CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FACULTY OF FORESTRY AND WOOD SCIENCES

Department of Forestry and Wood Economics

ECONOMIC STUDY OF A PYROLYSIS PLANT IN ATYRAU (KAZAKHSTAN)

DIPLOMA THESIS

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DIPLOMA THESIS ASSIGNMENT

Eduardo Jose Amado Garcia

Forestry, Water and Landscape Management

Thesis title

Economic Study of a Pyrolysis Plant in Atyrau (Kazakhstan)

Objectives of thesis

The main objective is to evaluate the possibility of applying the pyrolysis technology for the urban solid waste of Atyrau region (Kazakhstan) on an economic scale. SoroznoEco Company would be interested in opening pyrolysis market in Kazakhstan. Due to the disposition of a contact that is there and to the consent of the company itself, the intention is to initiate this project. Specific objective is to describe the operation of the waste market, determinate the predisposition of local entities, search the possibilities in terms of financing of project and propose the case of a thermal recovery plant that meets local conditions to determine its economic profitability and social benefit.

Methodology

Sources of data collection will include primary and secondary data and data analysis will be a vital part of this research. This thesis will collect the primary data from the use of qualitative and quantitative methods. The thesis is based on the study of the SoroznoEco technologies related to pyrolysis plants and analysis of the financial market. A detailed budget of project will be compiled. The profitability of the project will be determined by comparing prices.

The proposed extent of the thesis

50 standard pages

Keywords

Atyrau (Kazakhstan), economic study, profitability, pyrolysis plant, sustainable development

Recommended information sources

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Declaration

I declare that I wrote my Diploma thesis independently, and that I have cited all the information sources and literature I used. Neither this thesis nor any substantial part of it have been submitted for the acquisition of another or the same academic degree.

I consent to the lending of my dissertation for study purposes. By affixing his or her signature the user confirms using this dissertation for study purposes and declares that he or she has listed it among the sources used.

Prague, 2018

Signature: .... Eduardo José Amado García

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ABSTRACT

The municipal solid waste (MSW) is a global problem with cultural characteristics and for which the minimum necessary is invested to keep them out of the reach of urban centers and out of sight of any person, without considering the environmental and public health effects with proper management and decision making.. (CASAS, 2014)

When talking about an area delimited as the Atyrau region, it can be understood that this problem requires a social evolution, in which it is indispensable to manage the waste in a sustainable way without this representing a greater complexity, but on the contrary the simplicity in the process of MSW management from its generation to its final disposal. This study intends among other things to show the main available technologies such as Pyrolysis, its approximate investment costs for the adequate Integral Management of the MSW of the Atyrau region.

In order to carry out this study, specialized books and articles on the topic of MSW are consulted for each of the technologies and specialties on the sustainable management of large scale MSW.

This project it is intended to generate a proposal to apply the pyrolysis technology in the MSW of Atyrau region and be able to offer an alternative to the final disposal of waste.

As one of the objectives of this research is to introduce into the technologies of energy recovery of municipal solid waste, its comparison and current state of development in the world.

Keywords: Atyrau (Kazakhstan), economic study, profitability, pyrolysis plant, sustainable development.

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

In this first section the basic concepts about the project are developed, which is both the personal motivation and the technical objectives. In this way, a global vision of the project will be given.

1.1 Motivation

The generation of waste is an inherent consequence of the biochemical functions of all life functions. Ecosystems are based on an interaction of different organisms in which the waste of some are used or somehow recycled by others in a way that prevents the accumulation of waste that could cause damage to the health of the ecosystem or any of its elements. The accumulation of some material or waste created by an organism can lead to the modification of the ecosystem and the consequent evolution or extinction of the species that inhabit it (SEMARNAT, 2006)

The inadequate treatment of Municipal Solid Waste (MSW), produces multiple consequences in the quality of air, soil and water that result in problems for human health and the balance of the environment. Kazakhstan as a member of the Organization for Economic Cooperation and Development (OECD), is committed to advancing in various areas of growth and development, where the care and preservation of the environment should be considered as a fundamental element for sustainable development.

Additionally, the generation of waste has presented a sustained increase as well as the consumption of electricity, both signs of a developing economy. However, the high percentage of waste deposited in sanitary landfills and landfills accounts for an inefficient and environmentally unfriendly system, since materials with recycling or energy recovery potential are wasted.

The Ministry of Energy has expressed interest in evaluating waste treatment with energy recovery that will solve the current problems. Also some municipalities of the Metropolitan Region are willing to consider projects of this type as part of their local energy strategy.

Thus, the motivation of this report is to review the different thermal treatment technologies of MSW with electric energy recovery in order to propose the one that, within the regional context, is optimal and feasible for Atyrau region. Projects of this nature allow to reduce the demand for final disposal sites while reducing atmospheric emissions related to biodegradation in sanitary landfills and those due to the use of machinery for transportation and final disposal of waste.

It is expected that this work will be a contribution for those initiatives that seek to improve the waste treatment system in the country and resolve possible inefficiencies. In order to study the possibility of implementing pyrolysis technology in the country

1.2 Justification

SoroznoEco Company would be interested in opening pyrolysis market in Kazakhstan. Due to the disposition of a contact that is there and to the consent of the company itself, the intention is to initiate this project.

1.3 Objectives

1.3.1 General objectives

The main objective is to evaluate the possibility of applying the pyrolysis technology for the municipal solid waste of Atyrau region (Kazakhstan) on an economic scale.

1.3.2 Specific objectives

Within the specific objectives, the description of the operations of the waste market stands out, in this way we also want to know the predisposition of the local entities as well as the possibility of project financing.

It is also desired to propose the case of a thermal recovery plant that meets local conditions. In order to be able to finalize determining its economic profitability and its social benefits.

2 Background

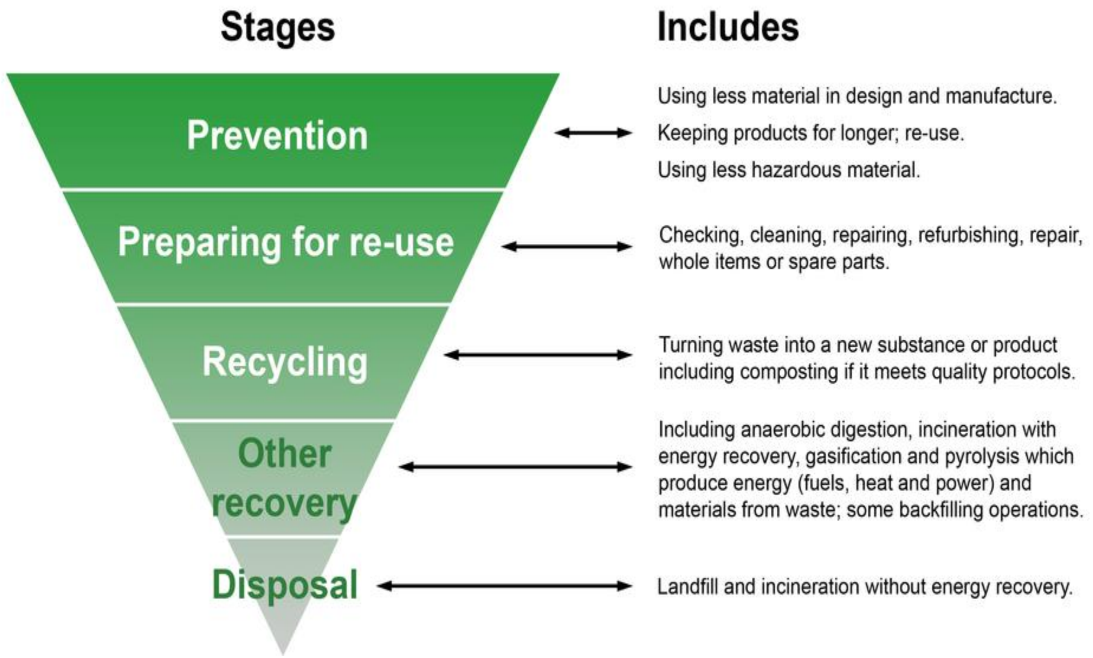
In this section we develop the basic concepts about what is pyrolysis as well as the social context in which we find ourselves and the relationship with that process.

2.1 Context

The United States Environmental Protection Agency (EPA) and other environmental organizations have also defined the Waste Management Hierarchy. This hierarchy establishes an order of priorities in the waste stream in order to improve waste management. It consists of five sections organized as an inverted pyramid with the following stages: Reduce, Reuse, Recycle, Valorization and Final disposition. In the upper part, the primary actions are located, while the lower sections are subsequently applied to the upper sections. (CID COFFRÉ, 2016)

In the figure 1 you can see everything developed in the previous paragraph.

FIGURE 1: Hierarchy of waste management.



SOURCE: (MARLOW, 2012)

The technologies that are evaluated in the following sections are part of the penultimate section of the waste management hierarchy corresponding to Valorisation. In particular, the technologies to be studied are energy recovery techniques of the thermal type with conversion to electrical energy to be injected into the network.

Valorisation is any operation whose main result is that the waste serves a useful purpose by substituting other materials that would otherwise have been used to fulfil a particular function, or what residue is prepared to fulfil that function in the facility or in the economy in general. For energy recovery, the main use of waste will be as fuel or another way of producing energy. (CILLERO, 2012)

2.2 General description of the pyrolysis in the municipal solid waste

Although gasification systems are often called pyrolysis, (TCHOBANOGLOUS, 1993) define pyrolysis systems as those in which an external heat source is used that energizes endothermic pyrolytic reactions in an oxygen-free environment, while gasification systems can sustain themselves and occur in the presence of air or oxygen.

Pyrolysis is defined as a thermochemical process by which the organic material of solid by-products, except metals and glass, is decomposed by the action of heat, in a deficient atmosphere of oxygen, in the case of the pyrolysis of biomass (although this term is very broad and includes MSW) and is transformed into a liquid mixture (tars and oils), gases (synthesis gas), fuels, carbonaceous waste (char) and water. The composition of these products is relative and depends on the operating conditions as well as the chemical composition of the waste. This process seeks energy efficiency through the generation of secondary chemical compounds and heat (AGROWASTE, 2013)

Pyrolysis is usually carried out in rotating cylinders where the residue is heated in total absence of air. This heating can take place in one or two stages (pre-drying). The source of heat necessary to carry out the reaction can be an auxiliary fuel, but it is more usual to come from the process itself, since some of the fractions obtained (with high calorific value) are usually burned. (BRIDGWATER, 2004)

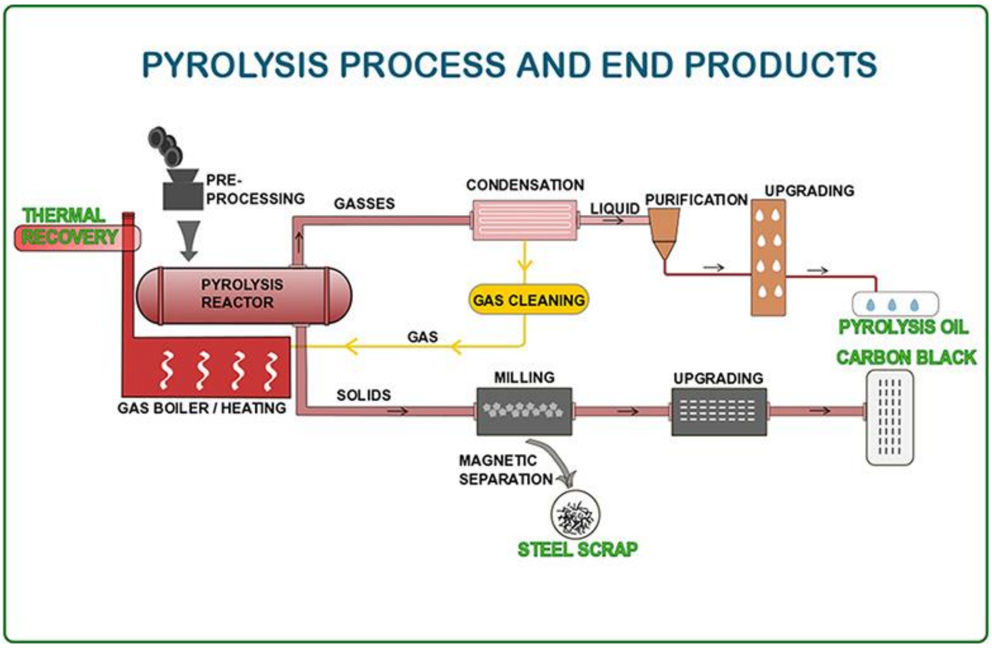
The combustion gases generated are at high temperature and are fed to the outside of the reactor as a heating source. The design of the reactor determines the transfer of heat by conduction, convection and radiation all this depending on the available particle size. Therefore, in the case of MSW cassium pyrolysis, a rotary kiln is always used.

The pyrolysis process is complex, the most accepted theory involves the decomposition of the solid through primary reactions whose resulting products can be degraded by secondary reactions. The characteristics of both primary and secondary products are a function of the conditions in which the process is carried out. (BRIDGWATER, 2004)

For example, when pyrolysis tries to optimize the production of coal, it is carried out very slowly with reaction times in hours or even days. If the reaction is carried out in seconds, the performance in liquids is favoured when temperatures lower than 650 ˚C are used and rapid cooling of the generated products, while at higher temperatures and high residence times the gas production is maximized.

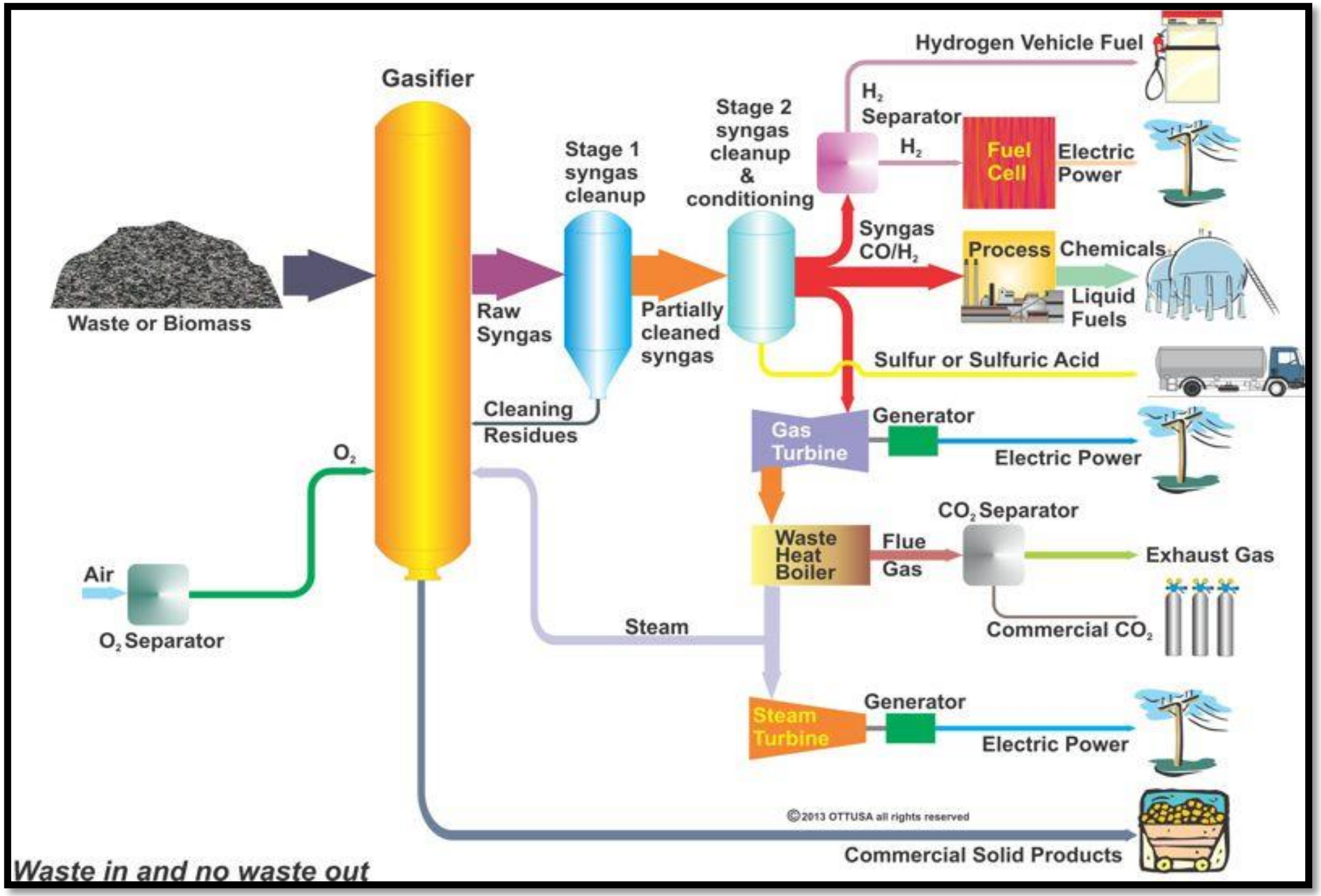
In figures 2 and 3 pyrolysis and gasification processes diagrams are observed.

FIGURE 2: Pyrolysis process diagrams.



SOURCE: (ADAMATIC, 2016)

FIGURE 3: MSW conversion system with gasifier

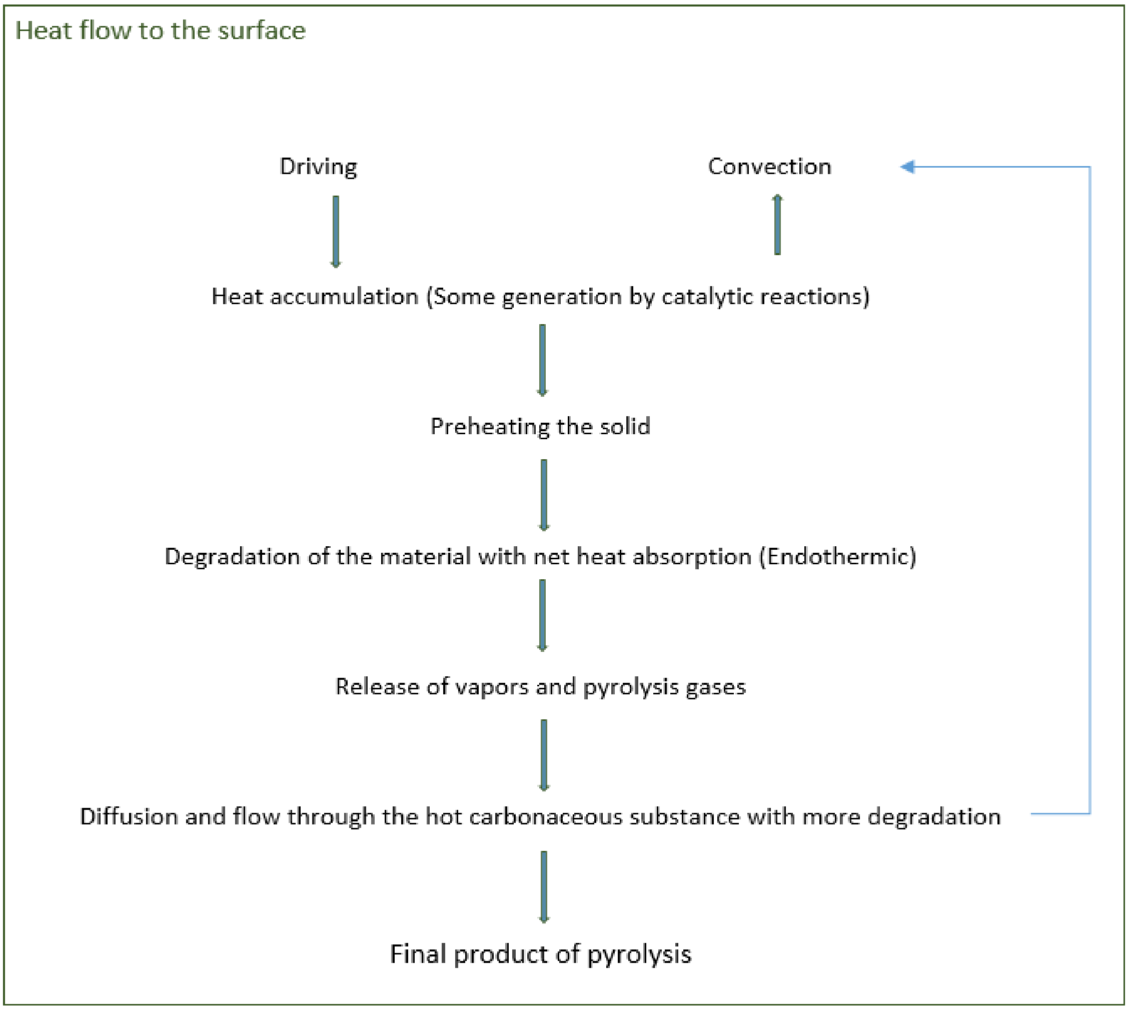


SOURCE: (OTTUSA, 2013)

In the last two figures there is a general view of a pyrolysis plant as well as gasification. In this way, the operation of these can be understood with a global vision. Otherwise, in future sections, the specific plant of the Atyrau region will be developed.

There are many parameters that influence the composition and performance of the resulting chemical products to a greater or lesser degree, so in the following figure 4 the most important variables that can affect the result of a pyrolysis process are mentioned (NIESSEN, 1978)

FIGURE 4: Parameters that influence pyrolysis



SOURCE: (NIESSEN, 1978)

Once the parameters that can greatly influence pyrolysis are known, they should be treated in the environmental possibilities in order to obtain quality products and optimize resources.

The pyrolytic systems that have been developed are grouped into two categories:

- Conventional pyrolysis
- Rapid pyrolysis or at high temperatures (fast)

Conventional pyrolysis can be carried out at low and / or medium temperature: the processes at low temperature are up to 550 ˚C and are used in the production of oils and tars; while the processes of average temperature are 550-800 ˚C, with which a production of methane and superior hydrocarbons is obtained. (KLUG, 2012)

Rapid pyrolysis is carried out at temperatures above 800 ˚C, which results in a production of gas with low calorific value, this type of pyrolysis operates with short times allowing a small part of solid material (10%) to be obtained and converts 60% in gas rich in hydrogen and carbon monoxide. This makes fast pyrolysis can compete with conventional gasification methods. (KLUG, 2012)

Currently the rapid pyrolysis process is of great practical importance, it is a process with high heat transfer speed to the feed and a short residence time of the hot steam in the reaction zone. This process has reached an important commercial use in the production of chemical substances and is being actively developed for the production of liquid fuels.

For its part, in slow pyrolysis poor gas is produced that can be used directly or this process can serve as the basis for the synthesis of a very important alcohol, methanol, which could substitute gasoline for feeding the internal combustion engines (carburol).

(AGROWASTE, 2013)

2.3 Difference between incineration, gasification and pyrolysis.

The gasification of waste is a technology designed to obtain a synthesis gas, "Syngas", that is, a product that can be used to produce fuels, chemical products or energy. It can be defined as an optimized pyrolytic process by which a solid or liquid substance with high carbon content is transformed into a gaseous fuel mixture by partial oxidation with the application of heat.

The difference between incineration and gasification lies in the presence of oxygen. In incineration, the process is complete combustion in the presence of oxygen, while in gasification and pyrolysis, the reduction is carried out in the absence or at a low concentration of oxygen, avoiding emissions to the atmosphere of CO_2.

Simplifying the physical process, when submitting a fuel of complex nature at high temperatures, in absence or with low concentrations of oxygen, those substances are released that, already existing or forming new, are volatile at these temperatures. Finally, a carbon-rich solid is obtained in equilibrium with a mixture of gases formed by water, CO_2, CO, CH_4, C_2H_6, CH_3OH, etc. (L.FAGBEMI, August 2001)

The gas obtained can be used for the production of energy in combustion processes alone or in combination with natural gas, in commercial boilers to produce thermal energy, in internal combustion engines to produce electric and thermal energy, in gas turbines in simple cycles and / or combined to produce electric power.

The gasification process generally works in an oxygen-free environment of 20-70 bar pressure (290.075 - 1015.26 PSI). Gasification can be used as fuel to generate a large number of applications.

Due to the limited amount of oxygen that is injected into the Biosphere, the system meets and exceeds all the atmospheric emission standards regulated by the Kyoto Protocol.

(SÁNCHEZ, 2014)

Pyrolysis and gasification

Pyrolysis and gasification are two forms of heat treatment in which the waste is heated at high temperatures with a limited amount of oxygen. The process is carried out in a sealed container at high pressure. Converting the material into energy is more efficient than direct incineration, generating energy that can be recovered and used, much more than in simple combustion.

The pyrolysis of solid waste converts the material into solid, liquid and gaseous products. Liquid oil and gas can be burned to produce energy or refined in other products. The solid residue can be refined in other products such as activated carbon.

Gasification is used to convert organic or non-organic materials (depending on the technology) directly into a synthetic gas (syngas) formed by carbon monoxide and hydrogen. The gas can be burned directly to produce steam or in a thermal engine to produce electricity. Gasification is used in biomass power plants to produce renewable energy and heat. (PINOCHET, 2013)

2.4 Products of MSW pyrolysis

The products obtained can be classified into three large groups:

- Carbon solid waste
- Hydrocarbon liquids
- Gases composed of hydrogen, carbon oxides and hydrocarbons

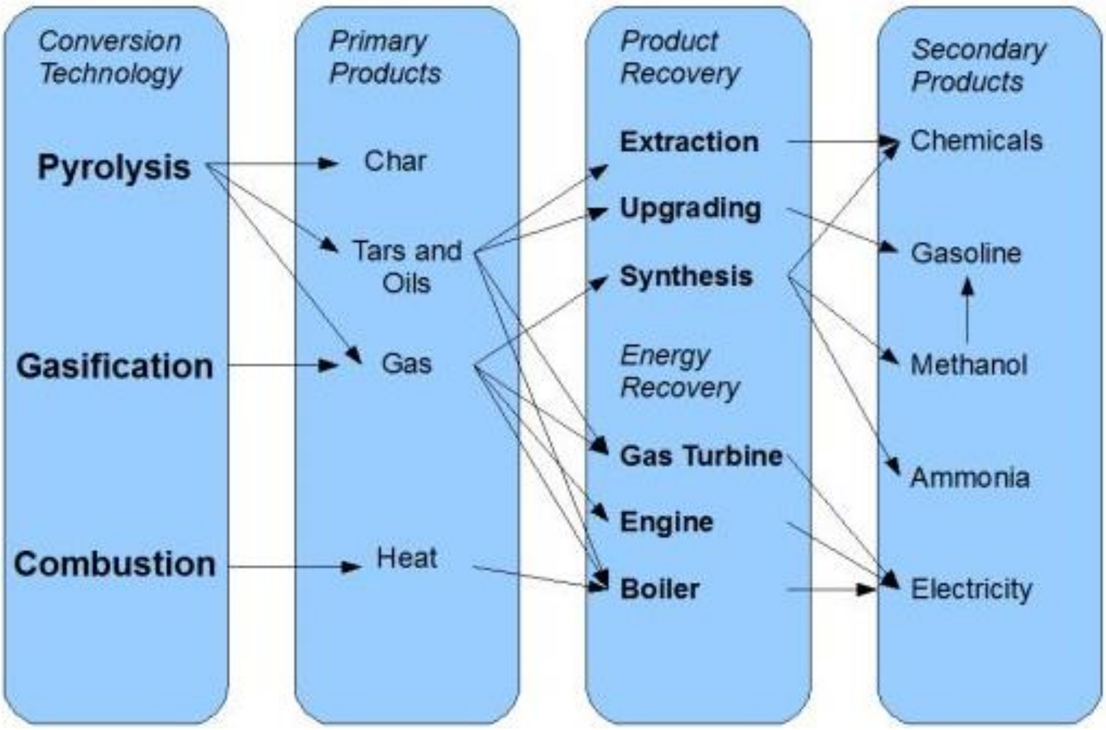
The group of carbonaceous solids can be used as a solid fuel, for the manufacture of briquettes or as a precursor for preparing activated carbons. The liquids are constituted by an aqueous and a tarry fraction that can be used as a liquid fuel adding it to gasoline or as a resource of chemical products of industrial interest. And the gases constitute a medium /

low calorific gas, which can be used to heat the pyrolysis reactor or generate electricity by combustion in engines, and if they constitute a high calorific gas, they are used both in engines and in gas turbines. (AGROWASTE, 2013)

Charcoal as a solid fuel has the advantage, compared to the food (biomass) that gave rise to it, of having a higher calorific value. However, pyrolysis means a significant loss of the energy contained in the biomass used as raw material. Its use is justified when the industrial process in which it is used requires it as an essential condition, such as in the steel industry, or when it must be distributed or transported. On the other hand, ashes are generated that must be managed.

In the figure 5 we can see the main product in the different thermal conversion processes.

FIGURE 5: Thermal conversion processes and products.



SOURCE: (BRIDGWATER, 1994)

In the image you can see the difference of products and by-products depending on the type of conversion as they are treated

3 Methodology

Sources of data collection will include primary and secondary data and data analysis will be a vital part of this research. This thesis will collect the primary data of the use of qualitative and quantitative methods.

The thesis is based on the study of SoroznoEco technologies related to pyrolysis plants and financial market analysis. A detailed project budget will be compiled and the profitability of the project will be determined by comparing the different economic variables.

In this way, it consists of following an order and developing the specific objectives already mentioned. Then several stages are developed: To know in a general way what is pyrolysis and what is the situation of Atyrau.

First, it is necessary to gather recent information in order to adjust the project to the needs of the region. For its realization, it is proposed to contact relevant people in the field of recycling (Ministry of the Environment, SoroznoEco ...).

- Update the Background of the methods of valorisation of the MSW

As explained in the background section, the general techniques are already known. The point of the objective is to learn about the improvements of these techniques that currently exist. For this, the technology research is followed by articles from companies, papers and patents and especially from the company itself (SoroznoEco).

- Choose a technology according to technical and economic feasibility criteria for the design of the recovery plant.

According to the two previous points, that is, the MSW treatment plants that already exist and the new technologies developed, we must choose an option taking into account the feasibility and viability of the said option with respect to what already exists in Atyrau and the market demand for finished products.

- Discuss the profitability of the plant using

1. Formula used to calculate the Net Present Value (NPV)

(1)
$$NPV = \sum_{t-1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where:

Ct = net cash inflow during the period t

Co = total initial investment costs

r = discount rate, and

t = number of time periods

2. Internal Rate of Return (IRR)

(2) 0 = P0 + P1/(1+IRR) + P2/(1+IRR)2 + P3/(1+IRR)3 + . . . +Pn/(1+IRR)n

Where:

P0, P1, . . . Pn = the cash flows in periods 1, 2, . . . n, respectively

IRR= the project's internal rate of return.

3. Payback

The amount of money a company will receive after a project has been completed over a certain amount of time. The company will record this transaction as income earned until the money has been received in full.

(3) $$\text{Payback} = a + \frac{I_0 - b}{F_t}$$

Where:

a is the number of the immediately preceding period until the initial outlay is recovered

Io is the initial investment of the project

b is the sum of the flows until the end of period "a"

Ft is the value of the cash flow of the year in which the investment is recovered

4. Return on investment

(4) $$\text{ROI} = \frac{(\text{Gain from Investment} - \text{Cost of Investement})}{\text{Cost of investment}}$$

In the above formula, "Gain from Investment” refers to the proceeds obtained from the sale of the investment of interest. Because ROI is measured as a percentage, it can be easily compared with returns from other investments, allowing one to measure a variety of types of investments against one another.

https://www.investopedia.com/terms/r/returnoninvestment.asp#ixzz563DBrRJX

4 SoroznoEco Company

Throughout the project the Soroznoeco Company provides information and support.

SoroznoEco belongs Sorozno Companies Group companies based in Spain which develops environmentally sustainable solutions for waste reduction and renewable energy production almost without polluting.

With global energy usage and waste production increasing at an alarming rate, SoroznoEco provides turnkey waste-to-energy plants that generate electricity, heat and/or diesel fuel from waste with minimal impact to the environment.

His mission is to convert the ever-increasing waste that is plaguing our planet into clean energy, recovered resources and revenue. SoroznoEco has raised an open fight against climate change and in favor of sustainable use of resources.

4.1 SoroznoEco Pyrolysis System (SPS)

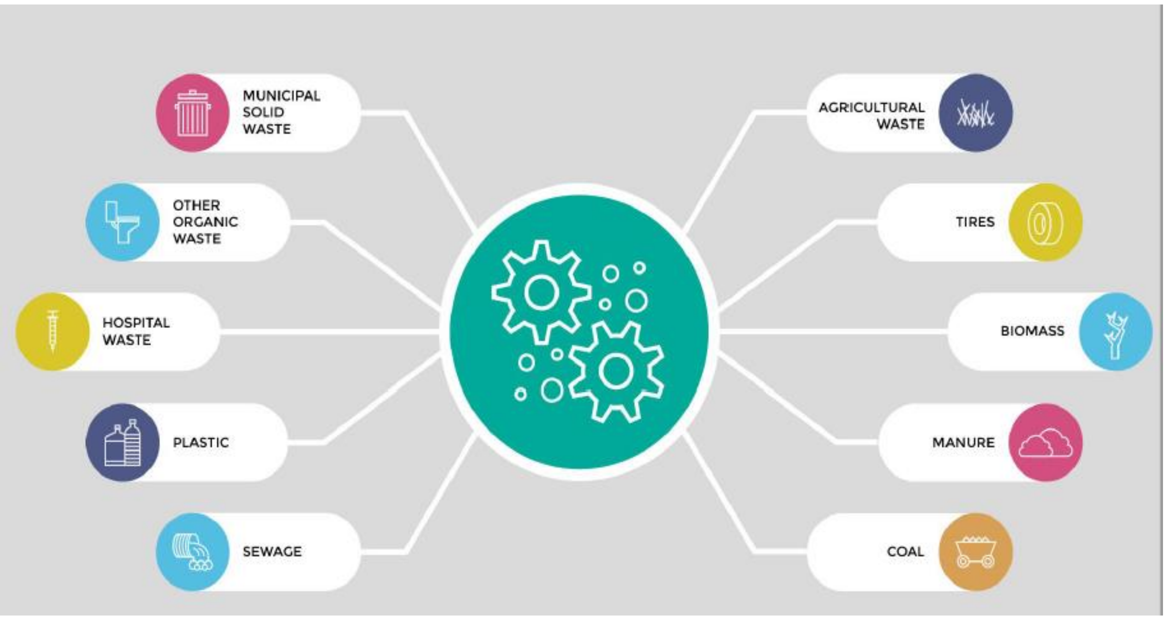
SPS is the acronym of our Sorozno Pyrolysis System. It is a machine that uses true pyrolysis technology – heating materials to high temperature in the absence of oxygen. No combustion of the materials takes place so emissions are very low – well within EU and US air quality standards.

4.2 The Process

Solid waste is initially sorted to remove recyclable materials. The residual waste is shredded before being fed into the SPS through an airlock to ensure an oxygen deficient environment in the retort chamber. SPS heats waste materials at temperatures up to 800 ° C producing different products such as synthetic gas, heat, fuel, coal and electricity.

In the figure 6 you can see the type of materials that can be used in this machinery

FIGURE 6: Types of material that can be processed.



SOURCE: SoroznoEco

For this technology to work properly, we must follow a few steps:

- Waste pretreatment.

- Processing and storage of waste.

- Thermochemical conversion.

The implementation of this process and our technology are able to jointly reduce waste by up to 90%, which generates great savings in landfill disposal costs.

In figure 7 and table 1 appears the plant that is wanted to be implanted in Atyrau. Obviously, it is subject to the changes resulting from the future project where it will specify the assembly of this.

FIGURE 7: Visualization of the plant.

TABLE 1: Different sections.

SOURCE: Elektroservis SLOVAKIA EW500-9of the pyrolysis plants.

SO 01	SO 02	SO 03	SO 04	SO 05	SO 06	SO 07	STAFF
Input communication	Initial preparation of waste	Four unit thermochemical decomposition of material.	Power generation	Outdoor space where they will be equipped with storage and homogenization tanks of gas	Tanks for wastewater and process water	Flares for disposal of surplus gas	The Control Center
Weighing of vehicles waste company in both directions.	Adjusted sorting starting material	Stocking central unit for cleaning of cooling and treatment produced synthesis gas.	Electrical Distribution Equipment power		Sewage treatment		Offices and control room
	RDF processing sift crushing compacting		Low voltage swich room				Social rooms for employees
	Interim compacted and drid material		Control room				
	Control room		HRM substations and high				

4.3 Preliminary notification of waste

The first step is the separation of inert materials (metal, glass, stones ...) and the elimination of waste. The waste is ground and dried to a moisture content of 20% or less. The figures 8 and 9 show the sorting machines.

FIGURE 8: Scheme of separation and treatment of MSW (SO 02).

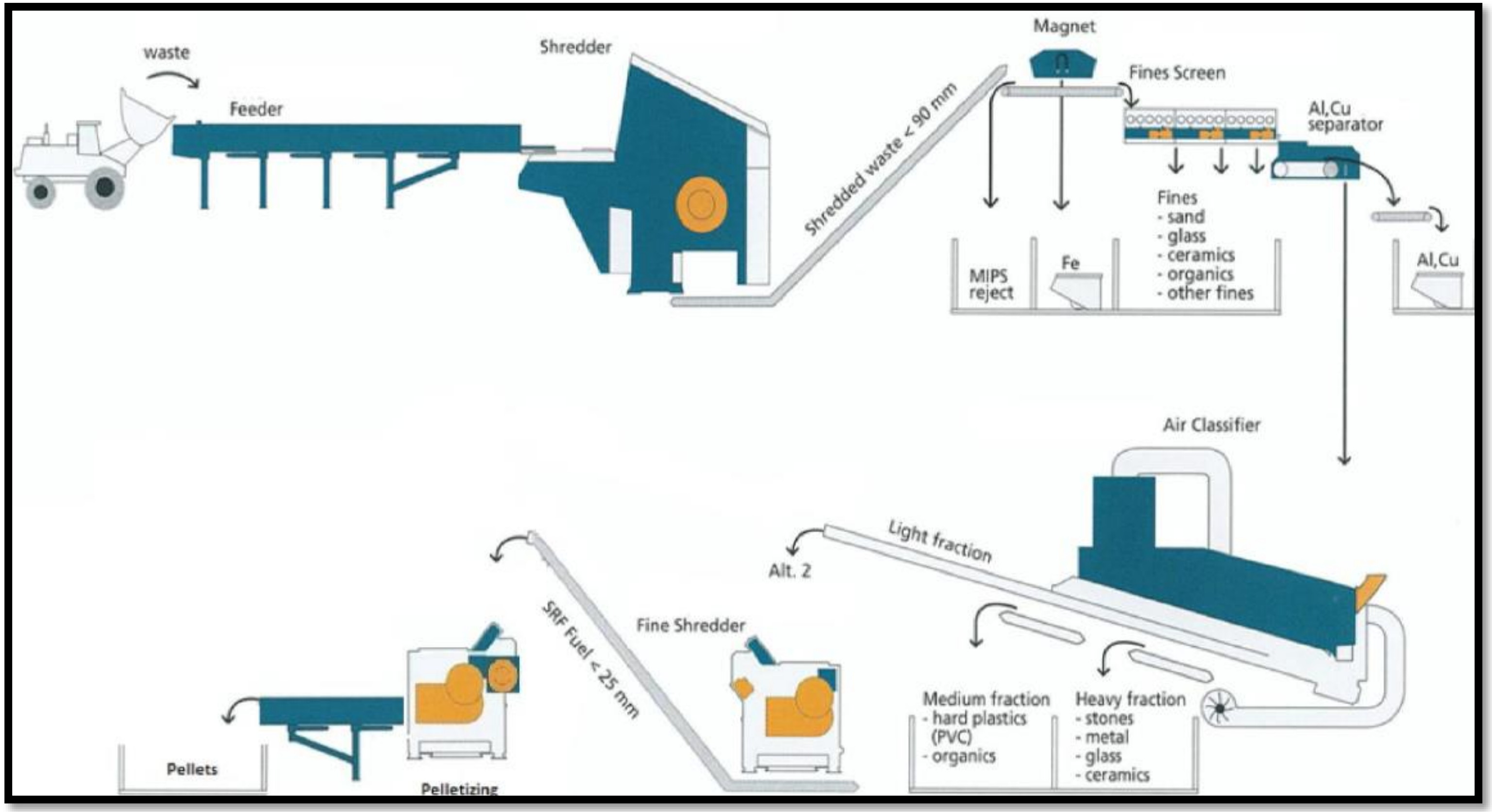
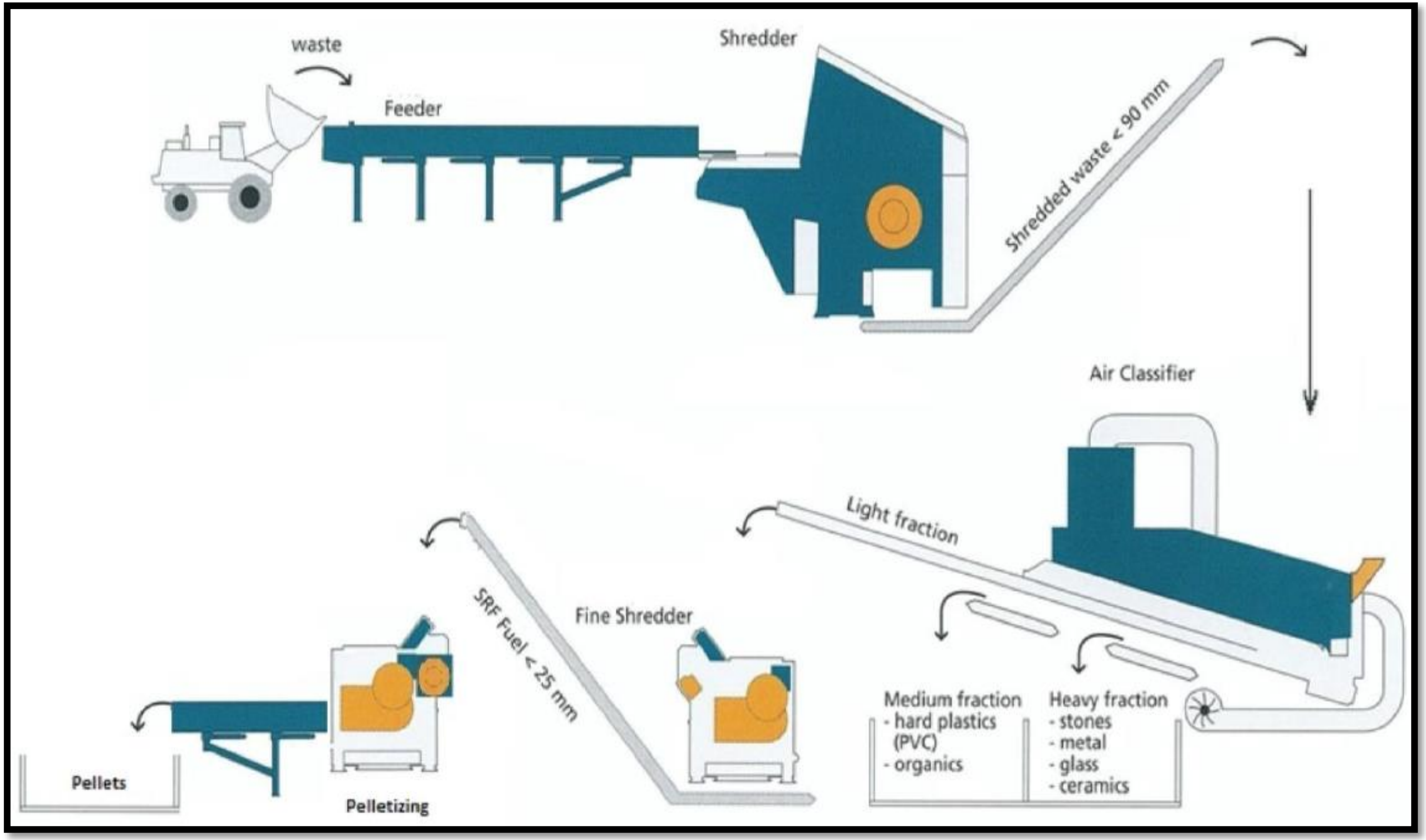


FIGURE 9: Scheme of separation and treatment of bio waste (SO 02).



SOURCE: Elektroservis SLOVAKIA EW500-9 (2017).

Some differences appear between the two sorting machines as they process different materials. Among them the magnet or the Al Cu separator in the case of the MSW.

4.4 Waste management and storage

The pelletizing is the process of compressing or molding a material into the shape of a pellet. Pelletizing is done in a pellet mill. Material (separated waste) is pushed through the holes and a pellet exit the pellet mill as input material for pyrolysis unit.

After the separation and the pelletizing the waste is moved into to the storage silo. The size of the silo is design to ensure constant feed in into the technology during maintenance breaks for separation line.

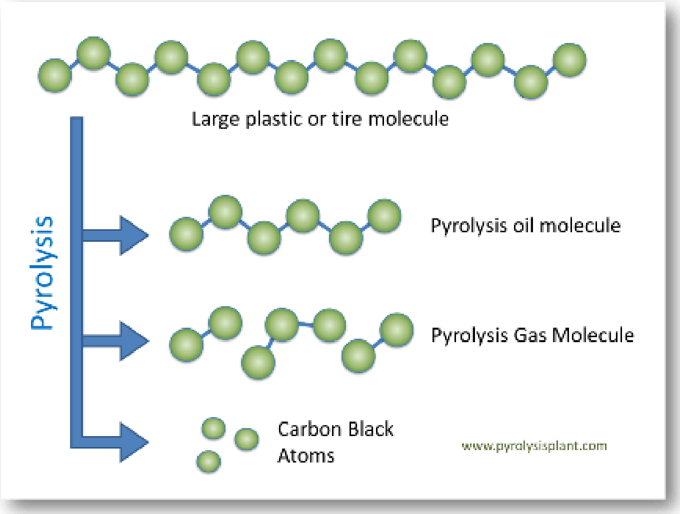
4.5 Thermochemical conversion

Pyrolysis, the chemical decomposition of organic (carbon-based) materials through the application of heat. Pyrolysis, which is also the first step in gasification and combustion, occurs in the absence or near absence of oxygen, and it is thus distinct from combustion (burning), which can take place only if sufficient oxygen is present.

The rate of pyrolysis increases with temperature. In industrial applications the temperatures used are often 430 °C (about 800 °F) or higher. Pyrolysis transforms organic materials into their gaseous components, a solid residue of carbon and ash, and a liquid called pyrolytic oil (or bio-oil).

The defragmentation of a plastic molecule in pyrolysis appears in the figure 10.

FIGURE 10: Transformation of plastic in pyrolysis

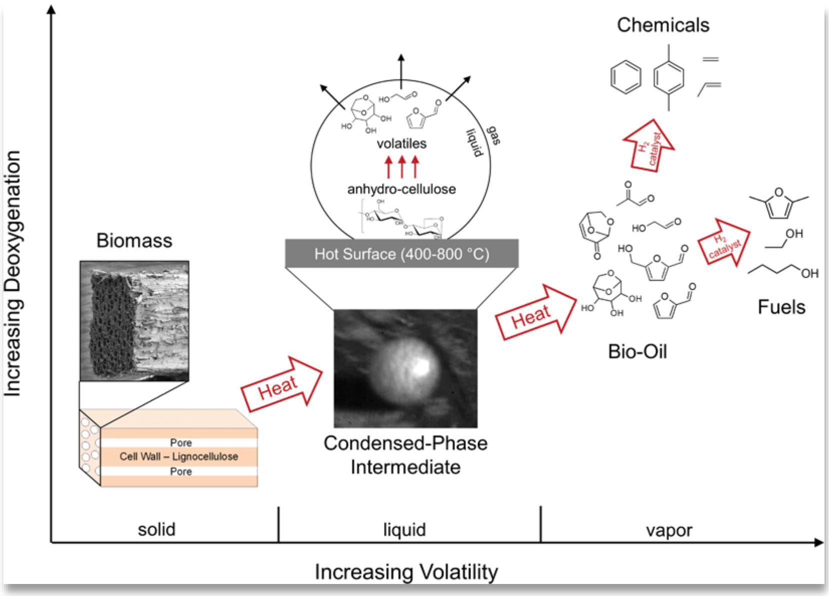


SOURCE: (MATTHEW 2012)

Pyrolysis is a useful process for treating organic materials that "crack" or decompose under the presence of heat; examples include polychlorinated biphenyls (PCBs), dioxins, and polycyclic aromatic hydrocarbons (PAHs).

The figure 11 shows the defragmentation of an organic molecule in pyrolysis

FIGURE 11: Decomposition carbon molecule



SOURCE: (MATTHEW,2012)

As shown in figures 10 and 11 both the plastic and organic molecules are reduced to become a gaseous state which can be used in different ways.

Applications

Pyrolysis has numerous applications of interest to green technology. It is useful in extracting materials from goods such as vehicle tires, removing organic contaminants from soils and oily sludges, and creating biofuel from crops and waste products.

Pyrolysis can help break down vehicle tires into useful components, thus reducing the environmental burden of discarding the tires.

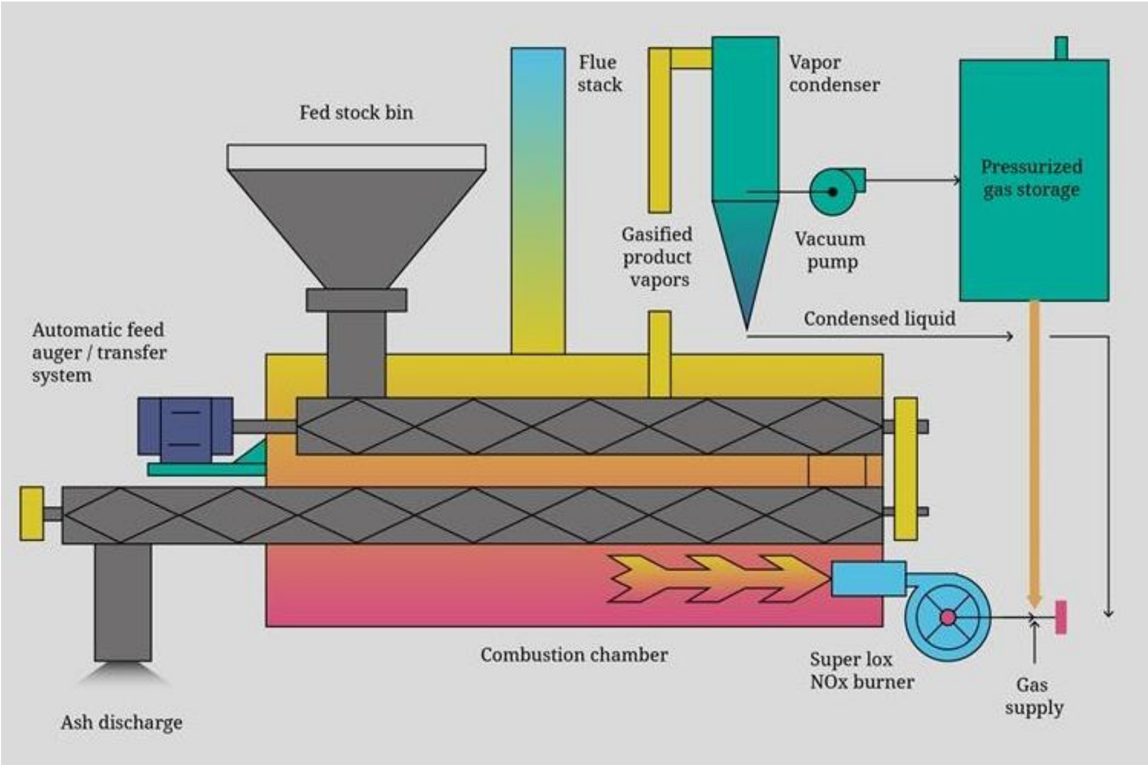
Tires are a significant landfill component in many areas, and they release PAHs and heavy metals into the air when they are burned. However, when tires are pyrolyzed, they break down into gas and oil (usable for fuel) and carbon black (usable as filler in rubber products, including new tires, and as activated charcoal in filters and fuel cells). (MADORSKY, 1964)

In addition, pyrolysis can remove organic contaminants, such as synthetic hormones, from sewage sludge (semisolid materials that remain after wastewater is treated and the water content reduced) and make heavy metals remaining in the sludge inert, which allows the sludge to be used safely as fertilizer.

Furthermore, pyrolyzing biomass (biological materials such as wood and sugarcane) holds great promise for producing energy sources that could supplement or replace petroleum-based energy. Pyrolysis causes the cellulose, hemicellulose, and part of the lignin in the biomass to disintegrate to smaller molecules in gaseous form. (BOSLAUGH, 2014)

In figure 12, you can see how the distillation technology from which the fuel is obtained.

FIGURE 12: The thermal distillation technology.



SOURCE: (SOROZNOECO, "ARTI Process Review MSW", 2016)

As it can be seen, the products obtained in the distillation are reused to keep the whole of the machinery in operation

5 The particular case of Atyrau (Kazakhstan)

In this section the information corresponding to the Atyrau region is shown. His general data as well as the composition of municipal waste.

5.1 General information of Atyrau

Atyrau is a city in Kazakhstan, and the capital of Atyrau Region. It is located at the mouth of the Ural River on the Caspian Sea, 2,700 kilometres (1,700 miles) west of Almaty and 351 kilometres (218 miles) east of the Russian city of Astrakhan.

Modern Atyrau is famous for its oil and fish industries. It has 154,100 inhabitants (2007), up from 142,500 (1999 census), 90% ethnic Kazakhs (up from 80%), the rest being mostly Russians and other ethnic groups such as Tatars and Ukrainians.

Atyrau (together with Aktau) is Kazakhstan's main harbour city on the Caspian Sea, Atyrau at the delta of the Ural River. Atyrau city is approximately 20 metres (66 feet) below sea level. The city is considered to be located both in Asia and Europe, as it is divided by the Ural River.

In the following map (figure 13) you can see the situation of Atyrau in Kazakhstan.

FIGURE 13: Map of Atyrau (Kazakhstan)

SOURCE: Wikipedia.org (2018)

The city is a hub for the oil-rich Caspian Depression; because of this, many oil wells have been drilled in the Tengiz Field and Kashagan Field areas. An oil pipeline runs from Atyrau to Samara, where it joins the Russian pipeline system. A separate oil pipeline runs from the Tengiz field to the Russian Black Sea port of Novorossiisk.

5.2 General information of the Project

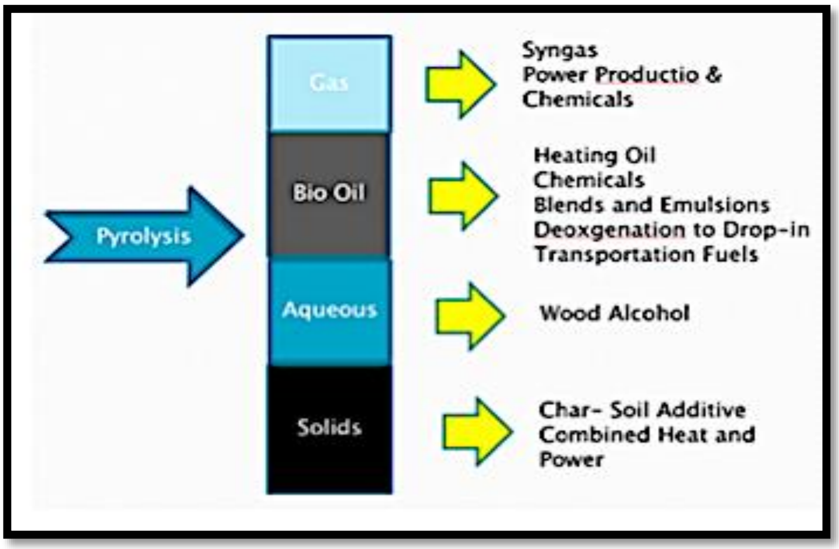
The project in Atyrau will be developed under the framework of the new landfill to be built at 17 km from the city. And as will be explained later, it is determined that the pyrolysis processing plant should have approximately 7000 m2

The Project will count with 4 modules (pyrolysis machines) able to process 1.5 tons of waste per hour each one. The machines are designed and performing in other plants 11 months of work, 24h/day, with a maintenance period between 15 days and 1month.

The intention is to transform the maximum waste of the city into electrical energy and other compounds. In this way, both social and economic Benedictions would be obtained.

In the following image you can see the specific products we want to obtain.

FIGURE 14: Biomass Pyrolysis Products.



SOURCE: (BOSLAUGH., 2014)

It will be necessary more than 1.5 tons of waste since part of them will not be introduced in the machines. But they will be separated and used for other usages.

Below, in table 1 you may check the exactly numbers of tons of the plant and by machine that will be able to process.

TABLE 1: Total municipal waste (tons)

Nº	Hours	Day	Year
1	2.08	50	16,666.75
4	8.33	200	66,667.00

SOURCE: Own elaboration

The table shows the numerical data for both a machine and the four machines to be installed.

5.3 Composition of municipal waste

The city of Atyrau is producing around 80,000 t of Municipal Solid Waste that represents around 58,000 t of Waste based in Organic Compounds.

The machines will be able to convert at least 70,000 t in gas, oil, electricity and heat. The rest will be composed mainly by paper and plastic bottles that will be recycled through other means. After a series of contacts with the environmental administration, it was ensured that the necessary quantities of waste would be provided.

The following table shows the composition of the garbage in Atyrau, in this way we can determine the number of machines that should be installed, as well as their different uses.

The column of none based in carbon is referred to these materials sorted that may be sold in order to get an economic benefit. They are composed mainly by metals and glass.

TABLE 2: Composition of waste of Atyrau city

Composition	%	Totals (t)	Based in carbon (t)	Not based in carbon (t)
Plastic	**8.3**	26.56	26.56	
Paper, Carton	**27.6**	88.32	88.32	
Cloth	**2.4**	7.68		7.68
Metal	**2.9**	9.28		9.28
Wood	**1.2**	3.84	3.84	
Glass	**4.3**	13.76		13.76
Rubber	**0.7**	2.24		2.24
Organic substance	**32.5**	104	104	
Ceramic, porcelain	**10.8**	34.56		34.56
Industrial waste	**8.6**	27.52	27.52	
Others	**0.7**	2.24		2.24
Total	100.00%	320	250.24	69.76
Density kg / m³	139			

SOURCE: (CRAIGMEISNER, 2012)

The efficiency depends on the quality of the materials (percentage of water and slag on the total weight).

In table 3 we observe the number of tons that will be processed once the waste is separated.

TABLE 3: Separated material used in pyrolysis units.

Quantity of separated material whose will be use in pyrolysis units per day [t] (humidity app. 10%)	198
Quantity of separated material whose will be use in pyrolysis units per hour [t]	8
Quantity of separated material whose will be use in pyrolysis units per year [t]	66,000

SOURCE: Own elaboration.

The amount of final material used in the 4 modules will be **66,000 tons** per year. As you can see, only 11 months a year are taken into account. Due to possible breakdowns and maintenance work on the 4 machines

6 Investement

The project will be developed in local currency (expenses and income) but to facilitate calculations and comprehension, all calculations have been changed to euros. With a change of monde of:

400 KZT (TENGE) = 1 € (EUROS)

SOURCE: (COINMILL.COM, 2017)

6.1 Capex (Capital Expenditure)

In this section, all capital expenditures will be developed. In this way they will be associated with all the physical assets acquired by the company.

6.1.1 Acquisition of land and licences

The lands will be ceded by the governmental entities, with the intention of alleviating the environmental problems derived from the accumulation of the garbage as well as a possible participation of the plant still to be determined.

The land would continue to belong to the town hall of Atyrau or otherwise a share would be ceded within the plant. Both possibilities do not influence the calculations since in the same way the expenses for acquisition of land is zero.

TABLE 4: Aquisition of project [€]

Land price	- €
Connection charge (to electrical power network)	- €
Input material	- €

SOURCE: Own elaboration

In this way, legal expenses and expenses derived from the acquisition of licenses have also been provided, in table5.

TABLE 5: Price acquisition of licenses

LEGAL AND LICENCES	
Legal matters	300,000.00 €
Designing works	150,000.00 €
TOTAL	**450,000.00 €**

SOURCE: Own elaboration

The final price of land acquisition as well as licenses amounts to **450,000.00 €**

6.1.2 Machinery

The investment in machinery has been provided by the company SoroznoEco. It develops not only the pyrolysis machines themselves, but the gasification machine, conections or pelletizer, among others.

In table 6 all the investments related to these modules are developed.

TABLE 6: Investment in machinery

TYPE OF MACHINERY AND DEVICES	
Input material preparation (shredding, separation, pelletizing, etc.)	4,000,000.00 €
Gasification and cleaning of gas	15,600,000.00€
Cogeneration units	10,600,000.00€
The other parts of technology tanks, compressors, connection pipes, etc.)	7,200,000.00€
Connection to the electrical power network (trafo station, connection, HV distributor, etc.)	597,196.18 €
TOTAL [€]	**37,997,196.18 €**

SOURCE: Own elaboration

The final investemen in mchinery and devices reach **37,997,196.18 €** being in this way the highest expense.

6.1.3 Civil work and other investments

This information has also been provided by the company. And likewise they have been compiled in table 7.

TABLE 7: Investment in civil work.

CONSTRUCTION WORK AND TECHNOLOGY [€]	
Construction work - 7.000 M2	2,500,000.00 €
TRANSPORTATION AND INSTALLATION [€]	
Transport to the installation site(up to 2.000 km from Slovakia)	600,000.00 €
Debugging, installation and testing of technologies	352,000.00 €
OTHER EXPENSE OF INVESTOR [€]	2,100,803.82 €
TOTAL [€]	**5,552,803.82€**

SOURCE: SoroznoEco.

The investment in civil work amounts to **5,552,803.82€€**

6.1.4 Total cost of Investment

In the last table of CAPEX, the total sum of the investment of physical goods is made.

TABLE 8: Total CAPEX investment.

Legal and licences	Machinery [€]	Civil work and others	Total cost of investment
450,000.00 €	37,997,196.18 €	3,552,803.82 €	**44,000,000.00 €**

SOURCE: Own elaboration.

The total investment of the plant will be **44,000,000.00 €**.

This amount may suffer small variations, but they are quite accurate since they are those contributed by the companies themselves that have already developed projects like these. Later, we will specify how the financing will be made.

7 Feasibility study

This section aims to guide decision making in project evaluation. In this way it is tried to determine if the project will be sufficiently viable, convenient or opportune: or to improve it. This will gather relevant data on the possible final development of the project and based on it take the best decision.

7.1 Incomes

The revenues will be due to the sale of already classified waste and that will not be introduced in the four pyrolysis modules because its sale generates more economic benefits. As well as to the sale of the electricity supplied to the electric network, oil and coal. In the next table you can see the number of tons of each material that will be sold after the separation, as well as the income obtained from it.

TABLE 9: Income obtained from the sale of sorting waste.

Type of classified material	Percentage	Tonnes	Price/ tone	Incomes per year
Paper, cardboard	27.60%	29,532.00	75.14 €	2,219,171.91 €
Black scrap metal	2.20%	2,354.00	125.24 €	294,817.52 €
Non-ferrous scrap metal	0.70%	749.00	1,126.58 €	94,810.13 €
Glass	4.30%	4,601.00	30.00 €	138,023.10 €
Stones, plaster	10.80%	11,556.00	5.91 €	47,115.90 €
Bones	0.10%	0.3		
Other	8.60%	27.5		
Total	54.3%	48,819,80		**2,793,938.56 €**

SOURCE: Own elaboration

The final income obtained from the sale of classified waste amounts to **2,793,938. 56 €.**

7.1.1 Outputs

This section gives us the price of the output products and energy in Euros. Please notice the exchange rate from of the Januray of 2017, plus prices provided by the info facts.

The calculations are carried out taking into account approximately 11 months of work corresponding to 8030 hours per year. In the following table you can see the sale price of electricity, heating oil and coal.

TABLE 10: Product sale prices

Estimated operation of all equipment in hours / year	8,030
Selling price of electric power [€ / MW]	87.5
Selling price of heat power [€ / MW]	45
Selling price of oil [€ / t]	465.29
Selling price of carbon [€ / t]	60

SOURCE: Eurasian Resources Group (ERG, 2017) and (MEWR, 2016)

All the prices developed in the table will be used to know the expected benefits by selling the different products,

In table 11 the different outputs of the Pyrolysis plant are developed.

TABLE 11: The estimated quantity of output

The estimated quantity of electric power output [MW / h]	6
The estimated quantity of heat power output [MW / h]	6
The estimated quantity of oil output [t / h]	0.3
The estimated quantity of carbon output [t / h]	0.9

SOURCE: (SOROZNOECO, 2016)

By means of a simple multiplication between the last two tables, the expected income will be known.

7.1.2 Inputs

In the table of inputs, all expected revenues are reflected annually due to each product obtained through the sorting of materials and their sale, as well as derivatives of the four pyrolysis modules.

TABLE 12: Annual income of the Atyrau plant.

INPUTS	
Cost price of unsorted input material	2,793,938.56 €
Sale of electric power	4,209,333.33 €
Sale of heat power	2,164,800.00 €
Sale of oil	1,119,168.12 €
Sale of carbon	433,393.39 €
TOTAL	**8,559,972.07**

SOURCE: Own elaboration.

The final amount of income of the plant would reach approximately **8,559,972.07 €** annually. If we add the sale of the sorting waste we reach the amount of incomes:

10,720,633.40 €

7.2 Costs

In this section, all the expenses derived from the development and the implantation of the project are developed.

7.2.1 Opex

This department will include the operational expenses of the machinery. Wages and electric power are overestimated since they could be lower. Please remember than these electrical expenses are to restart the machinery for the maintenance services. Are also overestimate. The calculations have been made only in annual maintenance and service.

In Opex table you can distinguish the expenses derived from maintenance, electricity consumed, salaries, etc.

TABLE 13: Operational expenses

OPEX - calculation processing of waste	
	6 MW/h
Operating expense [€ / year]	
Salaries	500,000
Operational electric power	480,000
Marketing	0
Insurance	0
Driving fuel	0
Maintenance and services*	947,328
Other operating expense of investor	0
TOTAL	**1,927,328 €**

SOURCE: SoroznoEco

"Maintenance and services" is needed to the good performance of the machinery. This works and services take between 15 days and one month.

The final amount of operational expenses amount to **1,927,328 €€**

7.2.2 Total expenses

The total expenses accumulated per year are shown in table 14.

TABLE 14: Annual expenses

TYPE OF EXPENSES	
Opex	1,927,328.00 €
Expense for liquidation of remainder materials	233,333.33 €
TOTAL	**2,160,661.33 €**

SOURCE: Own elaboration

The final amount of expenses of the plant would reach approximately **2,160,661.33 €** annually.

7.2.3 Social responsibility

The company is committed to making a social and environmental investment of 1% of annual cash flow. In this way it has been decided to allocate said investment in three different funds.

In each year, different payments will be made according to the destination in order to promote an adequate management of said income, a better efficiency of the works that will be carried out.

The table 15 shows the total investment for 10 years for each area.

TABLE 15: Social investment

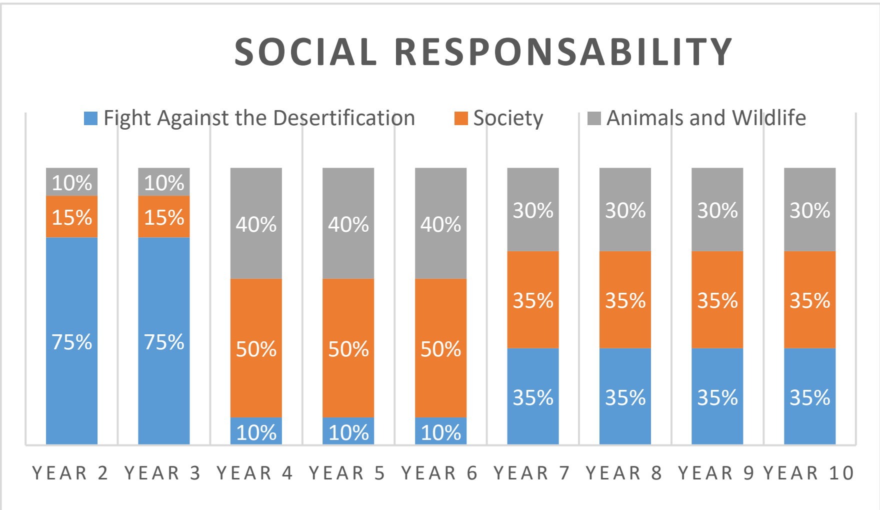
	First option	Second option	Third option
Fight Against the Desertification €	439,735	303,828	292,446€
Society €	409,469	2,762,186	262,491
Animals and Wildlife protection €	333,478	224,330	212,872
TOTAL €	1,182,684	804,377	767,811

SOURCE: Own elaboration

There is a greater investment in the first option since it has the highest inflation (7%) in addition to the extra income from the sale of energy in heating.

In figure 15 you can see what percentage of the investment will go to each area.

FIGURE 15: Percentages of social investment



SOURCE: Own elaboration

The percentages were decided based on promoting a better management of economic resources. In this way, first, greater investments in the environment could be made, such as repopulation, in the second period a greater social investment and finally an equitable one between the three.

7.3 Payoff

Finally the sale in heating is not possible in the short term so it is extracted from the final income, leaving a balance that is shown in table 16.

TABLE 16: Cash flow

Plus [€ /year]	Minus [€ /year]	Accounts staiment [€ /year]
10,720,633.40 €	2,160,661.33 €	**8,559,972.07 €**

SOURCE: Own elaboration

The annual cash flow is approximately **8,559,972.07 €** social spending is not taken into account, since this will have its base in the cash flow.

8 Financing structure

Every company requires resources to carry out its activities or to expand them. The start of new projects implies an investment for the company so they also require financial resources so that they can be carried out.

Where funding sources are an important role to increase the value of the company.

The financial function tries to maximize the present value of the company through:

- Obtaining financial resources, in the most economic
- Its correct management and investment in resources more productive.
- Financial management is justified by obtaining an adequate balance between liquidity and profitability that allow to maximize the present value of the company.

The equity loan for SoroznoEco is based on an interest of 7.23% given by the Česká národní banka (CNB, 2018) and 14% by the The National Bank of Kazakhstan (ADB, 2018). Both interests have been provided by both banks in addition to having been proven through the information of the respective web pages.

The (ADB) and (CNB) undertakes nonsovereign operations to provide financing to eligible recipients in developing member countries (DMCs). Nonsovereign operations comprise the provision of any loan, guarantee, equity investment, or other financing arrangement to privately held, state-owned, or subsovereign entities, in each case, (i) without a government guarantee; or (ii) with a government guarantee, under terms that do not allow ADB, upon default by the guarantor, to accelerate, suspend, or cancel any other loan or guarantee between ADB and the related sovereign.

ADB catalyzes private investments through direct financing, credit enhancements, and risk mitigation instruments. ADB provides direct funding assistance through loans and equity investments. We offer political risk guarantee and partial credit guarantee instruments to enhance the risk profiles of transactions to attract both foreign and local commercial lenders to projects in the developing member countries (DMCs), and to encourage them.

Through cofinancing and guarantees, we also support local investors, domestic banks, and financial institutions to provide funds on suitable terms for ADB-assisted development projects. ADB also mobilizes additional resources for projects through a "B-loan" arrangement.

Both the ADB with the CNB offers hard currency loans, both senior and subordinated, as well as mezzanine financing. We also offer local currency loans in selective markets on a case to case basis. Interest rates and other terms vary, depending on a company's or project's needs and risks.

- Rates - In pricing its loans, ADB considers prevailing market rates in the relevant country and sector, factoring in country and transaction risks. ADB provides floating rate loans at a spread above the London interbank offered rate (LIBOR) or Euro interbank rate, depending on the currency. It also offers fixedrate loans at the fixed-rate swap equivalent of floating-rate loans.

- Fees - Market-based fees are charged. Typically, on floating-rate loans, ADB charges a once-only front-end fee as well as an ongoing commitment fee on the undisbursed balance. We may also charge a fee to cover upfront costs associated with due diligence. Project sponsors or clients will reimburse out-ofpocket expenses, such as travel and external advisory services (i.e., legal counsel, technical consultants, and environmental and insurance advisors, if any).

- Security - We will seek security appropriate for the loan and type of financing.

The financing is divided into two large blocks, and the final amount would be around **44,000,000 euros.**

Table 17 shows the origins of capital and loans. As well as the concepts and amounts of investments.

TABLE 17: Source of funding for the project

ORIGIN FUNDS	ENTITY	PERCENTAGE	VALUE OF FUNDS	CONCEPTS	AMOUNT CONCEPT
CAPITAL	SOROZNO	14,70%	6.468.000,00 €	Equipment / machinery	6.468.000,00 €
	INVESTOR	15,30%	6.732.000,00 €	Consulting and licenses	450.000,00 €
				Plant and facilities	2.500.000,00 €
				Budget of expenses 1st year	1.927.328,00 €
				Deposit of arras	300.000,00 €
				Transportation and installation	952.000,00 €
				Other investment expenses	602.672,00 €
LOAN	SOROZNO	20%	8.800.000,00 €	Equipment / machinery	8.800.000,00 €
	ADB	50%	22.000.000,00 €	Equipment / machinery	22.000.000,00 €
TOTAL INVESTMENT					**44.000.000,00 €**

SOURCE: Own Elaboration

In table 17, it can be seen that the capital is contributed by Sorozno 14.7% and an investor with 15.3%. Regarding the credit, between ADB and 50%, the company owns 20%.Which means a total investment of 44 million.

FIGURE 17: Asian Development Bank

SOURCE: https://www.adb.org/

FIGURE 16: SoroznoEco

SOURCE: http://soroznoeco.com/es

On January 6, a meeting was held at the headquarters of the **Asian Development Bank** (ADB). The objective of the meeting was to transmit to the ADB the latest news about the waste recycling project in Atyrau and get an overview of what the ADB needs (documentation, guarantees, etc ...) to be able to finance the project. The ADB transmitted us that increase the size of the full project will be even better.

9 Sensitivity Analysis Discussion

Calculations are made from three possibilities, the first option will be based on the sale of heating and **7%** inflation. Based on the CPI provided by the Kazakh bank.

The following two options will take into account calculations in the absence of heating sale (still to be confirmed) and **5%** and **4%** respectively. What is desired is to adjust the model to the different possibilities of inflation, in this way the margin of error will be lower.

The table 18 shows the difference in cash flow for ten years for the three possibilities.

TABLE 18: Cash flow for for the three possibilities

	CASH FLOW (7%)	CASH FLOW (5%)*	CASH FLOW (4%)*
Year 1	8,559,972 €	6,395,172 €	6,395,172 €
Year 2	9,159,170 €	6,714,931 €	6,650,979 €
Year 3	9,800,312 €	7,050,677 €	6,917,018 €
Year 4	10,486,334 €	7,403,211 €	7,193,699 €
Year 5	11,220,377 €	7,773,372 €	7,481,447 €
Year 6	12,005,804 €	8,162,040 €	7,780,705 €
Year 7	12,846,210 €	8,570,142 €	8,091,933 €
Year 8	13,745,445 €	8,998,649 €	8,415,610 €
Year 9	14,707,626 €	9,448,582 €	8,752,235 €
Year 10	15,737,160 €	9,921,011 €	9,102,324 €
TOTAL	**118,268,409 €**	**80,437,787 €**	**76,781,121 €**

Source: Own elaboration

*As you can see the sum in the first possibility is greater since it takes into account a possible sale of energy for heating and consecutively the second and third option.

Both for this table and the following one they are summarized in order that their understanding is easier. All the calculations will be attached in the annexes.

9.1 Calculation of the Net Present Value (NPV)

The Net Present Value (NPV) is the best known method when evaluating long-term investment projects. The Net Present Value allows to determine if an investment fulfills the basic financial objective: MAXIMIZE the investment. The Net Present Value allows determining if said investment can increase or reduce the value of SMEs. That change in the estimated value can be positive, negative or continue the same. If it is positive it will mean that the value of the firm will have an increase equivalent to the amount of the Net Present Value. If it is negative it means that the firm will reduce its wealth in the value that the VPN throws. If the result of the VPN is zero, the company will not modify the amount of its value

It is important to bear in mind that the value of the Net Present Value depends on the following variables:

The previous initial investment, the investments during the operation, the net cash flows, the discount rate and the number of periods that the project lasts.

(DIDIER VAQUIRO, 29-03-2013)

The 9.5% will be used as the discount rate, since it is the highest Kazakh state bonus. The investment as it has been explained amounts to 44,000,000 €. In table 19 we can see the three NPV.

TABLE 19: NPV for the three possibilities.

	NPV (7%)	NPV (5%)*	NPV (4%)*
Cash flow €	118,268,409	80,437,787	76,781,121
Net Cash flow (9, 5%) €	70,611,730	48,705,333	46,824,337
NPV €	26,611,730	4,705,333	2,824,337

SOURCE: Own elaboration

* The sale of energy in heating is not considered

The differences between the three NPVs are mainly due to the income due to the heat sale.

9.2 Internal Rate of return (IRR)

The IRR is the rate at which the project breaks even. According to Knight, it's commonly used by financial analysts in conjunction with net present value, or NPV. That's because the two methods are similar but use different variables. With NPV you assume a particular discount rate for your company, then calculate the present value of the investment (more here on NPV). But with IRR you calculate the actual return provided by the project's cash flows, then compare that rate of return with your company's hurdle rate (how much it mandates that investments return). If the IRR is higher, it's a worthwhile investment. (GALLO, march, 2016)

Table 20 shows the internal rate of return for each possibility.

TABLE 20: Internal rate of return for the three options.

FIRST OPTION (7% Inflation)					
Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
8,559,972	9,800,312	11,220,377	12,846,210	14,707,626	15,7371,60
121,80%	181%	268%	398%	590%	719%
7,027,719	5,423,329	4,185,213	3,229,752	2,492,417	2,189,508
SECOND OPTION (5% Inflation)					
Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
6,395,172	7,050,677	7,773,372	8,570,142	9,448,582	9,921,011
112,77%	143%	182%	232%	295%	333%
5,671,037	4,916,563	4,262,465	3,695,387	3,203,753	2,983,037
THIRD OPTION (4% Inflation)					
Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
6,395,172	6,917,018	7,481,447	8,091,933	8,752,235	9,102,324
111,91%	140%	176%	220%	275%	308%
5,714,414	4,934,888	4,261,700	3,680,345	3,178,294	2,953,568

SOURCE: Own elaboration

As you can see in the tables for the first option we get an IRR of 21.80 %, for the second option 12.77 % and for the last option one of 11,91 %.

9.3 Payback

The Payback or Recovery Term is a criterion for evaluating investments that is defined as the period of time required to recover the initial capital of an investment. It is a static method for the evaluation of investments.

By means of the payback we know the number of periods (usually years) that it takes to recover the money disbursed at the beginning of an investment. What is crucial when deciding whether to embark on a project or not.

In table 21 we observe what the payback is for each case:

TABLE 21: Payback period for the three options.

	First option	Second option	Third option
Payback	Four years and seven months	Ten years and four months	Ten years and ten months

Source: Own elaboration

As the income is higher and the inflation rate is higher in the first option, the payback period is significantly lower

9.4 Return on investment ROI

A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. ROI measures the amount of return on an investment relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment, and the result is expressed as a percentage or a ratio.

In table22 we observe the ROI for the three possible options for ten years.

TABLE 22: ROI for the three options.

	First option	Second option	Third option
ROI	3.68 €	0.88 €	0.59 €

Source: Own elaboration

This reason is widely used in the analysis of financial institutions, since it measures the return on the average total assets or, what is the same, their capacity to generate value, thus allowing us to appreciate the ability to obtain a benefit from the total assets of the company. Company and thus putting the benefit in relation to the size of your balance.

10 Discussion and Conclusions

In this last section we will try to determine the profitability or not of the start-up of the plant, for this we will use the different elements of the sensitivity analysis.

10.1 Discussion

In this section you want to determine the feasibility or economic viability of a project. This must be designed from the technical point of view and must meet the objectives that it expects.

In other words, it tries to study if the investment we want to make is going to be profitable or not, if the results show, that the investment should not be made, another alternative should be taken or evaluate the alternative that best suits the company financially. According to their policies.

For this purpose, the following indicators are used, which will serve as the basis for the final and final part of the project, which is to conclude whether the viability of the plant is profitable or not.

- Calculation of the Net Present Value (NPV)

The NPV will express a measure of profitability of the project in absolute net terms, that is, in number of monetary units. All NPVs reach figures higher than two million, which means that we will recover the initial investment and we will have more capital than if we had set it to fixed income.

- Internal Rate of return (IRR)

The internal rate of return (IRR) gives us a relative measure of profitability, that is, it will be expressed as a percentage. Since the IRR is high for the three options, we are facing a profitable business project. In these cases, the internal rate of return that we obtain is higher than the minimum rate of return required for the investment, so the investment project should be accepted

- Payback

None of the payback periods exceeds 11 years, the machines are guaranteed to 20 years and it is estimated that they can work twice as much. The debt with the company itself ends at 5 years and that of the ADB at 10 years. For what is estimated with the return periods are relatively short.

- Return on investment

This data is essential to evaluate analyse the profitability of balance sheets and profit and loss accounts, brands and companies. In the three options for each euro invested, profit would be generated. Which means that the ROI is positive and therefore what we have measured has been profitable.

10.2 Conclusions

As a result of the analysis and evaluation studies to verify the feasibility and technical-economic feasibility of an investment project for the installation of a pyrolysis plant in the Atyrau region (Kazakhstan) concludes the following:

The economic feasibility study on the proposed project, a waste treatment plant, has yielded a positive result. This implies that, under the conditions that have been considered normal, the project is economically viable. The advantages of technology as such have been discussed in several sections, so that the economic viability ends up showing a positive result on the project.

However, the sensitivity analysis reveals different thresholds on the project, identifying what could be considered weak points. These will be those factors whose variation could affect the profitability of the project. As has been analysed, the two determining factors for obtaining a positive return on the project are the ability to sell energy for heating and the type of inflation to apply. Other factors studied, such as the interest rate of the loan used as a means of financing and the costs of the raw material, have proved not to be relevant enough to be considered influential on profitability. Since they are fixed values since it has the backing of the state and regional entities.

In this sense, the second and third option, both without a heating sale and with lower inflation rates, clearly indicate lower income and, therefore, benefits that are lower than those of the first option. Therefore it would be very useful if finally the sale of energy for heating was confirmed. In the same way, all the possibilities have shown their great possibilities and their more than possible profitability.

11 Annexes

11.11 NPV First Option

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Cash flow	8,559,972 €	9,800,312 €	11,220,377 €	12,846,210 €	14,707,626 €	15,737,160 €
Interest rate	109,5%	131,3%	157,4%	188,8%	226,3%	247,8%
Social Expenses	85,600 €	98,003 €	112,204 €	128,462 €	147,076 €	157,372 €
Net Cash flow	7,817,326 €	7,464,445 €	7,127,494 €	6,805,753 €	6,498,536 €	6,350,167 €
Investment	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €
Sumatory Cash flow	7,817,326 €	22,920,620 €	37,342,138 €	51,112,657 €	64,261,563 €	70,611,730 €
Pendind loan	-36,182,674 €	-21,079,380 €	-6,657,862 €	7,112,657 €	20,261,563 €	26,611,730 €

SOURCE: Own elaboration

11.2 NPV Second Option

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Cash flow	6,395,172 €	7,050,677 €	7,773,372 €	8,570,142 €	9,448,582 €	9,921,011 €
Interest rate	109,5%	131,3%	157,4%	188,8%	226,3%	247,8%
Social Expenses	31,976 €	35,253 €	38,867 €	42,851 €	47,243 €	49,605 €
Net Cash flow	5,840,340 €	5,370,175 €	4,937,861 €	4,540,349 €	4,174,837 €	4,003,269 €

Investment	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €	44,000,000 €
Sumatory Cash flow	5,840,340 €	16,810,841 €	26,898,185 €	36,173,469 €	44,702,065 €	48,705,333 €
Pendind loan	- 38,159,660 €	- 27,189,159 €	- 17,101,815 €	- 7,826,531 €	702,065 €	4,705,333.37 €

SOURCE: Own elaboration

11.3NPV Third option

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Cash flow	6,395,172	6,917,018	7,481,447	8,091,933	8,752,235	9,102,324
Interest rate	109,5%	131,3%	157,4%	188,8%	226,3%	247,8%
Social Expenses	31,976	34,585	37,407	40,460	43,761	45,512
Net Cash flow	5,840,340	5,268,373	4,752,422	4,287,000	3,867,158	3,672,917
Investment	44,000,000	44,000,000	44,000,000	44,000,000	44,000,000	44,000,000
Sumatory Cash flow	5,840,340	16,655,703	26,411,877	35,212,592	43,151,420	46,824,337
Pendind loan	- 38,159,660 €	- 27,344,297€	- 17,588,123 €	- 8,787,408 €	- 848,580 €	2,824,337 €

SOURCE: Own elaboration

11.4 First option accounts,

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash flow (income - expenses)	8.559.972 €	9.159.170 €	9.800.312 €	10.486.334 €	11.220.377 €	12.005.804 €	12.846.210 €	13.745.445 €	14.707.626 €	15.737.160 €
Amortization 20 years	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €	2.047.460 €
operating result	**6.512.512 €**	**7.111.710 €**	**7.752.852 €**	**8.438.874 €**	**9.172.917 €**	**9.958.344 €**	**10.798.750 €**	**11.697.985 €**	**12.660.166 €**	**13.689.700 €**
Capital loan		2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €	2.444.444 €
Accumulated paid		22.000.000 €	19.555.556 €	17.111.111 €	14.666.667 €	12.222.222 €	9.777.778 €	7.333.333 €	4.888.889 €	2.444.444 €
Accumalated capital paid		2.444.444 €	4.888.889 €	7.333.333 €	9.777.778 €	12.222.222 €	14.666.667 €	17.111.111 €	19.555.556 €	22.000.000 €

Interest rate	114%	114%	114%	114%	114%	114%	114%	114%	114%	114%
Interests	- €	341.733 €	683.467 €	1.025.200 €	1.366.933 €	1.708.667 €	2.050.400 €	2.392.133 €	2.733.867 €	3.075.600 €
SOROZNO CAPITAL	**1.760.000 €**	**1.760.000 €**	**1.760.000 €**	**1.760.000 €**	**1.760.000 €**					
SOROZNO PENDING	**8.800.000 €**	**7.040.000 €**	**5.280.000 €**	**3.520.000 €**	**1.760.000 €**					
SOROZNO INTERES	**636.240 €**	**508.992 €**	**381.744 €**	**254.496 €**	**127.248 €**					
Social Expenses	**85.600 €**	**91.592 €**	**98.003 €**	**104.863 €**	**112.204 €**	**120.058 €**	**128.462 €**	**137.454 €**	**147.076 €**	**157.372 €**
Financial expenses	**2.396.240 €**	**5.055.170 €**	**5.269.655 €**	**5.484.140 €**	**5.698.626 €**	**4.153.111 €**	**4.494.844 €**	**4.836.578 €**	**5.178.311 €**	**5.520.044 €**
Profit or loss of the year	4.030.673 €	1.964.949 €	2.385.194 €	2.849.870 €	3.362.088 €	5.685.175 €	6.175.444 €	6.723.953 €	7.334.779 €	8.012.284 €

11.5 Second option accounts

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash flow (income - expenses)	6,395,172 €	6,714,931 €	7,050,677 €	7,403,211 €	7,773,372 €	8,162,040 €	8,570,142 €	8,998,649 €	9,448,582 €	9,921,011 €
Amortization 20 years	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €
operating result	**4,347,712 €**	**4,667,471 €**	**5,003,217 €**	**5,355,751 €**	**5,725,912 €**	**6,114,580 €**	**6,522,682 €**	**6,951,190 €**	**7,401,122 €**	**7,873,551 €**
Capital loan		2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €
Accumulated paid		22,000,000 €	19,555,556 €	17,111,111 €	14,666,667 €	12,222,222 €	9,777,778 €	7,333,333 €	4,888,889 €	2,444,444 €
Accumalated capital paid		2,444,444 €	4,888,889 €	7,333,333 €	9,777,778 €	12,222,222 €	14,666,667 €	17,111,111 €	19,555,556 €	22,000,000 €

Interest rate	114%	114%	114%	114%	114%	114%	114%	114%	114%	114%
Interests	- €	341,733€	683,467 €	1,025,200 €	1,366,933 €	1,708,667 €	2,050,400 €	2,392,133 €	2,733,867 €	3,075,600 €
SOROZNO CAPITAL	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**					
SOROZNO PENDING	**8,800,000 €**	**7,040,000 €**	**5,280,000 €**	**3,520,000 €**	**1,760,000 €**					
SOROZNO INTERES	**636,240 €**	**508,992 €**	**381,744 €**	**254,496 €**	**127,248 €**					
Social Expenses	**63,952 €**	**67,149 €**	**70,507 €**	**74,032 €**	**77,734 €**	**81,620 €**	**85,701 €**	**89,986 €**	**94,486 €**	**99,210 €**
Financial expenses	**2,396,240 €**	**5,055,170 €**	**5,269,655 €**	**5,484,140 €**	**5,698,626 €**	**4,153,111 €**	**4,494,844 €**	**4,836,578 €**	**5,178,311 €**	**5,520,044 €**
Profit or loss of the year	1,887,521 €	-454,848 €	-336,944 €	-202,421 €	-50,448 €	1,879,849 €	1,942,137 €	2,024,625 €	2,128,325 €	2,254,297 €

SOURCE: Own elaboration

11.6 Third option accounts

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash flow (income - expenses)	6,395,172 €	6,650,979 €	6,917,018 €	7,193,699 €	7,481,447 €	7,780,705 €	8,091,933 €	8,415,610 €	8,752,235 €	9,102,324 €
Amortization 20 years	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €	2,047,460 €
operating result	**4,347,712 €**	**4,603,519 €**	**4,869,558 €**	**5,146,239 €**	**5,433,987 €**	**5,733,245 €**	**6,044,473 €**	**6,368,150 €**	**6,704,775 €**	**7,054,864 €**
Capital loan		2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €	2,444,444 €
Accumulated paid		22,000,000 €	19,555,556 €	17,111,111 €	14,666,667 €	12,222,222 €	9,777,778 €	7,333,333 €	4,888,889 €	2,444,444 €
Accumalated capital paid		2,444,444 €	4,888,889 €	7,333,333 €	9,777,778 €	12,222,222 €	14,666,667 €	17,111,111 €	19,555,556 €	22,000,000 €

interest rate	114%	114%	114%	114%	114%	114%	114%	114%	114%	114%
Interests	€	341,733 €	683,467 €	1,025,200 €	1,366,933 €	1,708,667 €	2,050,400 €	2,392,133 €	2,733,867 €	3,075,600 €
SOROZNO CAPITAL	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**	**1,760,000 €**					
SOROZNO PENDING	**8,800,000 €**	**7,040,000 €**	**5,280,000 €**	**3,520,000 €**	**1,760,000 €**					
SOROZNO INTERES	**636,240 €**	**508,992 €**	**381,744 €**	**254,496 €**	**127,248 €**					
Social Expenses	**63,952 €**	**66,510 €**	**69,170 €**	**71,937 €**	**74,814 €**	**77,807 €**	**80,919 €**	**84,156 €**	**87,522 €**	**91,023 €**
Financial expenses	**2,396,240 €**	**5,055,170 €**	**5,269,655 €**	**5,484,140 €**	**5,698,626 €**	**4,153,111 €**	**4,494,844 €**	**4,836,578 €**	**5,178,311 €**	**5,520,044 €**
Profit or loss of the year	1,887,521 €	- 518,160 €	- 469,267 €	- 409,838 €	- 339,453 €	1,502,327 €	1,468,709 €	1,447,416 €	1,438,941 €	1,443,796 €

SOURCE: Own elaboration

11.7 Social investment first option

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Fight Against the Desertification	64,199.79	73,502.34	11,220.37	44,961.73	51,476.68	55,080.05
Society	12,839.95	14,700.46	56,101.88	44,961.73	51,476.68	55,080.05
Animals and Wildlife	8,559.97	9,800.31	44,881.50	38,538.62	44,122.87	47,211.47
Total	85,599.72	98,003.12	112,203.77	128,462.09	14,7076.25	15,7371.59

SOURCE: Own elaboration

11.8 Social investment second

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Fight Against the Desertification	47,963.79	52,880.07	7,773.37	29,995.49	33,070.03	34,723.53
Society	9,592.75	10,576.01	38,866.85	29,995.49	33,070.03	34,723.53
Animals and Wildlife	6,395.17	7,050.67	31,093.48	25,710.42	28,345.74	29,763.03
Total	63.951.72	70,506.77	77,733.71	85,701.42	94,485.81	99,210.10

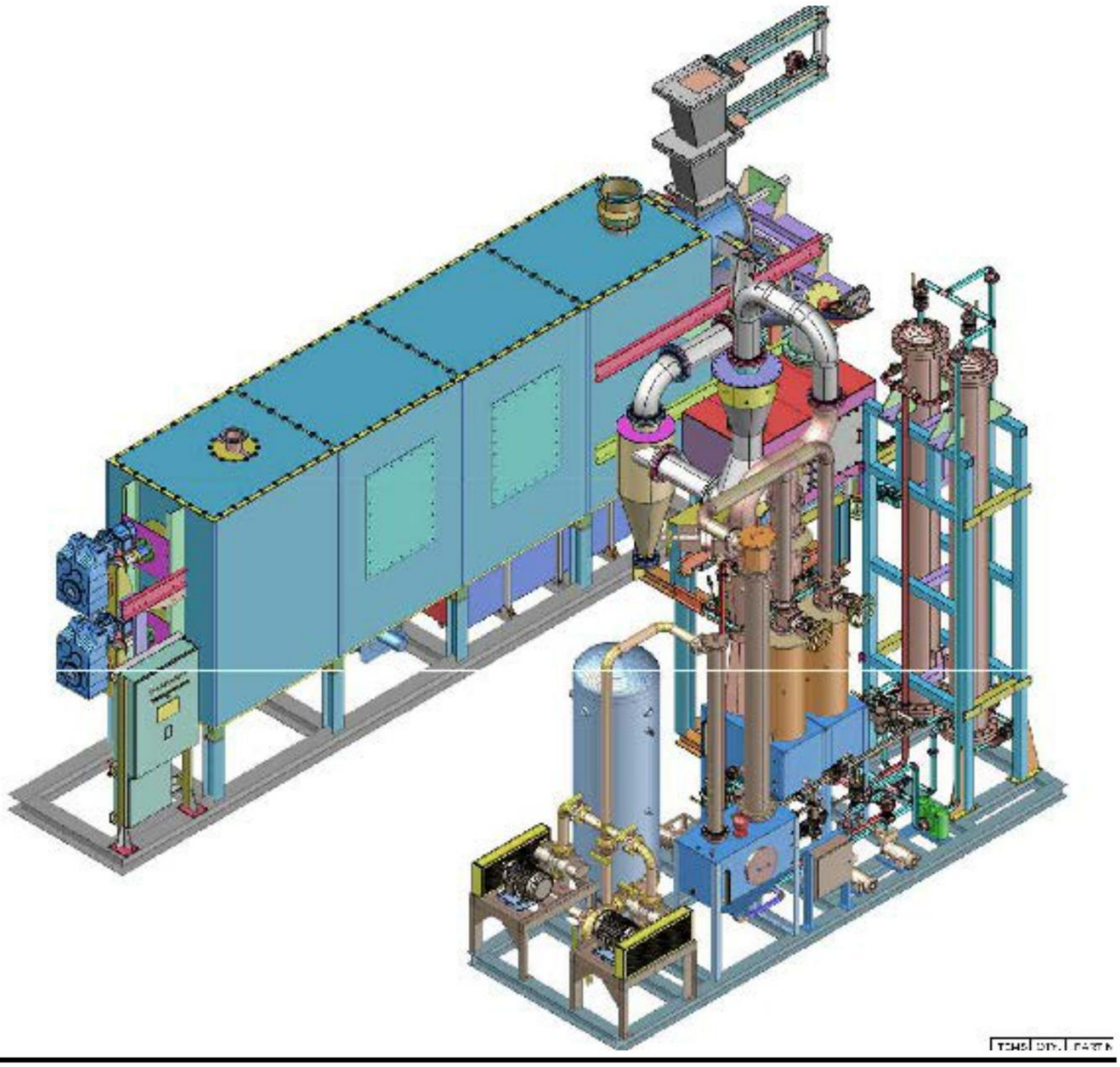
11.9 Social investment third

	Year 1	Year 3	Year 5	Year 7	Year 9	Year 10
Fight Against the Desertification	47,963.79	51,877.63	7,481.44	28,321.76	30,632.82	31,858.13
Society	9,592.75	10,375.52	37,407.23	28,321.76	30,632.82	31,858.13
Animals and Wildlife	6,395.17	6,917.01	29,925.78	24,275.79	26,256.70	27,306.97
Total	63,951.72	69,170.18	74,814.46	80,919.32	87,522.34	91,023.23

SOURCE: Own elaboration

11.10 SoroznoEco. "ARTI Process Review MSW" 2016

ARTI Process Review MSW



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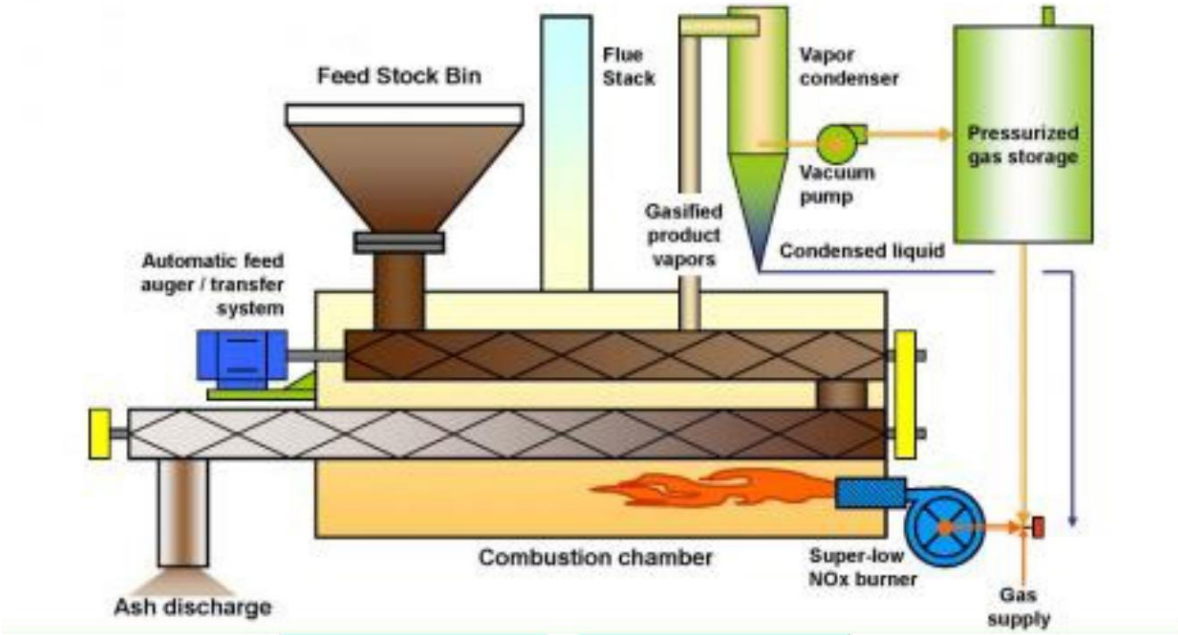
SoroznoEco

1.0 REVIEW OF THE THERMAL DISTILLATION TECHNOLOGY



1.1 Process Description

The pyrolysis demonstration unit at the site is a skid mounted. self-contained unit designed to convert waste into hydrocarbon fuels suitable for clean combustion and generation of electrical power. The unit consists of gas heated retort with internal transport augers. gas cleaning and condensing components. gas and liquid pumps. cooling tower. and a storage tank. The following components are the major parts of the pyrolytic system:

- The Furnace
- The Auger
- The Retort
- The Burner
- The Particle Wash System
- The Condenser
- The Gas Blower
- Storage tank
- The Cooling Tower

1.1.1 The Furnace:

An insulated box which contains the waste to energy retort. The retort is isolated from the furnace environment so the gases cannot leak in to the retort from the furnace. The furnace is equipped with a burner firing natural gas. The heat from the burner travels through two passes to heat the retort. The flue gas temperature should normally be 150 to 200 F above the retort operating temperature. The furnace is designed to allow the retort to easily expand and contract during the operation.

1.1.2 The Retort:

The retort is a sealed stainless steel vessel containing the two transport augers. The feedstock is manually fed to the retort via a double blade air sealed valve. This valve is installed to minimize the passage of air into the retort. The feedstock is fed into the retort when the top blade opens and allows the material to enter the valve. Once the top blade has closed the bottom blade opens to feed the material into the retort. This valve is synchronized with an auger feed into the valve. As the material travels through the retort it gasifies. The gases are collected under a slight negative pressure and sent out of the retort. As the gasification sequence of the material ends the carbon ash exits the retort through a similar double blade valve thus maintaining the slight vacuum during the discharge of this residue. In the case of AF pre shredded AF is fed into the supply bin feeding the retort. After the pyrolysis process the ash exits the retort into an ash bin. The metal from the AF is separated from the ash and is easily recovered.

1.1.3 The Augers:

The retort is equipped with high temperature stainless steel augers which move the material from the inlet. through the retort. and finally to the discharge point. These augers travel at a pre-set speed determined based on the type and characteristic of material processed. However. the speed of the augers can be changed at the Operator Control Panel to suit the changes in material processed.

1.1.4 The Burner:

The burner is manufactured by AC Technologies. Inc. and is a low emission and very efficient burner. This burner can operate at very low levels of excess oxygen if required and meet the European emission requirements. The furnace is equipped with a gas burner that is normally fueled with either natural gas or waste gas. The burner is supplied with a flame safeguard control and can be modulated to a higher firing rate on demand. A temperature control installed on the retort allows the burner to start and to modulate. Once the burner is turned on. it modulates to a firing position where it heats the retort to the pre-set temperature. When the temperature demand is satisfied the burner modulates back to its lower firing rate. If the temperature exceeds its pre-set upper limit the burner automatically shuts down. During the operation in many cases the material conversion process becomes exothermic and even though the burner has shut down the retort temperature [will remain high] may continue to rise. If the reto temperature falls below the lower set point the burner will automatically start and raise the temperature back to the upper set point.

1.1.5 The Particle Wash System:

When the pyrolytic system is in processing mode. gases travel from the unit to the Particle Wash System (PWS). The PWS is provided with a liquid pump. The Particle Wash System must contain either light oil or water (10 to 15 gallons) depending on the nature of the process. The Wash Pump energizes as the unit starts to operate and re-circulates the washing media. This washing process takes place in a venture and any heavy particles such as tar or wax can be removed from the gas and will be retained within the Particle Wash System. A glass level indicator is supplied with the Particle Wash System. The unit must be drained from time to time to keep the level low enough for the gas to travel through. Once the gas has been cleaned through the venture it travels through the demister and liquid particles are stripped from the gas.

1.1.6 The Condenser:

A condenser is installed at the end of the PWS to make sure the lighter condensable gases liquefy through this condenser. The light liquid collects in the tank installed at the bottom of the condenser and the non condensable gases travel through a demister separating the last liquid particles before the gas reaches the gas blowers.

1.1.7 The Gas Blower:

A Gas Blower is supplied to remove the gases from the system while maintain the slight negative pressure within the system. It is a Roots-type positive displacement blower. The blower is controlled through the use of a pressure transducer installed on the retort. This transducer senses the rate of gasification.
As the gasification process gas flow changes. the retort pressure rises or falls and sends a signal to the blower speed control to compensate. In this way the operating retort vacuum is maintained at a pre-set level. This insures the quality and uniformity of the by-products.

1.1.8 Intermediate Storage Tank:

The final gas product travels to an intermediate gas storage tank. This is a small tank and cannot be used as a permanent gas storage tank. This tank must be emptied continuously otherwise it will cause back-pressure on the system.

1.1.9 The Cooling Tower:

A cooling tower is supplied to cool and re-circulate cooling water to the condenser.

1.2 System Operation:

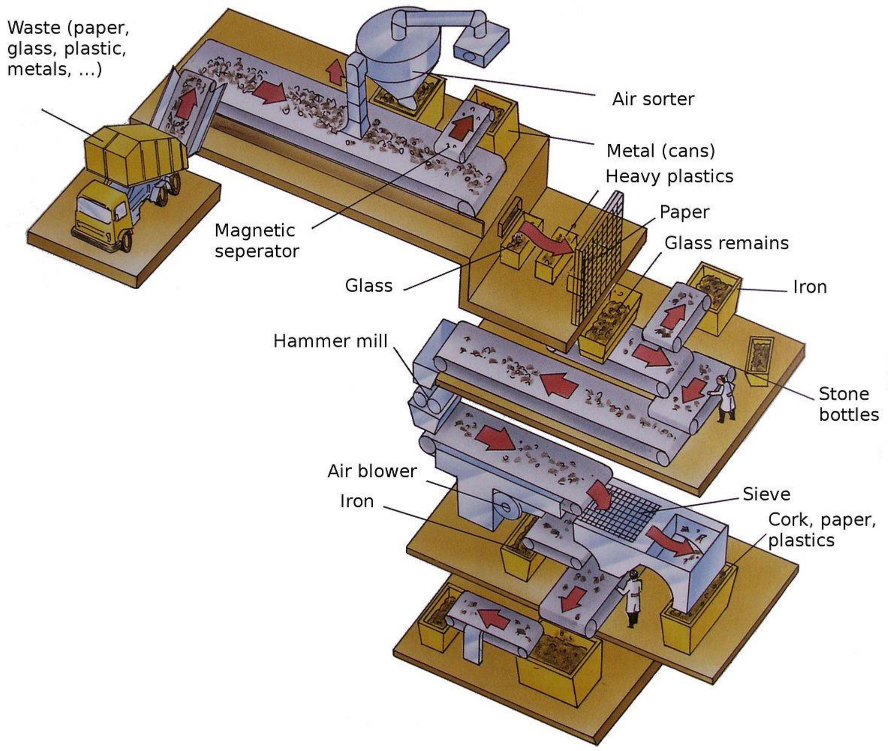
The pyrolysis system operation follows:
The burner in the furnace is started and a flame is established monitoring three important items. 1. Furnace temperature. 2. Retort temperature. and 3. Retort pressure. The retort pressure is kept at a slight negative level in inches of water column mainly between -0.5 to -2.00 "H2O". This helps to raise the retort temperature faster and insure a safe operation. The retort temperature normally varies between 650 ° F and 1600 ° F. For pyrolyzing MSW the retort temperature is maintained between 1100 ° F and 1200 ° F. The residence time for this material is also important. For MSW the residence time is one hour and the material is kept in the retort for one hour. As the burner operates it will increase the temperature of the pyrolytic unit until a temperature of 800 ° F is reached. At this point material can be fed to the retort via the air-locked valves initiating the pyrolytic process. Once the pre-set retort temperature is reached the burner will automatically shut down. The burner will not re-energize until another pre-set burner starting temperature is reached in the ideal pre-set operating temperature. As the material begins to gasify. the gases will build a pressure which is higher than the pre-set negative retort pressure. the pressure transducer senses this change and sends a signal to the gas blower and the blower is programmed to response to this demand to bring the pressure down to the pre-set level. The gases are drawn constantly from the retort and washed out of dust. dirt and maybe some pollutants such as some sulfur compounds. Once the gas is washed. in the next two stages of operation it is important that all condensed liquids are separated from the gas using a condenser and water separators before it reaches the gas blower(s). The gas blower sends this gas to an intermediate tank at a low pressure from which it is drawn and kept in a higher pressure tank (up to 200 psig).

The condenser is cooled using a cooling tower. which re-circulates the water as a cooling media to the condenser and the gas washing heat exchanger.

Once the pyrolytic media is completely finished. the unit has to run for at least another hour in order to gasify the material that was just introduced to the unit. It is important that the furnace temperature is monitored to make sure the flame temperature does not increase beyond 2000°F.

Although the retort is manufactured using high temperature alloys. it is important that too high temperatures are avoided at all time. This will insure a long retort life.

11.11 Sorting Machine



(SLOVAKIA, June 2017)

11.12 Pelletizer Machine

(SOROZNOECO, 2016)

11.13 Protocol No. 4551/2017

Napájadlá 17, 040 12 Košice
phone: 055/6411211, e-mail: info@ekolab.sk

Protocol No. 4551/2017

Amount of paages: 1
Order No. 1422/14

Customer:
National energetic company, Inc
Zvolenska cesta 1
974 05 Banska Bystrica

Place of collection: TARPIU, Romania

Sample/s took by: customer
Charapteristic of sample: gas

Type of collection: -
End day of the analysis: 29.8.2017

No. Sample	Name of sample	Day of collection	Delivery
6818/2014	G0002/2014	28.82017 - 28.8.2017	29.08.2017

Resault of measurement are relevant only for this analysys and they are not mentioned in other documents.
Without permission of testing laboratory can only be copied only as whole document.

Resault of measurement

Parameters	Units	No. Sample **6818/2014** **Value**	Uncertainty U	Working procedure according to the standard	
CO	%)	4,9	5%	N	STNEN ISO6974
CO2	%)	17.85	5%	N	STNEN ISO6974
H2	%)	18,6	5%	N	STNEN ISO6974
N2	%)	34,4	5%	N	STNEN ISO6974
CH4	%)	19,0	5%	N	STNEN ISO6974
O2	%)	3,3	5%	N	STNEN ISO6974
Ethan	%)	86,0	5%	N	STNEN ISO6974
Heat power	MJ/m^3	11,1	2%	N	STNEN ISO6974
Caloric value	MJ/m^3	9,9	2%	N	STNEN ISO6974
Ethene	%)	8,0	0,8	N	STNEN ISO6974

Executed: Ing E. Juskovà

A/N: accredited/Nonaccredited test
SA/SN: accredited/Nonaccredited subs delivery
Uncertainty U - Extended uncertainty with a coefficient k=2(95%)
* - per cent measured value
Deviation of the test method: none

in Košice 14.9.2017

Ing. Eva Jusková
Head of Testing Laboratory

P41

11.14 Emission control report in Romania

Reg. No.
311/S-186

Výtlačok
číslo

EMISSION CONTROL REPORT

RELEASED FROM THE PYROLYSIS PROCESS EQUIPMENT
DECOMPOSITION OF THE WASTE PLACED AT THE LANDFILL SITE
OF TARPI IN ROMANIA

Name of accredited testing laboratory:	National Energy Company a.s. Laboratory of Emission Measurements Zvolenská cesta 1. 974 05 Banská Bystrica IČO: 43769233

Report number:	**¡Error! No se encuentra el origen de la referencia.**	***Date:***	**¡Error! No se encuentra el origen de la referencia.**

Operating unit:	OMNIUM. Rumunsko		
Customer:	VS Elektroservis. s.r.o.. Robotnícka 4334. 017 01 Považská Bystrica IČO: 44 483 180		
Place/Location:	Landfill of Vitalia / Cataster of Tarpiu. Romania		
Type of measurement:	Measurement of the values of the physico-chemical quantities. which express the emission limit and the values of the associated status and reference quantities directly related to the emissions of polluted waste gases and the measurement of the qualitative composition and energy content of gaseous fuels.		
Order number:	25082014/01	***Date of order:***	25.08.2014
Date of measurements:	28. till 29.08.2014		
The person responsible for the measurement – the head technician:	Ing. Ján Körmendy . r. narodenia 1972		

Report content: 98 pages

Purpose of measurement:
Discontinuous measurement of pollutant emission values and related reference and status variables in the waste gas from a pyrolysis synthesis gas generator after its commissioning

and a verification measurement to determine the composition and caloric value of the synthesis gas produced.

Summary

Operation unit	Waste landfill near Tarpiu in Romania
Operation Time	planned operation: 24 h / day. approx. 8200 h / year. technology: emission single-mode (highest expected emissions of synthesis gas production). continuous emission steady
Soucres / devices producing emissions	1. Pyrolysis synthesis gas generator (steel exhaust at hight 10 m) 2. Technological equipment for pyrolysis decomposition of waste (flameless flame)
Measured elements	TZL. SO_2. NO_X. CO. TOC
Results	the mass concentration of the constituent in the waste gases in mg / m3. mass flow in g / h
Source number / device producing emissions	1. Pyrolysis synthesis gas generator (steel exhaust at hight 10 m) 2. Technological equipment for pyrolysis decomposition of waste (flameless flame)

Measured element	***N***	***Average value (concentration. mass flow) [mg / m 3; g / h]***	***maximum (concentration. mass flow) [mg / m 3; g / h]***	***Emission limit (concentration. mass flow) [mg / m 3; g / h] 3)***	***Highest emission mode [yes / no] 4)***	***Warning on compliance / mismatch 5)***
Soucres / devices producing emissions			1. Pyrolysis synthesis gas generator (steel exhaust at hight 10 m)			
Operationn time:			syngas 100%; nominal heat input			
TZL[1)]	3	2.1; 0.8	2.7; 1.0	5	Yes	**compliance**
SO_2[1)]	5	10.1; 3.8	13.1; 5.0	35. 800[6)]	Yes	**compliance**
NO_X ako NO_2[1)]	5	158; 59.9	158; 60.1	200	Yes	**compliance**
CO[1)]	5	4.5; 1.7	10.2; 3.9	100	Yes	**compliance**
TOC[1)]	5	1.7; 0.7	2.2; 0.9	-	Yes	**compliance**
Soucres / devices producing emissions			2. Technological equipment for pyrolysis decomposition of waste (flameless flame)			
PAU[2)7)]	3	*<0.001; -*	*<0.001; -*	0.05; 0.15	Yes	**compliance**

[1)] Status and reference conditions for mass concentration: 0 °C. 101.3 kPa. dry gas. reference oxygen 3% volume
[2)] Status and reference conditions for the mass concentration: 0 °C. 101.3 kPa. dry gas
[3)] The emission limit. the conditions of its validity set out in Annex no. 4 Section IV. Section 3.2. of Decree of the Ministry of Environment of the Slovak Republic no. 410/2012 Z.z. and for PAH as benzo (a) pyrene and dibenzo (a. h) anthracene from the 6th group of pollutants according to Annex no. 3 Part of the Decree of the Ministry of Environment of the Slovak Republic no. 410/2012 Z.z.
[4)] Mode of operation according to Annex no. 2 of Part B. item 1 of Decree of the Ministry of Environment of the Slovak Republic no. 411/2012 Z.z. measurements made in the selected production and operating mode. during which the emissions of all ZLs are the highest and the raw material parameters and the technical and

operational parameters of the production and technological separation and separation facilities are in accordance with the valid documentation. with the permit and at the same time correspond to the normal values

5) Requirement to comply with the emission limit pursuant to § 18 par. Article 2 a) Decree of the MoE SR no. 410/2012 Z.z.

6) Higher value applies to low-temperature industrial gases. for example low-caloric gas from refinery gasification. blast furnace gas. coke oven gas and mixtures thereof.

7) the reported average and maximum emission values are calculated on the basis of the data from the subcontractor - the analytical laboratory

N - the number of individual values of the measured emission quantities

List of abbreviations used

CO – carbon monoxide

EL – emission limit
IPP – Internal working procedure developed by National Energy Company a.s.
IM – Internal methodology prepared by National Energy Company a.s.
NO_X - nitrogen oxides. nitric oxide (NO) and nitrogen dioxide (NO2) expressed as nitrogen dioxide (NO2)
OA – sampling apparatus
PAU – polycyclic aromatic hydrocarbons - organic compounds composed of at least two fused benzene cores containing only carbon and hydrogenRIZ – riadený interný záznam
SO_2 – sulfur dioxide
TOC – volatile organic substances expressed as total organic carbon
TPP – technical-operating parameters
TZL – solid pollutants expressed as the sum of all particles
ZL – pollutant

standard situation conditions - temperature 0 ° C (273.15 K) and pressure 101.3 kPa

syngas - also synthesis gas; a mixture of combustible gases produced by the pyrolysis of organic material

Description of the purpose of the measurement

Discontinuous measurement of the emission values of pollutants (TZL. SO2. NOX. CO. TOC) and related reference (O2) and status (temperature. pressure. volume flow) quantities in the flue gases from the pyrolysis synthesis gas generator after commissioning and verification to determine the composition and caloric value of the synthesis gas (syngas) produced from the pyrolysis process decomposition equipment.

A description of the operation and the materials being processed

The principle of technology

The station for pyrolysis waste treatment is based on the thermo-chemical conversion of solid materials (communal waste) into flammable gas (syngas). It consists of a pyrolysis syngas generator. which includes a retort (two gasifier cylinders) and a gas overpressure low emission burner (ACT-03). a particle separator. a gas scrubber. a condenser / humidifier. a pump. a gas reservoir. compressors. and a system of conveyors and pipelines. The decomposed material (crushed and compacted) is transported and fed into the retort without air access in the cycles. which ensures tight flaps at the inlet and outlet of the retort. By passing the material through the retort. where it is moved by the screw conveyors. the material is thermally decomposed by the high temperature produced by combustion of the gas on the burner. The gaseous components produced are continuously exhausted from the retort via gas purging devices under moderate vacuum by gas pumps. Purified gas is sucked out and compressed at 6 bar and transported to SYNGAS trays. The fixed components from the retort are taken to the container for further

processing. The technology is controlled by the Micro Logix 1400 Allen-Bradley controller and the LMV51 automatic burner. The entire device is a product of the American company ACT

Inc. and the design parameters are given in the following **Table of projected device parameters**

The station needs a foreign source of gas to the burner. which is propane in this case. for starting and charging the retort to the operating temperature (about 8 hours). Once the required amount of gas has been generated (syngas). the starting gas (propane) is discharged and the plant is then permanently operated on a part of its own produced gas. the remainder being combusted in a 250 kW cogeneration unit (based on the Liebherr G926 engine) it is free-burned in the field burner (flare).

Table of projected device parameters

Pol.	*Parameter name*	*Value*
1.	Input amount of waste	1 ton per hour
2.	The amount of synthesis gas produced (according to the quality of the processed material)	600 till 800 m^3/h
3.	The maximum temperature in the combustion chamber of the pyrolysis gas generator	1200 °C
4.	Maximum temperature in the retort	650 °C
5.	Operating pressure in the retorte	- 10.3 till + 10.3 kPa
6.	Maximum discharge of compressors	600 kPa
7.	Leakage pressure on field burner	580 kPa
8.	Maximum rated thermal output of a pyrolysis gas generator	110 kW

Waste gases - flue gases are drawn from the syngas generator through a steel pipeline by two exhaust fans located on the shelter of the installation through the exits at a height of 10

From the emission-technological nature of the operation. **the technology** is in accordance with the production and operating regime of the **emission one-irradiation** and according to the duration and character of the emission changes **the continuous emission stable.**

Fuel and raw materials

All raw materials with sufficient energy content - biomass. coal. plastics. rubber. sludges and other wastes of various kinds - can be processed according to the documentation. The station is using separate. crushed and compacted municipal waste from a local landfill to produce syngas.

The pyrolysis generator produces a process gas which is composed of stable combustible gases (CO. H2. CH4) and non-flammable gases (CO2. H2O. N2). higher hydrocarbons. tar and other (small amount). According to the quality of the processed material. the caloric value of the produced gas amounts to 12.6 to 28.4 MJ / m3 with the production quantity of 600 to 800 m^3/ h.

Descripiton of place where measurement took place

The pyrolysis generator gas sampling site was formed in an equal section of the vertical section of the pipe with a constant circular cross section of 216 mm diameter behind the generator outlet and the T-piece with the exhaust fans. The existing measurement site is circular with a flange of 20 mm diameter away from the output of the 1600 mm generator (gaseous ZL and temperature measurement). At the same time. at a distance of 1000 mm above the flange. a square hole of 50 x 50 mm was created to take the TZL. Access to the measuring holes is made possible from a fixed platform to the syngas generator. the power connections are close to the measuring point up to 10 m. This measuring point was determined and listed in the measurement plan (Annex 1) in accordance with the requirements of STN EN 15259. The sampling of the syngas was carried out just behind the desulphurisation device on the existing ½ "connection. which serves to place the gas pressure sensor. The distances. the pipe dimensions and the source display with the location of the measuring points. the sampling plane and the sampling points are given in Annex no. 3

Measuring. analytical methods and equipment

Method and methodology of measurement of concentration of pollutants

Table of used operating procedures and technical standards

Measured emission element	***Name of the methodology***	***Namme of the method***	***Working procedure***
mass concentration of TZL	Air protection. Stationary sources of pollution. Determination of low weight concentrations of TZL. Part 1: Manual gravimetric method	STN EN 13284-1	IPP4 (30.5.2013)
mass concentration of CO	Air protection. Stationary emission sources. Measurement of the carbon monoxide (CO) mass concentration. Reference method: Non-dispersive infrared spectrometry	STN EN 15058	IPP1(30.5.2013)
mass concentration of NO_X	Air protection. Stationary sources of pollution. Determination of mass concentration of nitrogen oxides. Working characteristics of automated measuring systems	STN ISO 10849	
mass concentration of SO_2	Air protection. Stationary sources of pollution. Measurement of the mass concentration of sulfur dioxide. Working characteristics of automated measuring systems	STN ISO 7 935	
mass concentration of O_2	Air protection. Stationary sources of pollution. Measurement of concentrations of CO. CO2 and O2. Working characteristics and AMS calibration	STN ISO 12039	
mass concentration of TOC	Air protection. Stationary sources of pollution. Measurement of the mass concentration of total gaseous organic carbon. Continuous method with flame ionization detector	STN EN 12619	IPP9 (30.5.2013)

organic substances contained in gases	Air protection. Stationary sources of pollution. Determination of mass concentration of selected gaseous organic substances. Adsorption method on activated carbon and desorption with solvent	STN EN 13649	IPP11 (30.5.2013)
flow rate to volume flow	Air protection. Stationary emission sources. Measurement of velocity and volume flow of gases in pipelines. Part 1: Manual reference method	STN EN ISO 16911-1	IPP6 (30.5.2013)
humidity of the gas in the pipeline	Air protection. Stationary emission sources. Determination of water vapor in pipes	STN EN 14790	IPP5 (30.5.2013)
mass concentration of ZL	Air protection. Detection of time averaged emissions and emission factors. General procedure	STN EN ISO 11771	IPP6 (30.5.2013)

The number of individual measurements and withdrawals in a series at one measuring point. shown in Table no. 2. was planned in accordance with valid legislation for emission measurements used in the Slovak Republic (Annex No. 2 Part D of Decree of the Ministry of Environment of the Slovak Republic No. 411/2012 Zz).

Table of Technical operating proces of device during measurements

Device / production-operation mode			***pyrolysis***
Parameter	***Measure***	***Value of PD***	***Value (n)***
Gas pressure in front of the gas regulator	kPa	20 till 400	20 till 48
Gas pressure to the burner	kPa	0 till 10	0.5
Temperature in the retort	°C	max. 650	332 till 492
Preassure in the retort	kPa	- 10.3 till + 10.3	-38.1 till- 4.5
Temperature in the combustion chamber	°C	max. 1200	771 till 1001
Gas Gas Temperature - Part 1	°C	-	31.7 till 38.3
Temperature in the condenser	°C	-	14.4 till 15.0

Notes

The "TP value" column shows the significant TPPs listed in the documentation (2) that can be tracked during the measurement. in the column "Value (n)" of the values of the relevant TPPs recorded during the measurement

Devices for waste gas purification

There is no gas purification device behind the syngas generator. On the syngas treatment devices. the parameters listed in Table 5.1.3 above are followed. For gas temperature and condenser temperature values. the operating parameters are not listed in the documentation. and therefore no deviations of the allowed ranges have been found.

Results of meassurements

Overview of instrument measurement results

Operator:	OMNIUM. Rumunsko	***Date:***	29.08.2014
Source name:	Waste landfill near Tarpiu in Romania	***Device:***	Pyrolysis
Tim of	syngas 100%; nominal heat input		

Measurement interval	O_2 [% obj.]	NO_X[1)] [mg/m³]	NO_X [kg/h]	CO[1)] [mg/m³]	CO [kg/h]	SO_2[1)] [mg/m³]	SO_2 [kg/h]	TOC[1)] [mg/m³]	TOC [kg/h]
12:45 till 13:15	7.9	157	0.06	10.2	0.00	13.1	0.00	2.2	0.000
13:00 till 13:30	7.9	158	0.06	3.2	0.00	9.1	0.00	2.0	0.000
13:15 till 13:45	7.9	158	0.05	3.0	0.00	9.2	0.00	1.5	0.000
13:30 till 14:00	8.0	157	0.05	3.2	0.00	9.9	0.00	1.5	0.000
13:45 14:15	8.0	158	0.05	2.7	0.00	9.2	0.00	1.4	0.000
Average	7.9	158	0.05	4.5	0.00	10.1	0.00	1.7	0.000
U [%]	±	± 5.0	± 15	± 8.0	± 20	± 8.0	± 20	± 8.0	± 20

Overview of manual subscriptions results

Operator:	OMNIUM. Rumunsko	***Date:***	29.08.2014
Source name:	Waste landfill near Tarpiu in Romania	***Device:***	Pyrolysis generator
Time of operation:	syngas 100%; nominal heat input		

Measurement interval	O_2 [% obj.]	TZL[1)] [mg/m³]	TZL [kg/h]
12:48 till 13:07	7.90	2.7	0.0010
13:15 till 13:34	8.00	1.8	0.0007
13:42 till 14:01	8.03	1.9	0.0007
Average	7.98	2.1	0.0008
U [%]	±	± 1.8 mg/m³	± 30

Overview of manual subscriptions results

Operator:	OMNIUM. Rumunsko	***Date:***	28.08.2014
Source name:	Waste landfill near Tarpiu in Romania	***Device :***	Technology for pyrolysis decomposition odpadu

Measurement interval	O_2 [% obj.]	PAU[2)3)] / sum of all analyzed ZL/ [mg/m³]	PAU[2)3)] / only benzo (a) pyrene and dibenzo (a. h) anthracene / [mg/m³]
12:48 till	7.9	*0.02*	*below DL*
13:15 till	8.0	*0.00*	*below DL*
13:42 till	8.0	*0.03*	*below DL*
Average	7.9	*0.02*	*below DL*
U [%]	±	*± 20*	-

Notes

[1)] mass concentration under standard dry conditions in dry conditions and a reference oxygen content of 3% by volume
[2)] mass concentration under standard dry conditions
[3)] the reported emission values are calculated on the basis of the documents from the subcontractor - the analytical laboratory
below DL - below the detection limit (for ZL <0.001 mg.m-3)
U - relative extended uncertainty with coverage coefficient k = 2 at 95% of the statistical probability at the limit value of the specified parameter. expressed in% of the measured value. unless otherwise stated

11.15 BTU table

	kcal/kg	Fixed Carbon	Moisture	Ash	Volatiles	Btu/dry lb	kj/kg
Almond Prunings	3,058	21.54%	18.0%	1.63%	58.83%	5,500	**12,793**
Asphalt Shingles	8,339		5.0%			15,000	**34,889**
Auto Fluff	7,465	50.00%	18.0%		32.00%	13,428	**31,233**
Bagasse	4,436	14.95%	20.0%	11.00%	54.05%	7,980	**18,561**
Barley Straw	4,141	20.90%	14.0%	10.00%	55.10%	7,449	
Bamboo	3,800	20.00%	18.0%		62.00%	6,836	**15,900**
Brown coal	4,500		18.0%			8,095	**18,828**
Brown Paper	4,398	9.80%	10.0%	1.10%	79.10%	7,911	**18,400**
Cacao Shrub	3,298	24.00%	18.0%		58.00%	5,933	**13,800**
Car tires	8,300		18.0%			14,930	**34,726**
Cardboard	3,891	12.90%	18.0%	5.40%	63.70%	7,000	**16,282**
Cardboard corrugated	3,920	12.90%	18.0%	5.40%	63.70%	7,051	**16,400**
Casuarina	4,483	19.59%	18.0%	1.83%	60.58%	8,064	**18,757**
CDR	4,058	41.00%	18.0%		41.00%	7,300	**16,979**
Chicken Manure	3,780	10.30%	27.0%	15.70%	47.00%	6,800	**15,816**
China grass	4,039	20.00%	18.0%		62.00%	7,266	**16,900**
Citrus peels	4,500	20.00%	18.0%		62.00%	8,095	**18,828**
Coal	6,671	10.00%	18.0%		72.00%	12,000	**27,911**
Coal - Pittsburgh Seam	7,583	55.80%	18.0%	10.30%	15.90%	13,641	**31,728**
Coconut shell	5,984	32.00%	18.0%		50.00%	6,836	**15,900**
Coffee bean shells	6,000	10.00%	18.0%		72.00%	10,793	**25,103**
Commercial Waste	4,447	30.00%	18.0%		52.00%	8,000	**18,608**
Compost	4,207		18.0%			7,567	**17,600**
Cork	6,310	8.00%	18.0%		74.00%	11,350	**26,399**
Corn	4,398	20.00%	18.0%		62.00%	7,911	**18,400**
Corn Stover	4,405	19.25%	18.0%	5.58%	57.17%	7,924	**18,430**
Corncobs	4,483	18.54%	18.0%	1.36%	62.10%	8,064	**18,757**
Cotton gin trash	3,922	15.10%	18.0%	17.60%	49.30%	7,055	**16,409**
Cotton seeds	3,298	20.00%	18.0%		62.00%	5,933	**13,800**
Cotton Stalk	4,361	22.43%	18.0%	6.68%	52.89%	7,845	**18,247**
Cow Manure	4,725	15.00%	20.0%	13.00%	52.00%	8,500	**19,771**
Electrical Waste	7,154	21.00%	5.0%		74.00%	12,869	**29,932**
Food Waste	5,001	20.00%	18.0%		62.00%	8,995	**20,922**
Gin Trash	4,058	24.00%	18.0%		58.00%	7,300	**16,979**
Green Waste	4,070	20.00%	18.0%		62.00%	7,321	**17,028**
Hay	3,203	24.00%	18.0%		58.00%	5,761	**13,400**
Horse Manure	3,058		25.0%	4.00%		5,500	**12,793**
Hospital waste	5,473	10.00%	20.0%		70.00%	9,845	**22,899**
Household waste pre-sorted	4,500	10.00%	18.0%		72.00%	8,095	**18,828**
Human Sludge	6,671	5.00%	25.0%	35.00%	35.00%	12,000	**27,911**
King Grass	4,392	20.00%	15.0%		65.00%	7,900	**18,375**
Leather	4,169	8.00%	18.0%		74.00%	7,500	**17,445**
Lignin	5,059					9,100	**21,166**

Paper sludge	3,920					7,051	**16,400**
Macadamia shell	4,826	22.68%	18.0%	0.40%	58.92%	8,681	**20,206**
Manure (dried)	3,800		18.0%			6,836	**15,900**
Meat Waste	5,288	8.00%	18.0%		74.00%	9,512	**22,124**
Medical Waste	7,138	24.00%	18.0%		58.00%	9,845	**22,899**
MSW 5.5K	3,058	10.00%	40.0%	12.00%	38.00%	5,500	**12,793**
MSW 5K	2,780	10.00%	18.0%	12.00%	60.00%	5,000	**11,630**
MSW 6.5K	3,614	10.00%	18.0%	10.00%	62.00%	6,500	**15,119**
MSW 6K	3,336	10.00%	20.0%	12.00%	58.00%	6,000	**13,956**
MSW 7.0	3,891	10.00%	18.0%	12.00%	60.00%	7,000	**16,282**
MSW High Plastic	5,384	31.00%	15.0%	5.00%	49.00%	9,685	**22,526**
Natural Gas	8,895		18.0%			16,000	**37,215**
Neoprene	7,100		18.0%			12,771	**29,706**
Newspaper	3,920	12.20%	18.0%	1.50%	68.30%	7,051	**16,400**
Nylon	7,570		18.0%			13,617	**31,672**
Oat Hulls	3,855	16.55%	10.4%	5.22%	67.80%	6,934	**16,128**
Oil sludge	8,796		18.0%			15,822	**36,800**
Palm Oil EFB	4,048	14.00%	18.0%		68.00%	7,282	**16,938**
Pallet Wood	4,559	18.00%	20.0%	2.00%		8,200	**19,073**
Paper adhesive coated	4,207	20.00%	10.0%		70.00%	7,567	**17,600**
Paper Plastic Coated	6,816	15.00%	10.0%	2.00%	73.00%	12,261	**28,517**
Paper sludge	3,920					7,051	**16,400**
Paraffin	10,349		18.0%			18,616	**43,300**
Peach Pits	4,973	19.85%	18.0%	1.03%	61.12%	8,945	**20,806**
Peanut Hulls	4,450	21.09%	18.0%	5.89%	55.02%	8,005	**18,618**
Peat, S-H3	5,255	26.87%	18.0%	4.20%	50.93%	9,452	**21,985**
Pig Manure	4,466	12.00%	25.0%	25.00%	38.00%	8,034	**18,687**
Pineapple Waste	4,194	10.00%	10.0%	0.05%	79.95%	7,544	**17,547**
Plastic Roll	6,500	0.02%	1.46%	0.03%	98.49%	21,000	**48,845**
Plastics	7,758	1.46%	5.0%	2.00%	91.54%	15,000	**34,889**
Polyethane foam	9,770	5.00%	5.0%	3.00%	87.00%	17,574	**40,877**
Polyethylene	10,990	15.00%	5.0%	3.00%	77.00%	19,769	**45,981**
Polypropylene	11,030		5.0%	3.00%		19,841	**46,148**
Polystyrol carbon	10,480	30.00%	5.0%	3.00%	62.00%	18,851	**43,847**
Polystyrol EPS	9,800	30.00%	5.0%	3.00%	62.00%	17,628	**41,002**
Railroad Ties	4,447	20.00%			80.00%	8,000	**18,608**
RDF	6,006	41.00%	15.0%		44.00%	10,804	**25,128**
RGEN MSW	4,308	15.00%	15.0%	5.00%	65.00%	7,750	**18,026**
Rice Hulls	3,555	10.00%	10.0%	17.90%	62.10%	6,395	**14,874**
Rubber (Crum	7,500	33.00%			67.00%	13,491	**31,379**
Sewage sludge (dried)	3,298					5,933	**13,800**
Soybean Waste	4,169	20.00%	18.0%		62.00%	7,500	**17,445**
Sudan Grass	4,154	18.60%	18.0%	8.65%	54.75%	7,471	**17,378**
Sugar Beets	3,242	20.00%	18.0%		62.00%	5,831	**13,563**
Sugar Cane	6,810	10.00%	18.0%		72.00%	12,250	**28,493**

Sugarcane Bagasse	4,500	14.95%	18.0%	11.27%	55.78%	8,095	**18,828**
Sunflower Staple	4,300	10.00%	10.5%	7.60%	71.90%	7,735	**17,991**
Sunflower Seeds	4,559	8.00%	18.0%		74.00%	8,200	**19,073**
Switchgrass	4,503	21.00%		6.00%	73.00%	8,100	**18,840**
Tar acid	5,600	2.08%			97.92%	10,073	**23,430**
Tar and refinery residues	9,200	4.00%			96.00%	16,549	**38,492**
Tar paper	6,390	1.22%			98.78%	11,494	**26,735**
Textiles	3,500	10.00%			90.00%	6,296	**14,644**
Tire Chips w/o steel	7,500	35.00%		5.00%	60.00%	13,491	**31,379**
Tire Chips w/steel	7,500	32.00%		10.00%	58.00%	13,491	**31,379**
Tobacco powder	3,012	10.00%			90.00%	5,417	**12,600**
Turkey Manure	3,429	1.22%			98.78%	6,168	**14,346**
Walnut Shells	4,820	21.16%		0.56%	78.28%	8,670	**20,166**
Waste Oil	8,895	2.43%			97.57%	16,000	**37,215**
Waste Paper	3,891	10.00%	15.0%		75.00%	7,000	**16,282**
Wheat Straw	4,182	19.80%	12.0%	8.90%	59.30%	7,523	**17,498**
Beech	4,868		15.0%	0.65%		8,756	**20,366**
Blackhills Pine	4,868	11.41%	6.3%	0.48%	81.77%	8,319	
Black Locust	4,708	18.26%	15.0%	0.80%	65.94%	8,468	**19,696**
Black Walnut Prunings	4,736	18.53%	18.0%	0.78%	62.69%	8,520	**19,816**
Cedar	4,700	21.00%	15.0%	2.00%	62.00%	8,454	**19,664**
Digested Sludge	3,280	10.00%	18.0%		72.00%	5,900	**13,723**
Douglas Fir	5,028	13.70%	15.0%	0.80%	70.50%	9,044	**21,035**
Douglas Fir bark	5,278	25.80%	15.0%	1.20%	58.00%	9,495	**22,085**
Eucalyptus	4,638	17.82%	15.0%	0.76%	66.42%	8,344	**19,407**
Gmelina	4,753	18.00%	15.0%		67.00%	8,550	**19,887**
Hickory	4,818		15.0%	0.73%		8,666	**20,156**
Hybrid Poplar	4,661	18.00%	15.0%		67.00%	8,384	**19,501**
Madrone	4,660	16.44%	15.0%	0.57%	67.99%	8,382	**19,496**
Mango Wood	4,579	11.36%	15.0%	2.98%	70.66%	8,236	**19,157**
Maple	4,767		15.0%			8,576	**19,946**
Pine needles	4,806	26.12%	18.0%	1.50%	54.38%	8,644	**20,106**
Plywood	4,529	15.77%	5.0%	2.09%	77.14%	8,146	**18,947**
Ponderosa Pine	4,782	17.17%	15.0%	0.29%	67.54%	8,601	**20,006**
Poplar	4,629	16.35%	15.0%	1.33%	67.32%	8,326	**19,367**
Red Alder	4,610	12.50%	15.0%	0.40%	72.10%	8,292	**19,287**
Redwood	4,800	16.10%	15.0%	0.40%	68.50%	8,634	**20,083**
Salt Cedar	5,392	22.00%	40.0%		38.00%	9,700	**22,562**
Sycamore	4,715	19.21%	15.0%	0.67%	65.12%	8,481	**19,726**
Treated wood	4,500	1.23%			98.77%	8,095	**18,828**
Western Hemlock	4,789	15.20%	15.0%	2.20%	67.60%	8,614	**20,036**
White Fir	4,765	16.58%	15.0%	0.25%	68.17%	8,571	**19,936**
White Oak	4,638	17.20%	15.0%	1.52%	66.28%	8,344	**19,407**
Wood Pellets	4,683	18.00%	15.0%	1.40%	65.60%	8,424	**19,593**
Loblolly Pine bark	5,202	44.90%	15.0%	0.40%	39.70%	9,357	**21,765**

11.16 Machinery working in Europe

SoroznoEco

VS Elektroservis SLOVAKIA

REFERENCES

VS ELEKTROSERVIS & SoroznoEco

No.	Place	Capacity			Years of operation and exploitation	Note
		Sort	Power	Gas production		
1	BIOMASS POWER PLANT FILAKOVO, Slovakia	Biomass and MSW (future)	1MW	600-800 m^3 per hour	Since 2015, 8000 tons per year	Main contractor ARTI + VS Elektroservis Slovakia
2	OMNIUM, Romania	MSW and tires	1MW	600-800 m^3 per hour	Since 2013, 8400 tons per year	Main contractor ARTI + VS Elektroservis Slovakia
3	ARUBA, Caribbean Sea	MSW	- (only gas)	1950 – 2600 m^3 per hour	Since 2014, 26000 tons per year	Technology supplier ARTI + VS Elektroservis Slovakia
4	BEYPAZARI, Turkey	Chicken manure	2MW	1200 – 1600 m^3 per hour	Since 2014, 12600 tons per year	Technology supplier ARTI + VS Elektroservis Slovakia
5	BUDEJOVICE, Czech Republic.	Wood pellets	1MW	600-800 m^3 per hour	Since 2016, 8000 tons per year	Technology supplier ARTI + VS Elektroservis Slovakia

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