,5	1.666,7	227.875,9 €	169.481,2 €	0,744	130.000,0 €	21.100,0 €	151.100,0 €	112.379,6 €	57.101,6 €
6	2021	4.250,0	670.147,7	1.700,0	232.433,5 €	162.932,0 €	0,701	130.000,0 €	21.100,0 €	151.100,0 €	105.918,6 €	57.013,4 €
7	2022	4.335,0	683.550,6	1.734,0	237.082,1 €	156.635,8 €	0,661	130.000,0 €	21.100,0 €	151.100,0 €	99.829,0 €	56.806,8 €
8	2023	4.421,8	697.221,6	1.768,7	241.823,8 €	150.583,0 €	0,623	130.000,0 €	21.100,0 €	151.100,0 €	94.089,6 €	56.493,4 €
9	2024	4.510,2	711.166,1	1.804,1	246.660,2 €	144.764,0 €	0,587	130.000,0 €	21.100,0 €	151.100,0 €	88.680,1 €	56.084,0 €
10	2025	4.600,4	725.389,4	1.840,2	251.593,5 €	139.170,0 €	0,553	130.000,0 €	21.100,0 €	151.100,0 €	83.581,6 €	55.588,4 €
11	2026	4.692,4	739.897,2	1.877,0	256.625,3 €	133.792,0 €	0,521	130.000,0 €	0,0 €	130.000,0 €	67.775,7 €	66.016,3 €
12	2027	4.786,2	754.695,1	1.914,5	261.757,8 €	128.621,9 €	0,491	130.000,0 €	0,0 €	130.000,0 €	63.879,1 €	64.742,9 €
13	2028	4.882,0	769.789,0	1.952,8	266.993,0 €	123.651,6 €	0,463	130.000,0 €	0,0 €	130.000,0 €	60.206,5 €	63.445,1 €
14	2029	4.979,6	785.184,8	1.991,8	272.332,8 €	118.873,4 €	0,437	130.000,0 €	0,0 €	130.000,0 €	56.745,0 €	62.128,3 €
15	2030	5.079,2	800.888,5	2.031,7	277.779,5 €	114.279,8 €	0,411	130.000,0 €	0,0 €	130.000,0 €	53.482,6 €	60.797,2 €
16	2031	5.180,8	816.906,3	2.072,3	283.335,1 €	109.863,7 €	0,388	130.000,0 €	0,0 €	130.000,0 €	50.407,7 €	59.456,0 €
17	2032	5.284,4	833.244,4	2.113,8	289.001,8 €	105.618,3 €	0,365	130.000,0 €	0,0 €	130.000,0 €	47.509,6 €	58.108,6 €
18	2033	5.390,1	849.909,3	2.156,0	294.781,8 €	101.536,9 €	0,344	130.000,0 €	0,0 €	130.000,0 €	44.778,2 €	56.758,7 €
19	2034	5.497,9	866.907,5	2.199,2	300.677,5 €	97.613,2 €	0,325	130.000,0 €	0,0 €	130.000,0 €	42.203,8 €	55.409,5 €
20	2035	5.607,8	884.245,6	2.243,1	306.691,0 €	93.841,2 €	0,306	130.000,0 €	0,0 €	130.000,0 €	39.777,3 €	54.063,8 €
Total						2.800.101,5 €					1.633.624,8 €	

NPV	966.476,7 €
IRR	28%

Table 4.2: Calculation of N.P.V.

From the calculation it can be easily observed a high price of the N.P.V. at 956.476,7 €. A number that cannot go unnoticed since it almost multiplies the equity funds of the investor by 5 times. An other result which confirms the high results of this plan is the internal rate of return (IRR). The IRR was calculated at 28%, a high number which gives an other good sign for this business case. At last the final result needed is the payback period. In figure 4.1 is pictured the break even point at 3.56 years, a small period due to the big Capital cost needed for the investment.

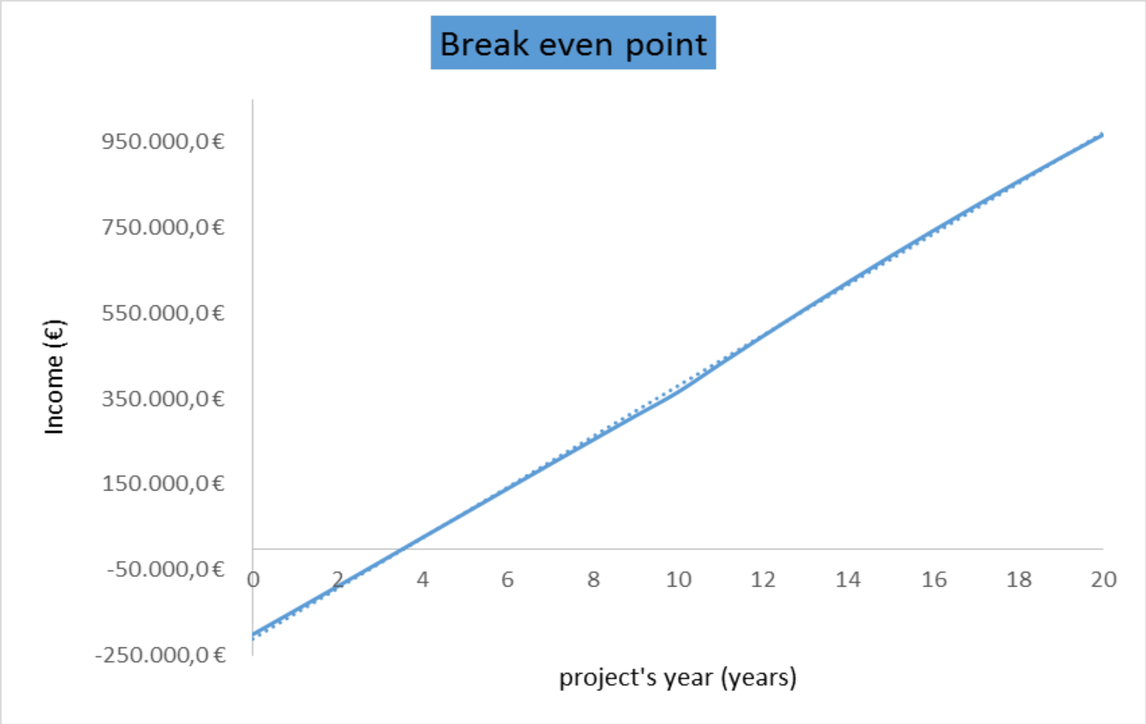

Figure 4.1 Break even point

In conclusion the key-points are:

- Total capital cost: 1.000.000 €
- Equity funds: 200.000 €
- Interest rate (loan): 5,5%
- Discount rate: 6,1 %
- Price of electricity: 0,22 €/kWhr
- Price of Compost: 50 €/tone
- Operational cost: 130.000 €/year
- No taxes
- N.P.V.: 956.476,7 €
- IRR: 28 %
- Payback period: 3.56 years

5. Risk Assessment

This is the last part in the analysis for the business case of the SMARTFERM BIOGUS UNIT at the island of Poros. In this chapter are going to be quoted the risks of this case, and it's going to be an analysis on how the result of the N.P.V. can be changed and can be ranged.

5.1. Sensitivity analysis

The first step that was made, was a sensitivity analysis in some that factors from which the N.P.V. depends. These factors are: the total capital cost, the operating cost, the amount of the wastes at the start of the project, the discount rate, the capacity factor and the yearly growth of the wastes. The range of the changes were from 80% to 120% of the original number that was taken into account in the calculation of the N.P.V. at the previous chapter (4). In figure 5.1 is pictured the diagramme with the way that the N.P.V. is formed by changing the factors which was mentioned earlier.

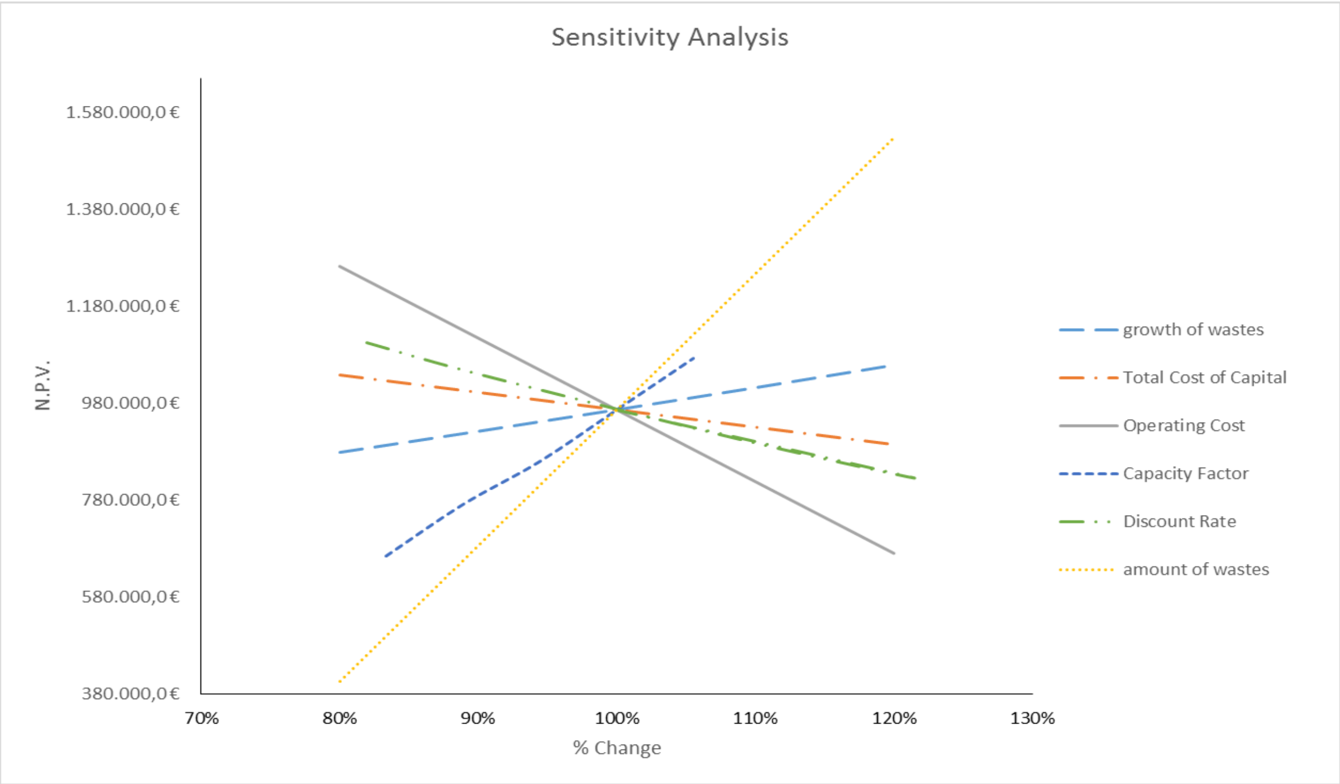

Figure 5.1 Sensitivity analysis

It is easily shown that the most sensitive factor is the amount of the wastes. This result is quite reasonable since the financial plan was for 20 years, and as a factor has a huge influence at the potential production (electricity, compost) of this project. The second more sensitive factor in the S.A. is the operating cost, a reasonable result too because it's price is repeated every year in the business case. Although the C.F. seems to be a high factor, the growth of the wastes is possibly more important because this factor sets the evolution of the amount of the municipal solid wastes in time and subsequently the growth of the production and the revenues. Thus, the capacity factor depends more from the amount of the M.S.W. than the utilization of the facility. The last important factor in the sensitivity analysis was the discount rate. The discount rate as it is known represents the risk of the investment. It's dependent comes from the subsidy cost the cost of equity and the interest rate. As long as the subsidy cost is at this level it is sure that the number of the discount rate won't have a big range.

It may look as a paradox but the total cost of capital doesn't seems to be a big factor for the N.P.V. . This is because the subsidy cost is quite big (60%) and the loan percentage is satisfactory. Thus, the investors are obligated to invest only the 20% of the required amount for the investment.

5.2. Scenarios of the N.P.V.

The second step of the risk assessment to develop 4 scenarios of the N.P.V. based on possible changes in some of the factors which were analyzed in the previous section.

The 3 most important factors which were chosen for analysis from the previous section, the sensitivity analysis. These factors are: the amount of the wastes at the beginning of the project, the operating cost and the discount rate.

We started by setting the range in which each of the 3 chosen factors will be analyzed and define the reason why these ranges were set. The operating cost (O.C.) was set at 130.000 €. In the analysis at 4.2 section it was cited that the O.C. was considered between the U.S.'s general cost and the greek one. However the decision made was to consider it closer to the greek cost. These two costs were 63.000 € and 240.000 € respectively. This is why the range for the operating cost was set between 100.000 € and 150.000 €. The amount of the M.S.W. of the area at the beginning of the project were estimated in the 3.2 section at 3.849,4 tones. There were many factors in the determination for this numbers and the main principle was the population of the island and it's change during the summer period. The possible number of the population doesn't have much room for being higher, this is why the selected range was a change of this number from: 5% to -10%. The discount rate was analyzed at section 4.3 in the calculation of the N.P.V. and was estimated at 6.1%. The discount rate depends from subsidy cost the equity cost and the interest rate. Since the subsidy cost can be granted from the life programme, the factors that can be chanced in the discount rate are the other two. The equity cost was 25% so we can assume a range between 20%-25%. The interest rate as mentioned ranges between 5%-7%. At last by using these two ranges for these factors we set a range for the discount rate between 5%-7%.

In continuing, 5 scenarios were set based on the ranges of the 3 factors which were analyzed in the previous paragraph. The first is the worst scenario where the 3 factors had their lowest price and the second scenario (bad) is the one with the second lowest price. The third scenario is the base case scenario the one that was used for the determination of the

N.P.V.. The fourth scenario (good) is the one with the second best prices and the last one is the best scenario where all the prices have the higher prices. At table 5.1 are shown all the scenarios with the changes in the factors analytically with the results of their N.P.V. and their IRR.

Scenarios	**Worst Scenario**	**Bad Scenario**	**Base case scenario**	**Good Scenario**	**Best Scenario**
% change in the operating cost	+15 %	+5 %	0 %	-10 %	-25 %
% change in the amount of wastes	-10 %	-5 %	0 %	+2.5 %	+5 %
% change in the discount rate	+13 %	+6.5 %	0 %	-10 %	-18 %
N.P.V.	**402.278,1 €**	**714.427,6 €**	**966.476,7 €**	**1.268.210,4 €**	**1.663.767,3 €**
IRR	12 %	21%	28 %	37 %	48 %

Table 5.1: The results of the 5 scenarios.

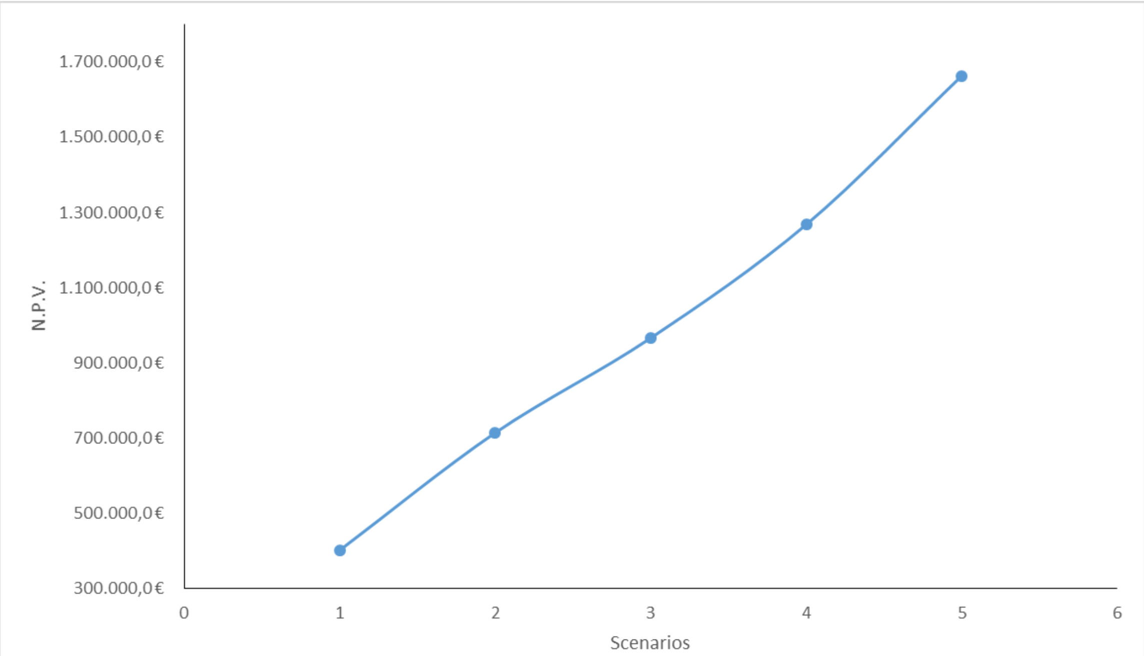

Figure 5.2 Graphical display of the results from the 5 scenarios.

The results are characterized with a big change in every scenario, especially the best and the worst scenario have a big difference from the base case scenario. This behavior is logical because the range in the first two factors (operating cost, amount of the wastes), which were the two most sensitive factors, was in some cases over 10 %. We have to remind that the worst and the best scenarios are the less possible scenarios, because the changes in our 3 factors are a little bit high. A focusing range would be better to be the one between the good and the bad scenario where each factor was less changed than in the extreme scenarios. This range indicates that the N.P.V. could have a change by 250.000 € and 300.000 €, a significant change compared to our base-case scenario's N.P.V. , but the project still remains extremely profitable nonetheless.

5.3. Assessment of biogas potential hazards

In the last section of this project some technical and other type of hazards are going to be presented.

At first we are going to quote some technical risks and some mitigations that could be applied in order to prevent any type of accident during the project. In table 5.2 all these risks are listed.

Risk	Why it's a problem?	Mitigation
Gas releases	Hydrogen Sulfide gas, Carbon Monoxide gas, Biogas are flammable, explosive or immediately toxic	-Regularly check the whole system for leaks -Use Air Tight Sealant
Confined spaces	When cleaning the biogas digester, exit strategies are necessary	Ladder and retractable hatch door
Failure of Biodigester	Could lead to failure of entire system	Using 3 different digesters
Improper preparation of influent solids	leading to blockage and scum formation	Removal of inert particles: sand and rocks
Temperature fluctuations	Could slow down system	Climate of India and low-cost insulating materials (sawdust, bagasse, grass, cotton waste, wheat straw)
pH Fluctuations (need 6.8-8.5)	Bacteria Sensitive to pH, and reaction could stop working	Continuous monitoring of pH within the feed and the digester, additives
Corrosion of gas holder, Occurrence of H_2S leading to corrosion	Could lead to leakage	Regular cleaning and use of proper sealant, H_2S removed by passing over ferric oxide or iron filings
Pressure Increases	Could lead to explosion	Removal of water condensate from piping system, use of pressure gauages

Table 5.2: Technical risks, the problems they cause and ways for their mitigation.

The main hazards associated with biogas productions are potentially explosiveness, asphyxia, toxicity and disease [16].

Explosion risk assessment

Many workplaces may contain, or have activities that produce, explosive or potentially explosive atmospheres. Such a workplace is also biogas plant. Methane, which makes up from 50% to 75% of biogas, forms explosive mixtures in air, and presents serious explosion dangerous. The lower explosive limit of methane being 4,4 vol. % and the upper limit 16,5 vol. %. Under and upper this limits methane cannot be ignited under normal ambient circumstances.

Explosions can cause loss of life and serious injuries as well as significant damage. Preventing releases of dangerous substances, which can create explosive atmospheres, and preventing sources of ignition are two widely used ways of reducing the risk. European Directives for controlling explosive atmospheres is named ATEX. ATEX contain two directives (Health & Safety Executive, 2010):

1) Directive 99/92/EC (also known as 'ATEX 137' or the 'ATEX Workplace Directive') on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

2) Directive 94/9/EC (also known as 'ATEX 95' or 'the ATEX Equipment Directive') on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres.

Spaces with risk of explosion are graded in zones according to the probability of the occurrence of a dangerous explosive atmosphere. If a dangerous explosive atmosphere can occur in a space, the entire space is to be regarded as highly explosive (Figure 5.3).

Zone 0 covers spaces with a constant, long-term, or frequent (most of the time) dangerous explosive atmosphere which consists of a mixture of air and gases, vapors, or mists.

In biogas plants, the gasholder, the air intake of the combustion engine, the combustion chamber of the gas flare, and under special operating conditions the bioreactor itself belong to zone 0. A special operating condition is given when air enters the interior of the bioreactor. Under normal operation conditions, a small positive pressure prevents the penetration of air into the bioreactor.

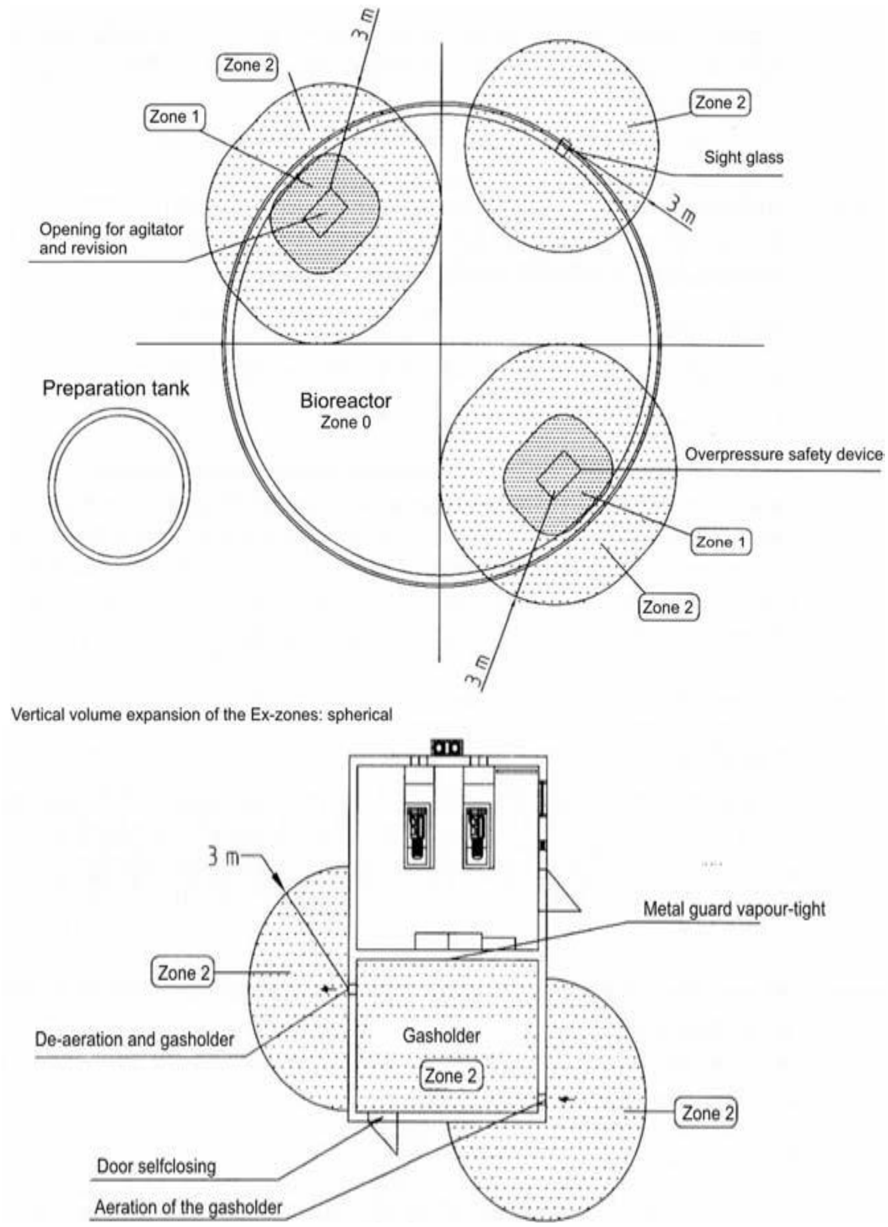

Figure 5.3 Explosive areas in biogas plants

In the air intake of the combustion engine or in the combustion chamber of the gas flare there is constantly an explosive mixture. The engine and the gas flare must be separated from the other gas system by a flame trap as safety device.

Zone 1 covers spaces with the occasional occurrence of an explosive atmosphere which consists of a mixture of air and gases, vapors, or mists.

In conditions of good ventilation, zone 1 is to be assumed in a region within 1 m from components of the plant, items of equipment, connections, sight glasses, grommets, and service openings at the gasholder and at the bioreactor, but only if leakage of biogas is technically possible. Likewise the space around the mouth of exhaust pipes, positive pressure safety devices, and gas flares is considered to be zone 1. In closed spaces, the endangered space is extended to a periphery of 4.5 m.

Enclosed spaces or pits through which anaerobic sludge flows belong to zone 1.

Zone 2 covers spaces where the occurrence of dangerous atmospheres from gas mixtures cannot be assumed, but if it does occur it is seldom and only for a short time. Zone 2 is in the region 1 – 3 m from components of the plant technically classified as leak-tight, items of equipment, connections, grommets, service openings, and bursting disks. Open pits (e.g., pits for pumps for anaerobic sludge) or basins, enclosed spaces wherein gas pipes are installed and which do not have ventilation, are zone 2.

The radius of 1 – 3 m is given for good ventilation. Closed spaces are considered to belong to zone 2 in their entirety.

Operating staff on biogas plants should ensure that no air is allowed to enter the digester or gasholder. All piping and equipment must be sealed properly to prevent gas from escaping to the outside. There must be no smoking and all electrical installations, including light switches, torches etc. must be of the explosion-proof type, as the smallest spark could ignite escaped gases [16].

Fire risk assessment

In order to reduce the fire risk, the plant is to be divided into fire protection sectors, e.g., the bioreactor and gasholder, the gas consumption equipment, and the gas compressor. Certain distances must be maintained between the fire protection sectors (Table 5.3-5.5). Depending upon how much space is available in between, the material of the external walls of buildings containing equipment or of protecting walls has to be chosen [16].

Gas volume per tank (m^3)	Up to 300	300 to 1500	1500 to 5000	Over 5000	Material of the walls
Fire brake (m)	6	10	15	20	Other materials
Fire brake (m)	3	6	10	15	Noncombustible
Fire brake (m)	3	3	6	10	Fireretardant, vapor tight

Table 5.3: Protection distances around above - ground fixed gasholders.

Gas volume per tank (m^3)	Up to 300	300 to 1500	1500 to 5000	Over 5000
Fire brake (m)	3	6	10	15

Table 5.4: Protection distances around cushions and balloon gasholders as well as around foil hoods for gas holding above liquid manure storage tanks or bioreactors.

Gas volume per tank (m^3)	Up to 300	300 to 1500	1500 to 5000	Over 5000
Fire brake (m)	4,5	10	15	20

Table 5.4: Protection distances around cushions and balloon gasholders as well as around foil hoods for gas holding above liquid manure storage tanks or bioreactors.

Health risk assessment

Each of these components of biogas has its own problems, as well as displacing oxygen.

Methane (CH_4) is a inert, colorless, odorless gas, lighter than air (will collect in roof spaces etc). In terms of health effects it is stifling gases and the most serious threat to health and life is choking expect explosion. At low concentrations can act narcotic. Victim may not be aware of asphyxiation, and when concentration arises can result in suffocation.

Carbon dioxide (CO_2) is a inert, colorless, odorless gas, heavier than air (will collect in sumps etc.). If air with increased CO_2 contents no more than 3% CO_2, toxic effects do not occur if the air contains enough oxygen. When increasing concentrations occurs, form anoxia and hypoxia, concentrations CO_2 above 5% affect respiration rate and irritation of respiratory tracts [16].

Concentration (in air)	Effect
0.03 – 0.15 ppm	Threshold of detectability (odor of bad egg)
15 – 75 ppm	Irritation of the eyes and the airways, nausea, vomiting, headache, unconsciousness
150 – 300 ppm (0.015 – 0.03%)	Palsy of the olfactory nerve
> 375 ppm (0.038%)	Death through poisoning (after some hours)
> 750 ppm (0.075%)	Unconsciousness and death by apnea within 30 – 60 min
Above 1000 ppm (0.1%)	Sudden death by apnea within a few minutes

Table 5.5: Toxicity of hydrogen sulfide

Hydrogen sulfide (H_2S) is a flammable gas, which can recognize by smell at concentrations of 1.4 to 2.3 mg. m^{-3} (rotten egg gas), destroys olfactory (smelling) tissues and lungs, and becomes odorless as the level increases. Impact on human is listed in Table 5.6.

Noise

Noise is defined to be disturbing sound. Any location where sound does not cause disturbance, even it is very loud, does not incur restrictions. The area in a biogas plant where noise is most intense is near the gas engine. Near CHP plants, the limiting value 80dB for workplaces is far exceeded. The noise radiates through the exhaust pipe and the ventilation openings of the plant area. Safety arrangements [16]:

- The operation of engines, machines, and plant must correspond to the state of the art of noise protection.
- Impact sound - radiating plants must be decoupled from airborne sound - radiating buildings and components.
- In exhaust gas pipes and/or in openings for ventilating enclosed spaces, sound absorbers have to be installed.
- Doors, gates, and windows of the generator house must be closed when the engine is under load.
- The space close to the generator house must be noise - protected by sound - damping measures according to local regulations.

Disease

As Anaerobic Digestion relies on a mixed population of bacteria of largely unknown origin, but often including animal wastes, to carry out the waste treatment process care should be taken to avoid contact with the digester contents and to wash thoroughly after working around the digester (and particularly before eating or drinking). This also helps to minimize the odors spread which may accompany the digestion process. The digestion process does reduce the number of pathogenic (disease causing) bacteria, particularly at higher operating temperatures, but the biological nature of the process need to be kept in mind [16].

In conclusion, in this section are mentioned some hazards which do not cover all the security risks associated with the operation of biogas plants. During operation, are particularly important regular checks on which to keep records, operational safety features for the possibility of early detection of potential danger, regular staff training and compliance legal and technical regulation.

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