Urban waste for biomethane grid injection and transport in urban areas

Project No: IEE/10/251

Biogas & Biomethane Production: Grid Injection & Transport in Abrantes/Portugal

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+ WP 5 – Task 5.2/5.3 / D 5.2/5.3

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Executive summary

This paper aims to analyze the technical and economic feasibility of implementing a biogas/biomethane production unit in Abrantes region.

For this analysis it was necessary to have knowledge of the quantities of waste available for their use. A detailed description was made of Abrantes area. Through the realization of a prospective model it was possible to quantify over the years the quantities of biogas, biomethane and electricity produced through such quantities of waste available.

The model needs as input data only the quantity of available waste (household waste, forestry, agriculture, sludge from the treatment of waste waters and animals) as well as the hydraulic retention time that should be the appropriate for the quantities we introduced in the model. Having only these data the model makes a theoretical calculation of biogas, biomethane and electricity. There are at least five upgrading systems for the production of biomethane, the model shows the amounts of biomethane produced by these five options (chemical absortion, High Pressure Water scrubbing of Pressure Swing Adsorption, Cryogenic Separation and Membrane separation). The presentation of options represents a greater choice and decision.

The model that was previously mentioned was applied in 3 possible scenarios created for the region Abrantes:

Scenario 1 – “User-Pays” scenario

Scenario 2 – Waste separation incentive scenario

Scenario 3 – Technological development of transfer stations scenario

For each of scenario it was performed an economic projection. The in-depth study of the region, the material model created and the economic analysis can be a good decision support.

1) Introduction

Region Note

Medio Tejo and Pinhal Interior Sul (NUTSIII PT166 and P16C) 280000 inhabitants, 4,211km^2 and 3,610M€ of GDP, 5 cities, including the following municipalities: Abrantes, Alcanena, Constância, Entroncamento, Ferreira do Zêzere, Tomar, Torres Novas, Oleiros, Ourém, Proença-a-Nova, Sardoal, Sertã, Vila de Rei, Mação, e Vila Nova da Barquinha.

To consolidate a network of actors as platform for exchange and dissemination of experiences made in the context of implementation of new financial instruments to support investment in sustainable energy solutions, SMEs operating in the energy sustainability sector and sustainable policy development. The focus will be on the development and implementation of non-grant based financial support instruments, such as revolving funds, transregional funds with public counter guarantee and venture capital funds.

The region is committed with innovation, sustainability and growth as a comprehensive approach aimed at repositioning it among the European emergent and competitive regions, manage a better entrepreneurial environment and create more and better jobs. Regional economic clusters promotion aims to exploit opportunities emerging from recent economic landscape changes –recent industrial investments, high way, research facilities, higher education school and investments in tourism infrastructures.

Abrantes is a Portuguese city in the District of Santarém, in the subregion of the Médio Tejo region, in the central region, with about 19132 inhabitants. Belongs to the province of Ribatejo today but without any administrative-political meaning.

It is headquarters of a municipality with 714.73 km^2 of area and 39325 inhabitants (2011), subdivided into 19 parishes. The population density is of 56 inhabitants per km^2.

The municipality is bordered to the North by the municipalities of Vila de Rei, Mação and Sardoal, the East by Gavião, on the South by Ponte de Sor and the West by Chamusca, Constância, Vila Nova da Barquinha and Tomar.

The municipality includes a city, Abrantes, and a village, Tramagal.

Document Organization

Chapter 1 Introduction – Generalities of the document such as: Region Note, Abbreviations and Methodology.

Chapter 2 Overview of Municipal Waste Management, Biogas and Gas Supply - Framework of the current situation in Abrantes and Portugal about Municipal Waste Management, Biogas and Natural Gas supply.

Chapter 3 Available Feedstock - analysis of biomass available in Abrantes.

Chapter 4 Technical requirements for biowaste management system implementation - description of all organs that should be placed in a biogas production unit.

Chapter 5 Proposal of best solutions of biomethane use in Abrantes - description of what the best solutions that should be adopted in Abrantes.

Chapter 6 Legal requirements for biomethane use - description of the legal framework for the installation of a biogas production unit.

Chapter 7 Strategies for a successful biomethane production in Abrantes - detailed description of the scenarios created for Abrantes (material and economic projections).

Abbreviations

AD – Anaerobic Digestion

AEBIOM – European Biomass Association

APA – Portuguese Agency for Environment

CFL's – Compact Fluorescent Lamps

CHP – Combined Heat and Power

CO_2 – Carbon Dioxide

DGEG – Directorate-General for Energy and Geology

DM – Dry Matter

EA – Environment Statistics

EC – Evaluation Committees

EIA – Environmental Impact Assessment

ERSE – Energy Services Regulatory Authority

ETS – Emission Trading Scheme

EU – European Union

EV – Electric Vehicles

GHG – Greenhouse Gases

GPP – Green Public Purchase

GWh – GigaWatt hour

ICNF – Institute of Nature Conservation Forestry

INE – National Institute of Statistics

IP – Public Lighting

LED – Light Emitting Diode

LPG – Liquefied Petroleum Gas

LNG – Liquefied Natural Gas

LV PRE – Low Voltage

MSW – Municipal Solid Waste

MW – Mega Watt

Nm^3 – Normal cubic meter

NSNG – National System Natural Gas

OM – Organic Matter

ODM – Organic Dry Matter

PESGRI – Strategic Plane for Industrial Waste

PIP – Request Prior Information

PIS – Pinhal Interior Sul

PNAPRI – National Plan for Prevention of Industrial Waste

PSA – Pressure Swing Adsorption

RES – Renewable Energy Sources

RESP – Public Service Electric Network

RNTGN – National Network of Natural Gas Transportation

SEI – Independent Electricity System

SEP – Electricity System of Public Service

SENV – Non-Binding Electricity System

SNGN – Natural System of Natural Gas

SMA – Municipal Services of Abrantes

t – tones

UAA – Utilized Agricultural Area

UV – Ultraviolet Rays

WWTP – Waste Water Treatment Plant

Methodology

In this study it is intended to analyze the technical and economic feasibility of implementing a biogas production plant in the region of Abrantes.

Before analyzing the technical and economic feasibility it was necessary to perform a thorough study of the area. For this, we created three scenarios related with the concept of household waste separation within the population and together a study and analysis of various case studies presented by the project itself (UrbanBiogas).

For the study area was necessary to use data provided by INE (National Statistics Institute), through these it was possible to get the data input of the desired station and make a theoretical calculation of how much biogas and biomethane produced annually in the region.

To proceed to the theoretical calculations was necessary to create a process model (explained in the annex). This model can then be applied to the three aforementioned scenarios. The application of this process model aims the perception of the technical feasibility of each scenario itself.

The economic model was also designed so that you can understand if the implementation of biogas production unit is viable or not, taking into account parameters of the process model.

The case-studies are existing biogas production units in Europe, so the analysis of case-studies became interesting because it helps in the evaluation of the values found for each scenario.

2) Overview of Municipal Waste Management, Biogas and Gas Supply

Municipal waste generation in Portugal

Each Portuguese generated between 2004-2009 in the mainland, about 470 kg of municipal waste per year, putting into recycling 46 kg. In 2008 the recycling rate in the mainland was 12% however in UE its value reached 17%. (INE, 2010)

The waste recycling has been the management operation that in the period under review has bigger grown on average. The quantities of waste collected selectively multimateriais showed an average growth rate of about 15% per year between 2004 and 2009, well above that demonstrated for the total waste generated. (INE, 2010)

Paper and cardboard are the main material placed for recycling.

The recovery of waste management entities promoted by specific flows in the period totaled about 6 million toe, registering an average annual growth over the past four years of 18%. The main materials were recycled packaging and vehicles from the end of life. (INE, 2010)

The household waste, which were always an issue of great concern for the implications that, when improperly collected or deposited, have public health and the environment, deserve a more detailed treatment of this prominence. In 2009 each Portuguese in mainland generated about 511 kg of waste. The collection represented about 13% of the total waste, and was equivalent to 67kg/inhab.year, about 57% of the EU average. The main material is selectively collected were paper and cardboard, although the selective collection of packaging has more than quadrupled between 2004 and 2009. (INE, 2010)

The amount of waste collected in the period grew at an annual rate of 3%, registering in 2009 a daily production exceeding 14 thousand toe. On average over the past six years, 10% of waste was collected separately. The undifferentiated collection's main destination is landfilling (65%) followed by energy recovery (18%) and organic recovery (7%) (INE, 2010).

The total production of Urban Waste in Portugal, in 2010, was approximately 5.239 million toe, and there has been a decrease of about 0.03% compared to 2009. In regard to the quantity of waste produced per capita, it is found that the annual capitation in 2010 was 512 kg/cap.year, corresponding to a daily production of 1.4 kg urban waste per capita. (INE, 2010)

In the table below it is possible to see the amount of waste by sector in Portugal (glass, paper and cardboard, packaging, batteries and biodegradable).

Table 1 - Total amount of urban waste and waste composition in Portugal. (Source: INE, 2010)

Municipal waste collected per capita (kg/cap.)	Selectively collected municipal waste (t) by type of waste collected separately; Annual					
	Type of waste collected separately					
	Total	Glass	Paper and Cardboard	Packaging	Batteries	Biodegradable
Kg/cap	t	t	t	t	t	t
512	523950	182541	182981	77840	169	80420

In Portugal recycling and organic recovery rates are progressing favorably, approaching gradually EU average (16.4% and 9.8%, respectively).

10,1% of the total waste produced were send for recycling, 7,6% were send to organic valorization, 18% were send to energetic valorization and 64,3% were send to landfill. This scenario must change, we should send to landfill less percentage of waste and we should recycle more. Portugal is doing an effort to change and to get closer of UE averages.

Municipal waste management system in Portugal

Organizational model of waste management sector in Portugal is historically associated with municipalism by its proximity and association with health conditions and safeguard public health. However, the Community requirements and the need for large investments in infrastructure of reasonable size such as landfills, organic recovery stations and/or energy recovery centers, imposed the development of an organizational model that exceeded the boundaries of municipalities. There were well-municipal systems consisting of two or more municipalities and companies managed by majority public-owned utilities. (INE, 2010)

Currently, we are witnessing a new trend which involves the integration and merger of some of these systems that gaining size, acquires new economies of scale, looking for profitable means and equipment available, as well as ensuring sustainability for the future and positioning to ensure support financial community. (INE, 2010)

Waste management is currently carried out by 23 waste management systems, in Portugal, 12 municipalities associations and 11 municipal systems. The distribution systems are as follows:

- Northern Region: 8 systems, including 5 multimunicipal systems;

- Central Region: 5 systems, which 3 are multimunicipal systems;

- Region of Lisbon and Tagus Valley: 5 systems, including 2 multimunicipal systems;

- Region Alentejo: 5 Systems, including 1 multimunicipal system;

- Algarve Region: 1 System which is multimunicipal.

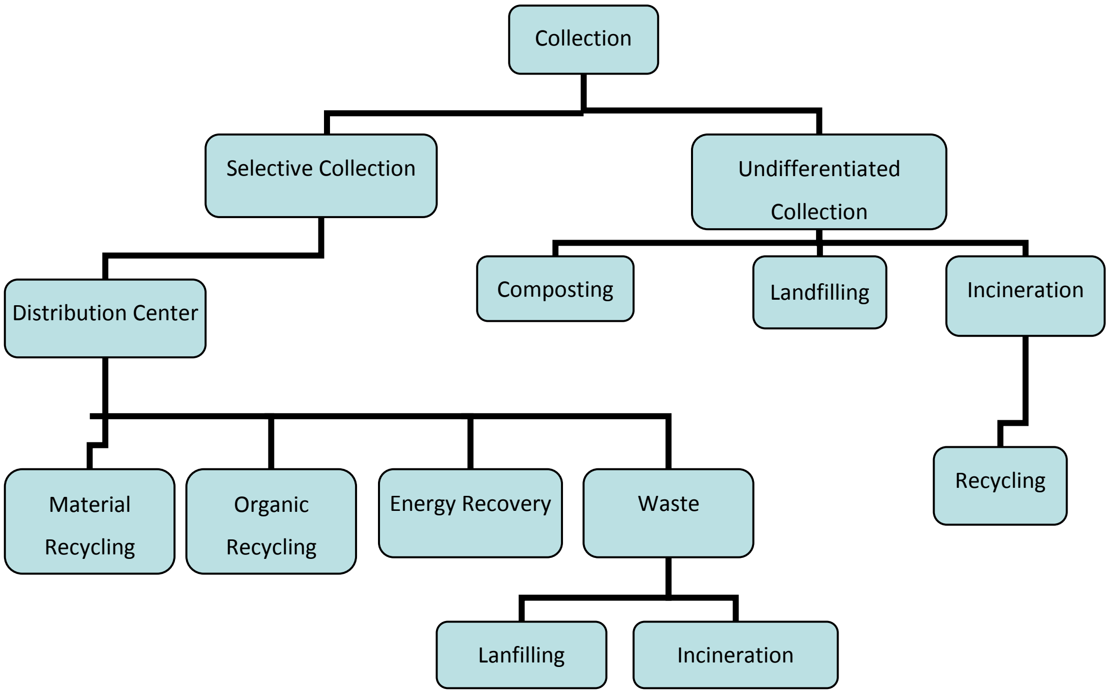

Figure 1 - Waste flow in Portugal. (Source: INE, 2010)

Currently the main challenge for the sector is taking steps to reduce waste and to increase levels of recycling and recovery. The economic advantages are evident, since the deviation of biodegradable and landfilling recyclable waste, permits to prolong its lifetime and simultaneously re-use products, like organic compounds which are applicable in agriculture substituting, in part, chemical fertilizers (INE, 2010).

Municipal waste management system in Abrantes

Municipal waste management system in Médio Tejo and Pinhal Interior Sul is responsible for collection, sorting, recovery and treatment of solid waste in 25 municipalities and its main mission is the environment preservation where it operates and improves the service provided to people in Urban Solid waste management.

Consumption tends to increase. Waste production and waste quantities are nowadays one of the problems that modern societies are struggling and these environmental pressures require careful attention.

The solution to these problems is thus the adoption of responsible behavior from people with the support and encouragement of their representatives, Local Authorities and Governments. In recent years has been traversed a path whose results were rewarding, and, continuing its policy of improving continues to work knowing that there is still much to do. Public contribution and encouragement is essential to proceed, facing the municipal solid waste as a raw material with economic value and contribute to sustainable development of our region, which is essential for improving the quality of life of all of us.

It was assumed from the beginning of its constitution an integrated treatment of all waste. Over the years, this goal has become a reality and the system has extended its range of intervention, assuming today as a system of treatment and recovery of waste truly integrated.

Total natural gas supply in Portugal

The decision of introducing natural gas in Portugal aimed to give the country access to a new source of energy competitive, convenient and clean. Simultaneously it was created a structural project of the Portuguese economy and diversifier of hydrocarbons supply, having created the National System of Natural Gas.

This system can be divided into six main activities:

- Reception,

- Storage and regasification of LNG (Liquefied Natural Gas),

- Natural gas underground storage,

- Natural gas transportation,

- Natural gas distribution,

- Marketing of natural gas,

- Operation of the natural gas market.

The legal activities of import, storage and handling, transportation and distribution of natural gas has the nature of public service, to be provided by companies geared to that end, by allocating public service concessions, which are of two types:

- Import, storage and handling of liquefied natural gas and its transportation.

- Regional distribution of natural gas

Portugal does not have, on its territory, their own reserves of natural gas, so all gas stored and marketed in Portugal comes from imports from Algeria and more recently from Nigeria. According to the Decree-Law 30/2006 of 15 February, the activities of reception, storage and regasification of LNG, underground storage and transport, comprising the overall technical management system (SNGN), are carried on under concession of public service.

The receipt, storage, transportation, distribution, marketing and operation of the natural gas market now are made by private companies subject to regulations by the Energy Services Regulatory Authority (ERSE).

Table 2 - Companies involved in acquisition, reception, storage, transport, distribution and commercialization of natural gas in Portugal. (Source: Portugal Information, 2008)

<table>
<tr><th>Acquisition /Import</th><th>Reception, Storage and Regasification</th><th>Underground Storage</th><th>Transport</th><th>Distribution</th><th>Commercialization</th></tr>
<tr><td rowspan="11">GALP, natural gas, SA</td><td rowspan="11">REN Atlântico, SA</td><td rowspan="11">REN Storage, SA
Transgás Storage, SA</td><td rowspan="11">REN Pipelines, SA</td><td rowspan="9">Energy Group GALP</td><td>Beiragás, SA – natural gas company of Borders</td></tr>
<tr><td>Dianagás, SA – natural gas distributing company of Évora</td></tr>
<tr><td>Ouriense, SA – natural gas distributing company of Douro</td></tr>
<tr><td>Medigás, SA – natural gas distributing company of Algarve</td></tr>
<tr><td>Paxgás, SA – natural gas distributing company of Beja</td></tr>
<tr><td>Tagusgás, SA – natural gas distributing company of Vale do Tejo</td></tr>
<tr><td>Lisboagás, SA – natural gas distributing company of Lisboa</td></tr>
<tr><td>Lusitaniagás, SA – gas company of central region</td></tr>
<tr><td>Setgás, SA – production and distribution of natural gas</td></tr>
<tr><td>Portgás, SA – production and distribution of natural gas</td><td>Portgás Universal Services, SA</td></tr>
<tr><td colspan="2">Dourogás, SA – production and distribution of natural gas</td></tr>
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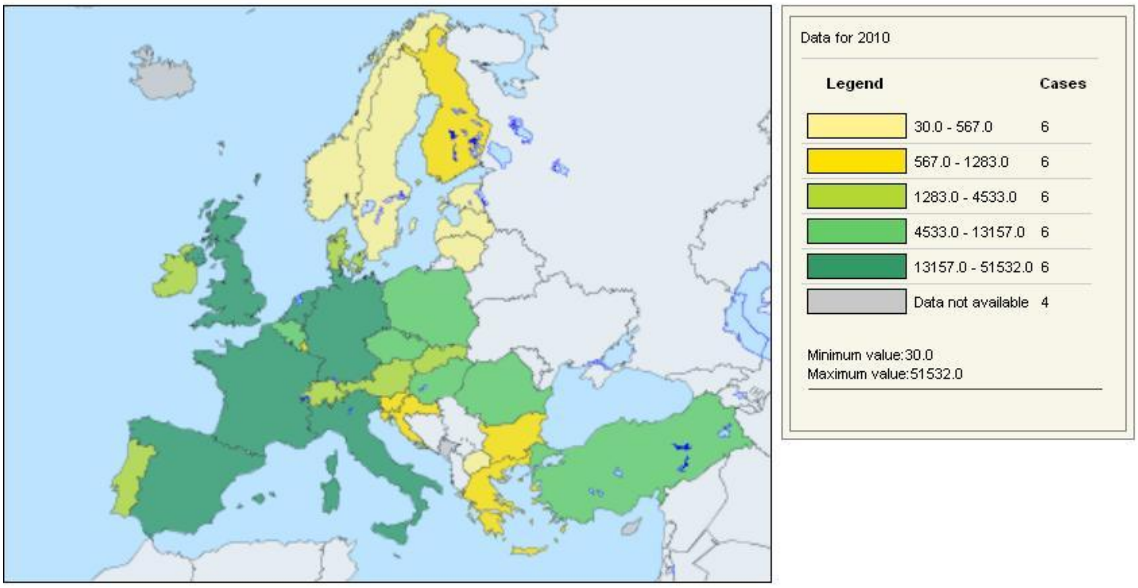

Figure 2 - Final energy consumption of natural gas in Europe. 1 000 toe of oil equivalent. (Source: Eurostat, 2010)

Making a comparison with other European countries, we can say that Portugal is part of the mid-table of the consumers of natural gas, corresponding to green light class (1283 - 4533 thousand toe of oil equivalent).

In 2011, primary energy consumption in Portugal was 22 237 ktoe, having gradually decreased about 12% between 2007 and 2011. (INE, 2012)

Regarding the structure of primary consumption in 2011, oil accounted for 49% of primary energy consumed followed by natural gas well represented by 20% of the primary energy consumed (INE, 2012).

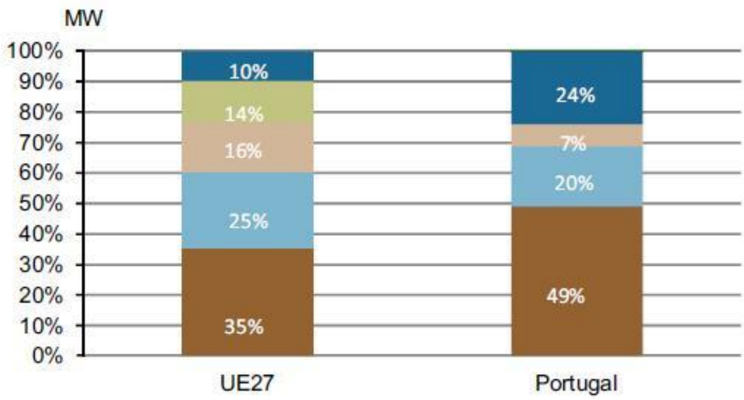

Figure 3 - Primary energy consumption by energy source - EU 27 and Portugal. (Source: INE, 2010)

Making an analysis of the graph shown above [Figure 3], we can see that Portugal compared to the EU27 countries have higher consumption of oil (49%). For the natural gas consumption is observed that is below the average consumption of the European countries (20%), the use of coal represents 7% of primary energy consumption and ultimately renewable energy (24%). Renewable energy represents the higher value as compared with the rest of Europe.

Table 3 - Natural gas consumption by geographic location (Source: Directorate-General for Energy and Geology (DGEG))

Geographical Location	Natural gas consumption 10^3(Nm^3) in 2009	Natural gas consumption 10^3 (Nm^3) in 2010	Natural gas consumption 10^3 (Nm^3) in 2011
Portugal	4 465 752	4 858 459	4 921 856

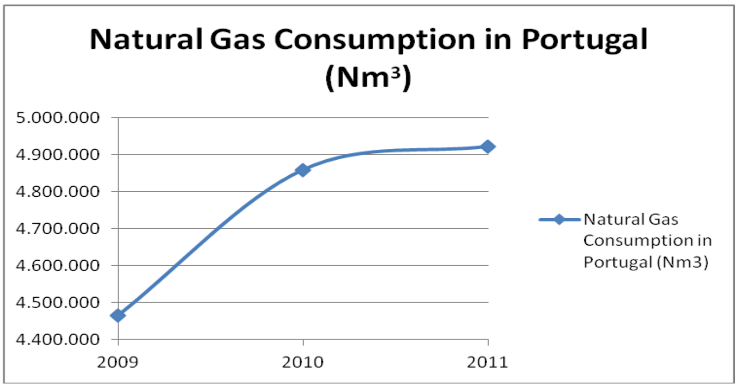

Figure 4 - Natural gas consumption in Portugal (10^3 Nm^3). (Source: INE, 2011)

Making an analysis of the table and the graph shown above [Figure 4] it can be seen that the consumption of natural gas in Portugal from 2009 to 2011 has clearly been increasing. One reason may be related to the fact that Portugal in recent years is more concerned with issues related to the environment in terms of CO_2 emissions. This justifies the descent of coal consumption for example. The consumption has not decreased so it was necessary to fetch the energy sources such as natural gas.

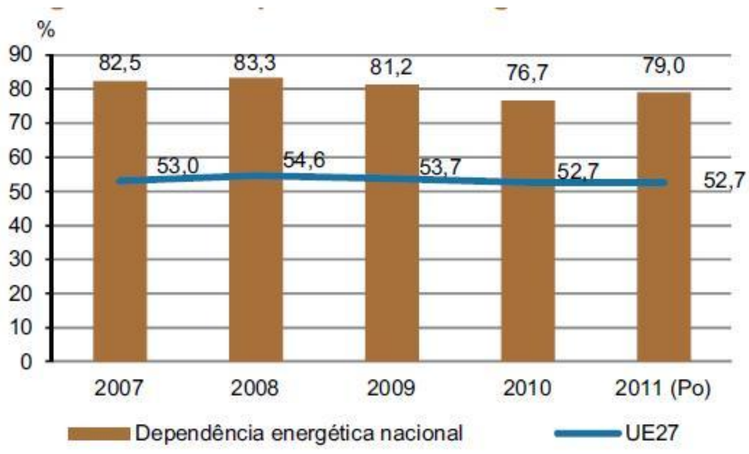

Figure 5 - National energy dependence comparing with EU27. (Source: INE, 2011)

In 2011, about 79% (bars shown in brown) of the primary energy consumed in Portugal was imported, which translates the high energy dependence of our country to the outside and that is well above the EU27 average, which in 2010 was 53%.

Final Natural Gas Consumption in Portugal and Abrantes

The industrial sector is the sector that consumes greater amount of natural gas followed by the domestic sector. Next will be an analysis of the natural gas consumption in the industrial sector by region.

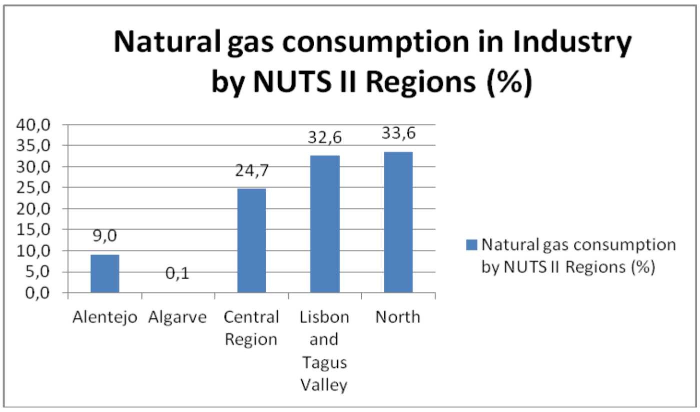

Figure 6 - Natural gas consumption in industry by NUTS II Regions (%) in 2010. (Source: DGEG, 2011)

The central region represents 24.7% of the total natural gas consumed in the industrial sector as can be seen by the graph shown above [Figure 6].

Table 4 - Natural gas consumption in Abrantes (10^3 Nm^3). (Source: DGEG, 2012)

Abrantes	2008	2009	2010	2011
Consumption (10^3 Nm^3)	896	1.271	107.590	278.346

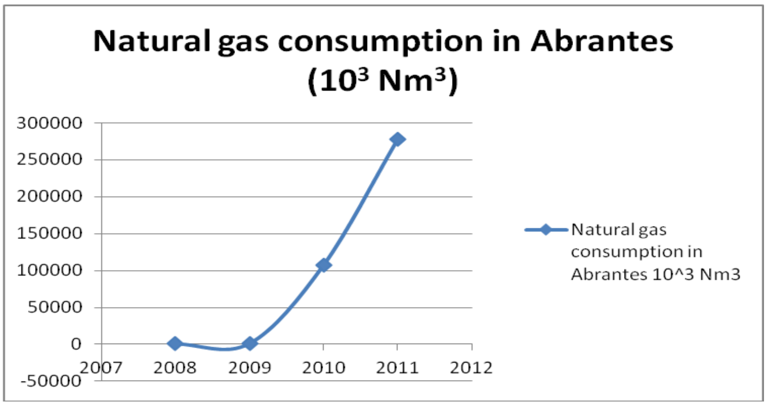

Figure 7 - Natural gas consumption in Abrantes (103 Nm3). (Source: DGEG, 2012)

Abrantes assists an exponential growth of its consumption of natural gas, as we can see in the chart shown above [Figure 7]. This exponential growth may be linked to the fact that the supply of gas in houses or industrial plants to be changing over the years. A few years ago they used up gas bottles for water heating and stoves, but today has changed this paradigm. Almost everyone has already natural gas in their homes and this is an advantage because it becomes less dangerous in housing gas supply.

In Abrantes the company that makes the supply of natural gas is Tagusgás.

Natural Gas Transmission and Distribution

In Portugal

The activity of transporting natural gas is developed in accordance with a contract of exclusive concession granted by the Portuguese government to the system operator, REN Pipelines (Energy National Network). The delivery of the National Transport Natural Gas Pipelines to REN occurred following the decision in order to separate the business of marketing of natural gas transportation business. The terms of the concession agreement were established by Resolution of the Council of Ministers no. 105/2006 of 3 August, having been awarded to REN Pipelines in September 2006. (Source: edp.pt)

The Grid Access Regulations, Infrastructure and Interconnections establish the conditions and obligations access RNTGN (national network of natural gas transmission), which must be met by regulated companies operating in the natural gas sector as well as consumers eligible. These regulations also set out the conditions under which the operator may refuse access to networks, interconnections and storage media. (Source: edp.pt)

The activity distribution of natural gas through concessions or licenses granted by the Portuguese Government and is the distribution of natural gas through the pipelines of medium and low-pressure. The entities that operated a network of natural gas distribution on the date of ratification of Decree-Law 30/2006 will continue to operate the distribution network of natural gas as dealers or entities authorized under exclusive territorial public service in accordance with Article 66 of Decree-Law 30/2006.

The concessionaires shall ensure that relevant third parties access to the distribution system for natural gas by paying published tariffs applicable to all eligible customers, including retailers, since they must be applied objectively and without discrimination between system users.

The distribution network consists of pipelines medium and low-pressure and serves the residential, commercial and small and medium industries. The natural gas distribution activity is performed based on a public service concession. Marketing activities previously undertaken by distributors migrated to the last resort, companies wholly owned by concessionaires and distribution network responsible for the supply of natural gas to consumers and not eligible consumers who have decided to continue to be supplied at regulated rates. The rates of the last resort are defined and published by the sector regulator, ERSE.

In Médio Tejo

The company that serves the Médio Tejo is Tagusgás as can be seen in the image that is below.

Figure 8 - Influence areas of distribution operators in Portugal. (Source: Investment sector analysis of natural gas, ERSE 2012)

Tagusgás ensures the distribution and transportation of natural gas to 38 municipalities in the region of the Tagus Valley, and serves approximately 25,408 customers and has a network of 733 km.

Each natural gas distributor has an exclusive concession long time for their respective area of operation, with the distribution network to be connected to the high pressure.

The UADs (Automous Units Gas Distribution) were created in the areas where the construction of the high pressure network was not economically viable. Thus Tagusgás is considered one of the distribution units. The UADs are supplied by tankers from the terminal LNG (Liquefied Natural Gas) and have regional distribution networks to supply their customers.

(Source: Distribution - Galp Energia)

Public Transport in Abrantes

The Rodoviária Tejo is the company responsible for public transport in the region of Abrantes and vicinity. It's coverage area includes the following Counties: Abrantes, Chamusca, Tomar, Torres Novas, Alcobaça, Fátima, Figueira da Foz, Leiria, Nazaré, Ourém, Almeirim, Bombarral, Caldas da Rainha, Lourinhã, Peniche, Rio Maior, Santarém, Azambuja, Alcoentre, Cartaxo and Marinha Grande. It has a fleet of 384 buses powered by fossil fuels, travelling per year about 25.1 million km.

Guests have at their disposal a wide variety of buses (more than 100) urban, interurban and fast.

Figure 9 - Area covered by the public transport company Rodoviária Tejo. (Source: rodotejo.pt)

Natural gas in transport – Portugal and Abrantes

Natural gas is a cleaner fuel alternative because:

- The exhaust emissions from natural gas vehicles are much lower than those of gasoline-powered vehicles;

- Emissions of carbon dioxide from natural gas vehicles are about 20% lower

- Emissions of hydrocarbons nonmetallic are 80% lower

- The nitrogen oxides are 40% lower;

- The natural gas vehicles emit significantly lower amounts of greenhouse gases and toxins compared to gasoline vehicles.

Besides the environmental benefits associated with this type of fuel also have economic benefits:

- In a one liter equivalent basis, natural gas costs about 70% less than diesel

- Reduced maintenance requirements as regards the oil change

In Portugal there are already about 334 buses, 38 trucks and 46 cars all powered by natural gas for a total of 418 natural gas vehicles (Source: Portuguese Association of Natural Gas Vehicles Moved, 2011).

In the following table are presented the data on the consumption of fuels in road transport in Portugal.

Table 5 - Fuel consumption in road transport in Portugal (tep). (Source: DGEG, 2012)

Type of fuel	2010	2011
LPG	31.801	28.970
Gasoline	1.450.134	1.318.959
Oil	4.654.280	4.384.332
Lubricants	40.686	36.617
Natural gas	12.581	13.000
Biodiesel	3.965	4.097

We highlight the decreases in consumption of petrol (-9%), LPG (-8.9%) and diesel (-5.8%), unlike natural gas consumption and consumption of biodiesel, which recorded (both) increases of 3.3%.

Since no publicly available data on the consumption of natural gas for transport by regions, for natural gas consumption in Abrantes must be extrapolated taking into account the national values.

The resident population in Portugal in 2011 was 10,562,178 inhabitants and associated a consumption of 13,000 toe of natural gas. That same year the resident population was 39,325 inhabitants in Abrantes. Making the extrapolation, it is estimated that in Abrantes natural gas consumption in 2011 was around 48 toe of natural gas.

Biogas production and consumption in Portugal and Abrantes

In the area of "Resource Management" it can be included any programming activities, construction and installation of systems, or management services for production, collection and/or transmission of energy from renewable sources, as well as to reduce the consumption of heat and power (reducing the use of steam) and/or minimize the loss of heat and power (CHP).

Renewable energy comes from natural processes that are replenished constantly. There are several forms of renewable energy source with direct or indirect sunlight or the heat generated in the deeper layers of the Earth. Includes energy generated from the sun, wind, tides, waves, geothermal, biogas, biodiesel and other sources.

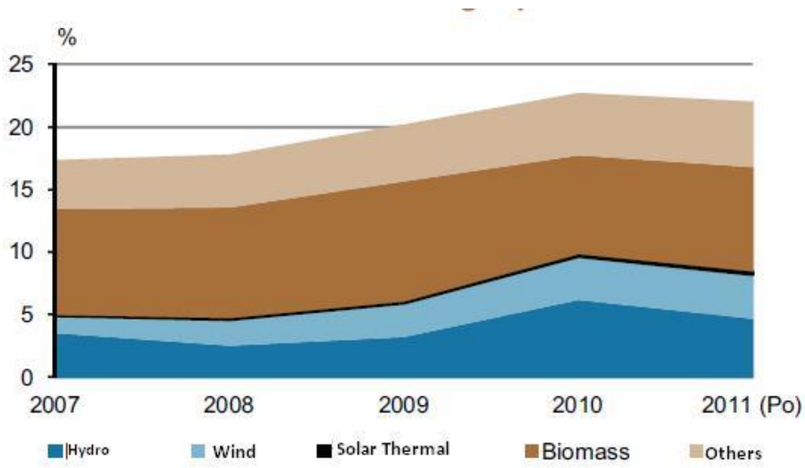

Figure 10 - Proportion of renewables in primary energy consumption. (Source: INE, 2011)

The contribution of renewables to primary energy consumption was 22% in 2011, a decrease of 3% compared to 2010 [Figure 10]. This decrease doesn't represent a slowdown betting on renewable energy sources, but is a reflection of the high levels of precipitation recorded in 2010, which increased the contribution of hydropower to the total renewable energy consumption in the primary source energy this year. As 2011 has not produced the same levels of precipitation, the contribution of renewables decreased, however being higher than in 2009 (20%). Biomass (wood and forest residues, biogas and biodiesel) remains the largest source of energy consumption contribution to the primary consumption (8%). (Source: INE, 2011)

Table 6 - Locations where biomass is transformed into electricity and biogas is used. (Source: www.energiasrenovaveis.com)

Projects	Total Capacity [MW]	Transformation of biomass into electricity	Biogas utilization
Power Station of Mortágua	9	Yes	No
Central Processing Municipal Solid Waste of São João da Talha	50	Yes	No
RÓDÃO POWER II	14	Yes	No
Lipor II - Gaia	26	Yes	No
CENTROLIVA – Vila Velha de Rodão	4	-	-
Rodão Power I – Vila Velha de Rodão	30	Yes	No
Biomass Thermal Power Plant of Terras de Santa Maria	10,4	Yes	No
System Energy Biogas Use of Palmela	1,5	Yes	Yes
Trajouce Landfill	0,1	Yes	Yes
Mato da Cruz Landfill	0,3	Yes	Yes
Leiria Landfill	0,9	Yes	Yes
Colares Station of Wastewater Treatment	0,06	Yes	Yes
Sermonde Lanfill	2,11	Yes	Yes
Central Processing Municipal Solid Waste of Planalto Beirão	3	Yes	Yes
Penafiel Landfill	1	Yes	Yes
Vale do Lima e Baixo Cávado Landfill	0,6	Yes	Yes
Valorisation of Biogas Cogeneration in the Landfill of Abrantes	0,15	Yes	Yes
Livestock company of	0,05	No	Yes

Torrinha			
Station of Wastewater Treatment of Coimbra	0,14	Yes	Yes
Barlavento Landfill	0,9	Yes	Yes
Cruz Valente - Guarda	0,3	Yes	Yes
Sopecuária – Batalha, Leiria	0,06	Yes	Yes
Biocentro – Batalha, Leiria	0,05	Yes	Yes
Station of Wastewater Treatment of Leiria	0,17	Yes	Yes
Station of Wastewater Treatment of Beirolas	0,4	Yes	Yes
Station of Wastewater Treatment of Frielas	1,8	Yes	Yes
Station of Wastewater Treatment of Parada	0,5	Yes	Yes
Livestock company of Golegã, Santarém	0,05	Yes	Yes
ADSAICA - Livestock company of Rio Maior	0,13	Yes	Yes
Center for Integrated Recovery and Treatment of Solid Waste of Seixal	2,3	Yes	Yes
Livestock company Bernardino de Almeida Costa & Filhos	0,06	Yes	No

Table 7 - Locations where biogas is produced. (Source: APA, 2011)

Location	Biogas Production Capacity	Destination
Codessoso Landfill	5,740 GWh	Injection into the national energy grid Use at the facility
Central Biogas Energy Recovery - VALORMINHO	1 MWh	
RESULIMA – Viana do Castelo Landfill	2 MWh	
AMBISOUSA – Penafiel Landfill	4,7 MWh	
SULDOURO – Sermonde Landfill	4,5 MWh	
Resíduos do Nordeste, EIM – Urjais Landfill	6,8 MWh	
VALORIS – Leiria Landfill	0,9 MWh	
RESINORTE	0,8 MWh	
RESIESTRELA	0,8 MWh	

ERSUC	2,9 MWh	
VALORSUL	2,7 MWh	
AMARSUL	4,1 MWh	
VALNOR	0,8 MWh	
ALGAR	2,9 MWh	
Ecolezíria – Raposa Landfill	1 MWh	

3) Available Feedstock

Municipal solid waste, organic in Abrantes and vicinity

Climatic conditions and orographical of Portugal, associated to cultural practices misfits, led to an impoverishment of the national agricultural soils in organic matter (OM) particularly in the central and southern parts of the country. It is thus essential to contradict the trend towards depletion of this important component of soil, using among other measures like using of organic waste which characteristics confer agricultural interest. Moreover, the huge amount of organic waste that is being generated, some of which may exhibit relatively high levels of heavy metals, organic micropollutants and pathogens have been a major concern not only in the official bodies responsible for the management of these wastes, but also institutions involved in environmental protection and in populations awakened to this issue. (Source: Organic Waste Management)

The organic wastes contain, when they are subjected to effective treatment, pathogens and parasites and the quantity and diversity depends on the source and nature of these residues. The livestock waste, sludge from treatment plants and waste from septic tanks contain certainly high concentrations of pathogens of fecal origin and nature of residues in plant pathogenic microorganisms are obviously affecting the plants. In MSW, it possible to find a presence of a wide range of pathogens, since they integrate waste from various backgrounds. In the table below provides an indication of some of the organisms that are able to affect the animals and/or public health, in cases of contact or exposure, or conveyed by organic waste for soil and water resources. (Source: Organic Waste Management)

Table 8 - Organisms that are able to affect animals and/or public health in case of contact or exposure. (Source: Organic Waste Management)

Taxon	Pathogenic organism	Diseases caused
Bacteria	*Vibrio cholerae*	Cholera
	Salmonella sp.	Salmonellosis
	Salmonella tiphy	Typhoid
	Dtaphylococcus aureus	Diarrhea
	Brucella abortus	Brucellosis
	Mycobacterium tuberculosis	Tuberculosis
	Shigella dysenteriae	Dysentery
	Bacillus antrhacis	Anthrax
	Clostridium tetani	Tetanus
	Escherichia coli	Colibacilosis
	Listeria monocytogenes	Listeriosis
Protozoa	*Entamoeba hystolytica*	Dysentery
	Giarda lamblia	Giardiasis
	Eimeria sp	Coccidiosis
	Toxoplasma sp.	Toxoplasmosis
Helminths	*Trichinella spiralis*	Trichinosis
Nematodes	*Enterobius vermiculares*	Oxyuriasis
	Ascaris lumbricoides	Ascariasis
	Tricuris trichiura	*Tricocefalosis*
Tapeworms	*Taenia solium, T. saginata*	Tapeworm
	Echinococus granuloses	Hydatid cyst
Trematode	*Schistosoma mansoni*	Schistosomiasis
Fungi	*Histoplasma capsulatuns*	Histoplasmosis
	Cryptococcus neoformans	Cryptococcosis
	Sporothrix schenki	Sporotrichosis
	Candida albicans	Candidiasis
	Aspergillus funigatus	Aspergillosis
Virus	Various groups and strains	Aseptic meningitis
		Acute myocarditis
		Polio
		Pneumonia
		African swine fever
		Aujeszky's disease
		New Castle Disease

In recent years, we have seen the population concerning about waste separation due publicity and diffusion that it has been doing over the years.

In the table below [Table 9Table 9] are the figures for municipal waste collected by type of destination.

Table 9 - Municipal waste collected by type of destination in Portugal, Médio Tejo and Abrantes. Reference period of data: 2011. (Source: INE, 2012)

Geographic Location	Disposal of Waste				
	Total (t)	Landfill (t)	Energy Recovery (t)	Organic Recovery (t)	Recycling (t)
Portugal	51.386.465	3.020.857	1.091.250	433.219	593.318
Continent	4.879.940	2.901.418	972.858	431.949	573.715
Médio Tejo	90.882	73.676	0	7.336	9.869
Abrantes	16.618	8.336	0	5.203	3.080

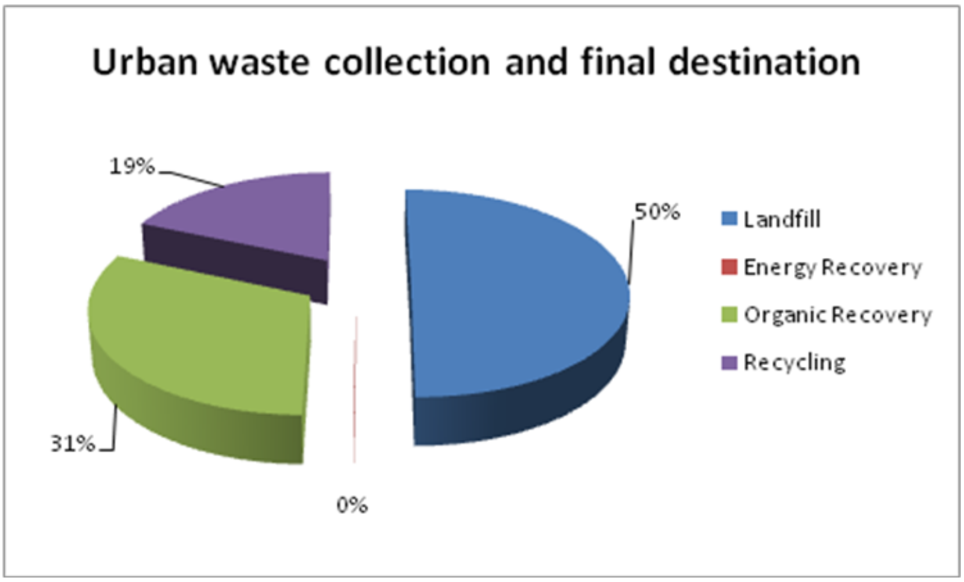

Figure 11 - Urban waste collection and final destination (%). (Source: INE, 2011)

As can be seen from the graph shown above [Figure 11], 50% of the collected waste which is going to landfill does not suffer any treatment before.

According to statistics for the year 2011, it was not made the collection of organic waste in the Médio Tejo nor Abrantes (Source: INE, 2012).

The total production of urban waste in Abrantes in 2010 was 17.747 t. In regard to the quantity of waste produced per capita, it is found that the annual capitation in 2010 was 450Kg/cap.

In the table below it is possible to see the amount of waste (t) by sector in Abrantes (glass, paper and cardboard, packaging, batteries and biodegradable).

Table 10 - Total amount of urban waste and waste composition in Abrantes in 2010. (Source: INE, 2011)

	Municipal waste collected per capita (kg / cap.) By geographical location; Annual	**Selectively collected municipal waste (t) by Geographic localization and Type of waste collected separately; Annual**					
		Type of waste collected separately					
		Total	Glass	Paper and Card	Packaging	Batteries	Biodegradable
	Kg/cap	t	t	t	t	t	t
Abrantes	450	1877.966	547.036	895.242	434.396	1.292	0

19,3% of the total waste produced were send for recycling, 35,7% were send to organic valorization, 0% were send to energetic valorization and 45% were send to landfill.

Industrial organic residues in Abrantes and vicinity

Industrial ecology is an emerging concept still considered the basis of which, a given industrial system is not seen in isolation but in line with other systems surrounding it, seeking to optimize the total materials cycle from virgin material or original , the transformed material, product, and waste product to its final destination. Factors to be optimized include resources, energy and capital. (Source: PNAPRI)

The goal of industrial ecology is to interpret and adapt what we understand the natural system, applying it to the design of man-made system, so as to achieve a pattern of industrialization that in addition to be more efficient, it is inherently more adjusted the tolerances and characteristics of the natural system. (Source: PNAPRI)

The emphasis is on technologies that "work" with and not against natural systems. (Source: PNAPRI)

The national situation in terms of industrial waste is still insufficiently known. Studies conducted by TECNINVEST under the PESGRI and INE achieve values that reflect this uncertainty and values have not broken down by industrial sector (Source: PNAPRI).

For the characterization of industrial sectors in its various forms resorted to, firstly, the existing information and, secondly, undertook a set of actions aimed at obtaining additional information from the companies through a survey (post) and visits. The sources of data collection were briefly as follows:

- Maps waste register

- Documentation attached Contracts for Environmental Adaptation

- Studies of Tecninvest

- Studies offered by some Sectoral Associations

- Statistics INE and the Ministry of Labour and Solidarity

- Business survey

- Visits to companies

Table 11 - Waste generation by type of industry in Portugal. (Source: PNAPRI, 2001)

Industry Type	Total Waste (t)	Total Organic Waste (t)
Tanning sector	41.000	28.000
Textile sector	54.453	18.454
Wood and furniture sector	630.592	608.539
Inks, varnishes and glues sector	29.078	840 (WWTP sludge)
Chemical sector	49.835 70.276	49.835
Footwear sector	179.076	2
Manufacturing sector of rubber	1.385	561
Metallurgy and metalworking sector	-	9.171 (WWTP sludge)

All sectors listed above cover all industrial activities across the country.

Biomass Exportation

The difficulty that some companies have in accessing information causes conceptual obstacles to pollution prevention. There are many landfills which do not accept waste from industry and this means that there is an increase in export of them presenting itself in the following figure relative percentages for export exported material. (EA, 2011)

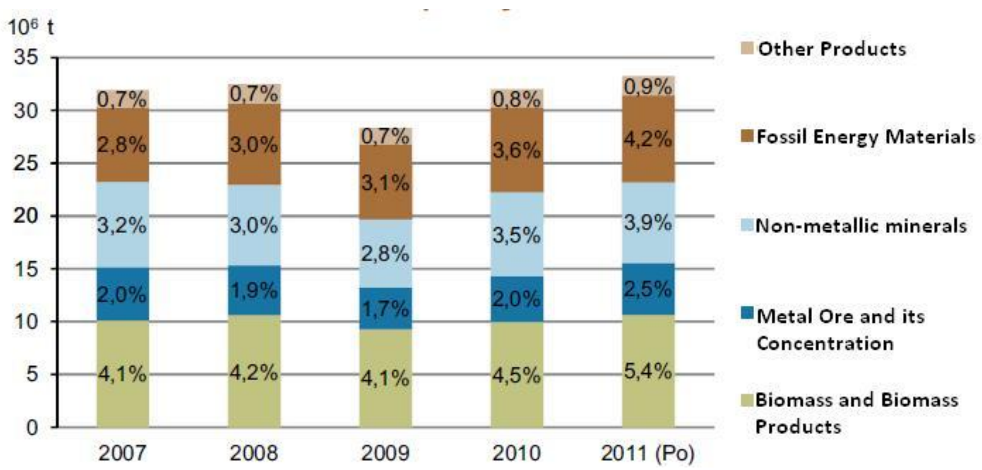

Figure 12 - Total material exportation. (Source: EA 2011, INE)

With regard to exports of materials, biomass is the most important category (mainly forest products and the products of the pulp of paper, paperboard), representing 32% of both the total volume of exports in 2011 both the quantity exported in the five years under review. In 2011 the volume of exports peaked with 33.3 million toe, growing at an annual rate of 4%.

Agricultural, Forestry energy crops and Sewage Sluge from WWTP in vicinity of Abrantes

Agriculture

Considering the period of analysis from 1999 to 2009, for agriculture it is clear that:

One in four farms stopped their activity, but the surface of the farms still occupies half of the national territory;

The small farms continue to dominate, but 2/3 of the Utilized Agricultural Area (UAA) is now managed by farms larger than 50 hectares of utilized agricultural area;

The number of agricultural societies (farms) grew 23% and now operates 27% of utilized agricultural area;

The agricultural landscape has changed to more extensive production systems, with permanent pasture occupying almost half of the utilized agricultural area;

The farms have on average 15,200€ Value of Total Production Standard (Source: INE, Agricultural Census 2009).

Table 12 - Surface area (ha), Production (t) and Produtivity (kg/ha) of major crops in Center Region. (Source: Agricultural Census 2009, INE)

Geographic Location	Cultivated Crop	2011		
		Surface area (ha)	Production (t)	Productivity (kg/ha)
Center	Cereal grains	55.072	297.021	5.393
	Major dried leguminous vegetables	2.018	1.219	604
	Potato	9.121	135.877	14.898
	Major crops for Industry	469	29.389	62.711
	horticultural crops	-	-	-
	Major forage crops	62.551	-	-
	Major fresh fruits	23.494	414.057	17.624
	Small fruit berry	-	-	-
	Major subtropical fruits	356	5.473	15.360
	Citrus	1.309	12.097	9.240
	Major nuts	5.478	4.343	793
	Vineyard	51.170	221.322	4.325
	Olive grove	-	86.170	1.063
	Total	211.038		

By analyzing the table presented above [Table 12], it can be seen that in 2011 the cereal grain uses larger areas comparing with other cultures, followed by vines.

Regarding fresh fruits production represent the largest share in the sector, followed by the vines (grapes). Finally, the sector that has higher productivity is major crops for industry. In these very intensive agriculture is not surprising being this high value on their productivity.

Table 13 - Utilized agricultural area (ha) in Center Region, Médio Tejo and Abrantes. (Source: Agricultural Census 2009, INE)

Geographic Location	Levels of Expertise		
	Specialized farms - crop production (ha)	Mixed farms (animals and crop production) (ha)	Total (ha)
Center	116.059	100.252	462.467
Médio Tejo	21.574	10.814	43.332
Abrantes	4.592	3.167	12.915

For the Médio Tejo is only possible to estimate how much waste from agriculture taking into account the table above [Table 13]. Whereas the amount of humus produced annually in crop production is 12000 kg/ha (Source: Organic Waste Management), so we have a total annual production of 25,889 toe of humus in a culture of production in the Médio Tejo.

Potencial of the livestock sector

In Portugal, one of the sectors that leads to huge quantities of waste suitable for anaerobic digestion is the agricultural sector, this activity result large quantities of organic matter ready to be put into a digester, producing biogas.

Will then made a brief analysis of what the potential of the agricultural sector in Portugal and in the Center.

Table 14 - Effective number of animals in the agricultural sector. (Source: Agricultural Census 2009, INE)

Geographic Location	Bovine (no.)	Swine (no.)	Ovine (no.)	Caprine (no.)	Horses (no.)	Rabbits (no.)
Portugal	1.519.000	1.985.000	2.170.000	413.000	55.000	5.346.000
Center	196.000	803.000	534.000	154.000	12.000	2.202.000
Médio Tejo (Projection)	75.950 (5%)	23.820 (1,2%)	28.210 (1,3%)	12.390 (3%)	24.750 (4,5%)	117.000 (2%)
Abrantes	-	-	-	-	-	12.000

Table 15 - Major macronutrient content and other characteristics of excrement (feces and urine) generated daily per 500 kg live weight of some livestock species. (Source: Organic Waste Management)

Livestock Species	Weight (kg)	Total production of excrement		CQO
		kg/day	dm^3/day	kg/day
Bovine	450	30,2	31,5	3,00
Swine	110	33,6	35,5	3,03
Ovine	45	20,0	18,9	5,50
Caprine	40	1,5	-	-
Horses	450	22,7	23,4	-

Médio Tejo has 75,950 head of cattle, if each day this species produces 30.2 kilograms of excrement and knowing that the percentage of fresh weight is 11.6%, we have an annual production of 97,114 toe per year of fresh droppings.

Médio Tejo 23,820 heads of pigs given the picture above, this species produces 33.6 kilograms of excrement daily. The percentage of fresh corresponds to 9.2%. Thus, we have an annual production of 26,875 t of fresh droppings.

Médio Tejo has 28,210 heads of sheep given the picture above, this species produces 20.0 kilograms of excrement daily. The percentage of fresh corresponds to 25%. Thus, we have an annual production of 51,483 t of fresh droppings.

Médio Tejo has 12,390 heads of goats, given the picture above, this species produces 1.5 kg of manure daily. The percentage of fresh corresponds to 9.2%. Thus, we have an annual production of 624 toe of droppings fresh.

Médio Tejo has 24,750 horse heads, given the picture above, this species produces 22.7 kilograms of excrement daily. The percentage of fresh corresponds to 20.5%. Thus, we have an annual production of 42,038 t of fresh droppings.

Table 16 - Annual total production of excrement in Médio Tejo Region (t).

Activity	Annual Total Production of Excrements (t)
Bovine	97.114
Swine	26.875
Ovine	51.483
Caprine	624
Horses	42.038
Total	218.134

Forestry

The use of forest residues is performed usually by hand and in a complementary manner, resorting to the collection and transport of branches, pecking, cones etc., for the local processing operations after pruning, cleaning or logging. The traditional cleaning scrub to obtain biomass for livestock bedding or for energy fell almost into disuse.

About the use of forest biomass for energy purposes, some studies have concluded that despite the abundance of the resource (38% of the country is covered by forest), there is difficulty in achieving its realization, mainly for social, economic and technical. However, it recognized the importance of this indigenous resource for energy, susceptible of a clear commercial interest and business opportunities. Furthermore, the current policy of defense against forest fires and even forest fire occurrence in our country, hold one hand, the existence of markets for forest biomass. (Source: "Biomass and Renewable Energy in Agriculture Fisheries and Forestry". Ministry of agriculture, rural development and fisheries, 2005)

The woody crops for obtaining biomass for energy purposes consist of sowing or planting of selected species, mainly for its precocity, rapid growth, with the main objective of producing the greatest amount of biomass per unit and surface time.

Examples of energetic species that may be seized and/or produced in our climate and soil conditions there are the below mentioned.

Table 17 - Information about plant species with interest for biomass. (Source: National Energy Crops. National Directorate of Forestry Rows, 2010)

Plant Species	Crop Cycle/Cutting Cycle
Eucalyptus dalrympleana, Eucalyptus gunnii, among others	4 to 6 years. 50% of the leaves and twigs stays on the soil
Willow Trees *like Salix viminalis* e *Salix dasyclados*	3 or 4 years during 25 or 30 years
Poplar Trees like Hybrids of *Populus trichocarpa*.x P. *deltoides and others*	Consecutive cutting cycles every 3 to 5 years for about 25 to 30 years
Paulownia tomentosa	Cutting cycles every 3 years

It will then be submitted to the forest area by geographic location in Portugal and in the central region.

Table 18 - Forest surface in ha (thousands) in Portugal and Center Region, PIS and Abrantes. (Source: INE, 2011 and ICN)

Geographic Location	Forest Surface ha (thousands)			
	Total	Forest Areas	Areas of clearcutting	Other forest areas
Portugal	3.564,4	3.216,3	34,5	213
Center Region	1.159,5	1.058,5	16,2	30,3
Abrantes	47,184	45	0,924	1,260

Geographic Location	Forest area (ha)	Error (%)	Shredders (ha)	Error (%)
PIS	85.905	2,5	83.078	2,6
Abrantes	48.185	2,5	5.786	12,3

Table 19 - Areas of forest stands by dominant tree species. (Source: FloreStat, IFN5, Institute for Nature Conservation and Forest)

Species (ha)/Geographic Location	PIS	Abrantes
Wild Pine	52.014	9.026
Eucalyptus	20.634	17.983
Corktrees	111	16.936
Holmoak	25	10
Oaks	204	4

Table 20 - Total biomass of forest trees according to the specific composition of populations. (Source: FloreStat, IFN5, ICNF)

Geographical Region	Species	Biomass of living trees (ktoe)	Biomass of dead trees (ktoe)	Total Biomass (ktoe)
Center	Wild Pine	30.532	1.759	32.291
	Eucalyptus	19.265	789	20.054
	Corktrees	1.403	249	1.652
	Holmoak	429	41	470
	Oaks	1.590	55	1.645
PIS	Wild Pine	-	-	1.350
	Eucalyptus	-	-	613

Sewage Sludge from WWTP

Wastewater is basically comprised of a mixture of water and organic and mineral solids, which 99.9% is water and 0.1% are solids. Of total solids, about 70% are organic materials such as proteins, carbohydrates and fats: the remaining 30% are constituted by inorganic materials such as sand, salts and metals. (Source: Dissertation submitted for the degree of Master of Engineering Environment (Business Management and Industrial Waste Treatment) - MANAGEMENT STRATEGIES FOR TREATMENT PLANTS WATER RESIDUAL Sludge (WWTP). EXTRUSION FOR APPLICATION OF AGRICULTURE IN Sludge, 2005, Ricardo José Vieira de Sousa)

The optimal approach to management of this waste depends on multi-factors: origin, quantity, composition, production region (area, accessibility, climate); season in which they are produced; technologies available for your treatment and/or recovery; treatment costs, deposition costs, availability of skilled manpower according to the technological requirements; environmental policy in the region, public acceptance of the proposed solution at local and regional level. (Source: Agnes Battle Reis et al, "Optimization of sludge management: processing, storage, and ultimate destination")

The sludge treatment plants have a complex composition containing higher or lower concentrations of organic matter and various nutrients that could be valuable from the standpoint of their use in agriculture. It also contains various contaminants (heavy metals, pesticides, detergents, etc..), Pathogens (viruses, helminthes eggs, protozoa, bacteria and fungi) and organic biologically unstable, potentially causing emission of strong odors and vectors attraction (insects, rodents, etc.). which, depending on its concentration, may exhibit greater or lesser risk of environmental pollution. (Source: Optimization of sludge management: processing, storage, and final destination, Ines Battle Reis et all)

Table 21 - Geographical location (Médio Tejo) and sewage sludge production (t). (Source: IrRADIARE, Science for Evolution, 2010)

Geographic Location (Médio Tejo)	Sewage Sludge Production, 2010 (t)
Abrantes	817,6
Alcanena	301,0
Constância	72,9
Entroncamento	468,7
Ferreira do Zêzere	172,9
Ourém	1028,2
Sardoal	74,4
Tomar	865,0
Torres Novas	733,0
Vila Nova da Barquinha	170,1
Total	4.703,8

Through the table presented above [Table 21] is possible to observe that the overall sludge production in 2010 in the Médio Tejo was 4703.8 tonnes. These come from the water treatment station.

The final destination of sludge currently in Portugal has been mostly the landfill. It is necessary to change this trend, since the sludge has a high energy potential associated that is being unused.

Compilation of Input Information

The following table is compiled all the input information.

Table 22 - Compilation of all information related to chapter 3.

Materials	Amount (t/yr)
Sewage Sludge	4.704
Household Waste	73.676
Livestock Waste	218.134
Forest Waste	1.963
Agriculture Waste	25.889
Total	324.366

4) Technical requirements for biowaste management system implementation

Biowaste collection systems/approaches and proceeding technologies/solutions – Biogas plant components

A biogas plant is a complex installation, consisting of a variety of elements. The layout of such a plant depends to a large extent on the types and amounts of feedstock supplied. As there are many different feedstock types suitable for digestion in biogas plants, there are, correspondingly, various techniques for treating these feedstock types and different digester constructions and systems of operation. (Source: Biogas Handbook)

The main process steps in a biogas plant are outlined in Figure 13 above.

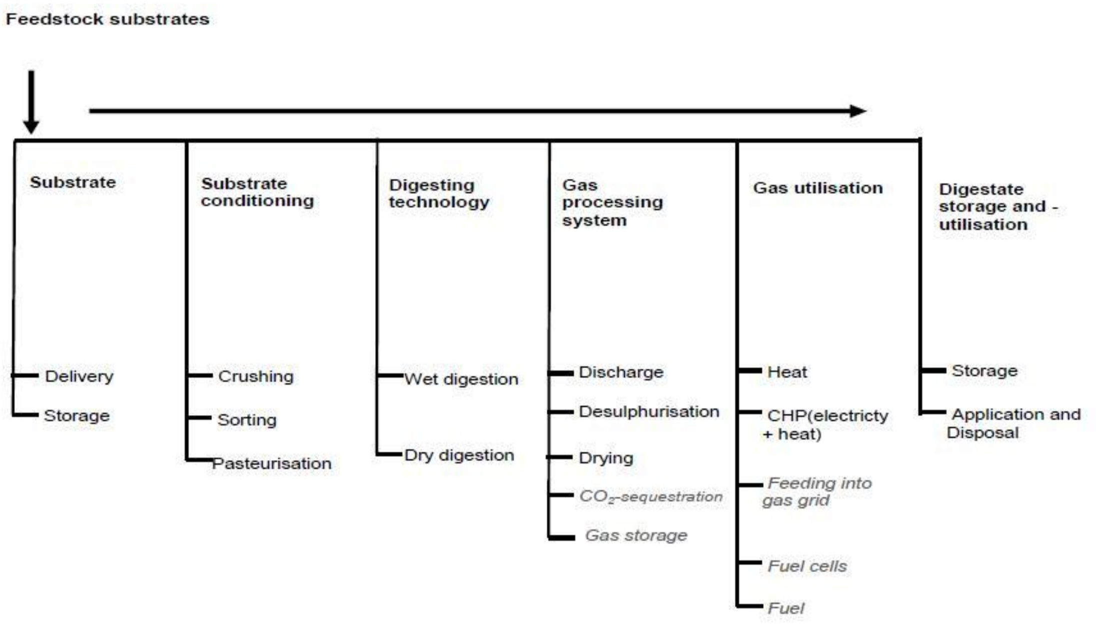

Figure 13 - Process steps of biogas technologies. (Source: Biogas Handbook)

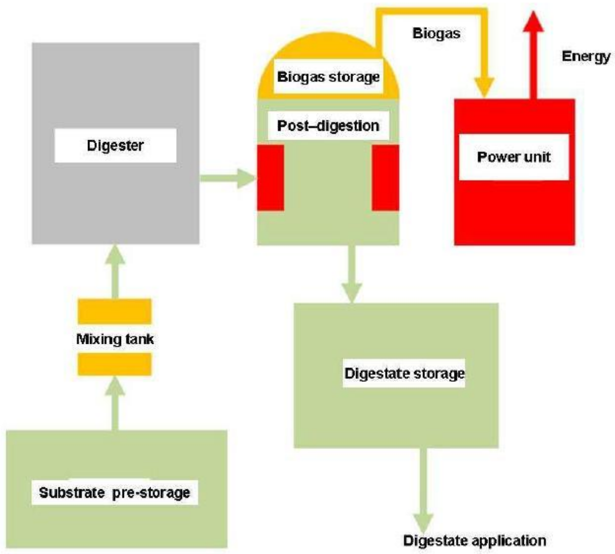

Figure 14 - Main components and general process flow of biogas production. (Source: Biogas Handbook)

When building a biogas plant, the choice of type and the design of the plant are mainly determined by the amount and type of available feedstock. The amount of feedstock determines the dimensioning of the digester size, storage capacities and CHP unit. The feedstock types and quality (DM-content, structure, origin etc.) determines the process technology. (Biogas Handbook)

Next, it will be presented all the components that are present in a biogas plant.

Feedstock Receiving Unit

Transport and supply of feedstock plays an important role in the operation of a biogas plant.

It is thus important to ensure a stable and continuous supply of feedstock, of suitable quality and quantities. (Biogas Handbook)

In many cases, the biogas plants receive additional feedstock (co-substrates), produced by neighboring farms, industries or households. In these cases, management of feedstock quality is necessary, in order to check, account and verify the supplied material. In a first step, it is absolutely necessary to make visual control of each feedstock load. Then, the delivery weight and all feedstock data (supplier, date, quantity, type of feedstock, processes of origin and quality) should be recorded. (Biogas Handbook)

Feedstock Storage and Conditioning

Feedstock Storage

Feedstock storage serves primarily to compensate the seasonal fluctuations of feedstock supply. It also facilitates mixing different co-substrates for continuous feeding of the digester.

The type of storage facilities depends on the feedstock used. Storage facilities can be mainly classified into bunker silos for solid feedstock (e.g. maize silage) and storage tanks for liquid feedstock (e.g. liquid manure and slurries).

Bunker silos for energy crops

Bunker silos were originally developed to store silage as animal fodder and thus to balance its seasonal availability. Nowadays this type of storage is frequently used for storing the energy crops used as feedstock for biogas production.

Silage must be made from plant material with suitable moisture content (55-70%, depending on the means of storage, degree of compression and water content that will be lost during storage). Silage undergoes a fermentation process where fermentative bacteria use energy to produce VFA such as acetate, propionate, lactate, and butyrate, which preserve the silage.

The result is that silage has lower energy content than the original plant material, as fermentative bacteria use some of the carbohydrates to produce VFA. In the case of bunker silos, it must always be considered that the fermentation process of the silage releases liquids which can contaminate water courses, unless precautions are taken.

Storage tanks for pumpable feedstock

Pumpable feedstock is generally stored in sealed, water-tight and reinforced concrete tanks in or above the ground. These tanks, similar to the ones used in agriculture, for storage of liquid manure, usually have a storage capacity sufficient for one to two days. To prevent emissions, all storage tanks should be covered. The chosen solution for cover must ensure easy opening and removal of settled sediments. If storage tanks are placed on a higher level compared to the digester (sloping topography), the hydraulic incline eliminates the need for transport equipment (pumps) and saves energy.

Co-substrates (liquid or stackable) can be mixed with the main substrates inside the storage tank, crushed, homogenised and transformed into a pumpable mixture. Clogging, sedimentation, floating layers and phase separation of the feedstock mixture must be avoided. For this reason, storage tanks are outfitted with stirrers often combined with tearing and cutting tools for crushing the feedstock.

Storage tanks for pumpable feedstock require limited maintenance, this including removal of sediment layers of sand and stes, which reduce the storage capacity of the tanks. Sediments are removed using scrape floors, conveyor screws, sump pumps, collection tanks or countersink aggregates.

In order to minimise odours from the biogas plant as well as for practical reasons, delivery, storage and preparation of feedstock must take place in closed halls, equipped with biofilter ventilation. The equipment is thereby protected and operation, as well as monitoring activities can be carried out regardless of weather conditions.

Feedstock Conditioning

Feedstock conditioning influences the flow and the efficiency of AD process. The main aim of conditioning is to fulfill the demands of sanitation and to increase feedstock digestibility.

Feedstock sorting and separation

The necessity of sorting and separating impurities and problematic materials from the feedstock substrate depends on the origin and composition of the feedstock. Silage is among the cleanest feedstock types while e.g. manure and household wastes can contain stones and other physical impurities. These are usually separated by sedimentation in storage tanks (and in the case of sand, even inside the digesters) and they have to be removed from the bottom of the tanks from time to time. A pre-tank outfitted with special grills, able to retain stones and other physical impurities before pumping the feedstock into the main storage tank, is used in many cases.

Household waste, catering and food wastes can contain various impurities (packing and wrapping residues of plastic, metal, wood, glass and other non-digestible materials, which can cause damage on pumps, block pipes and even the digesters. These impurities can be removed by a separate collection system of e.g. household wastes or they can be removed from bulk collected wastes by mechanical, magnetic and manual methods.

Sanitation

Handling, treatment and recycling of digestate must be done safely, without contamination risks for humans, animals or the environment.

In all cases, sanitation of specific AD feedstock types must be done before pumping the respective feedstock in the digester. The reason is to avoid contamination of the whole feedstock load and to keep sanitation costs low. Sanitation is usually carried out in separate, heated stainless steel tanks, connected to the digester feeding system. The temperature of the material after the sanitation process is higher than the AD process temperature. For this reason and before being fed into the digester, the sanitized material should pass through a heat exchanger, where some of the heat is transferred to the fresh biomass, which is pumped in the digester.

Crushing

As a general rule, the decomposition process is faster when the particle size is smaller. However, particle size only influences digestion time, but does not necessarily increase methane yields. Feedstock crushing is usually directly connected to the feeding system. Both can be powered by an electric motor or by the drive shaft of a tractor.

Mashing, homogenising

Mashing of feedstock can be necessary in order to obtain feedstock with a higher water content, which can be handled by pumps. Mashing takes place in storage tanks or predigesters, before pumping the material into the main digester. The advantage of using digestate for mashing lies in the reduction of fresh water consumption and in the inoculation of the substrate with AD micro-organisms from the digester. This can be important after sanitation.

There are same precautions that must be taken if water from cleaning processes is used for mashing, as disinfectants can have a negative impact on AD microorganisms. Use of fresh water should always be avoided due to high costs.

Besides pumpability, substrate homogeneity is another important factor for the stability of the AD process. **The already pumpable feedstock is homogenised by stirring the storage tank while solid feedstock must be homogenised during the feeding process**. Large fluctuations of the supplied feedstock types and of feedstock composition stress the AD microorganisms, as they have to adapt to new substrates and to changing conditions. Experience shows that usually these results in lower gas yields, thus **it is important to have a stable and constant supply of feedstock, over a long period of time,** in order to have a balanced and "healthy" AD process, with a high methane yield.

Feeding system

After storage and pre-treatment, AD feedstock is fed into the digester. The feeding technique depends on the feedstock type and its pumpability. Pumpable feedstock is transferred from storage tanks to the digester by pumps. The pumpable feedstock category includes animal slurries and a large number of liquid organic wastes (e.g. flotation sludge, dairy wastes, fish oil). Feedstock types which are non-pumpable (fibrous materials, grass, maize silage, manure with high straw content) can be tipped/ poured by a loader into the feeding system and then fed into the digester (e.g. by a screw pipe system). Both feedstock types (pumpable and non-pumpable) can be simultaneously fed into the digester.

From a microbiological point of view, the ideal situation for a stable AD process is a continuous flow of feedstock through the digester. In practice, the feedstock is added continuously to the digester, in several batches during the day. This saves energy as feeding aggregates are not in continuous operation.

Special attention must be paid to the temperature of the feedstock which is fed into the digester. Large differences between the temperature of the new feedstock and the operation temperature of the digester can occur if the feedstock has been sanitised (up to 130°C) or during winter season (below 0°C). Temperature differences disturb the process microbiology, causing losses of gas yield and must therefore be avoided.

Pumps for transport of pumpable feedstock

The transfer of pumpable feedstock substrate from the storage tank into the digester is done by pumps. Two types of pumps are frequently used: the centrifugal and the displacement pumps. Centrifugal (rotating) pumps are often submerged, but they can also be positioned in a dry shaft, next to the digester.

Displacement pumps (turning pist pumps, eccentric screw pumps) are more resistant to pressure than rotating pumps. However through their lower price, rotating pumps are more frequently chosen than displacement pumps.

The selection of appropriate pumps and pumping technology depends on the characteristics of the materials to be handled by pumps (type of material, DM content, particle size, and level of preparation). Biogas plants use the same pumps that are used for liquid manure, which proved to be suitable for feeding the digester and for handling the digested substrate.

All movable parts of the pumps are subjected to high wear and must therefore be replaced from time to time. This should be feasible without interrupting biogas production. For this reason, the pumps must be equipped with stop-valves, which allow feeding and emptying of digesters and pipelines.

The function of pumps, and by this the transport of pumpable substrate, is controlled automatically, using process computers and timers. In many cases the entire feedstock transport within the biogas plant is realized by one or two pumps, located in a pumping station.

Centrifugal pumps

Centrifugal pumps are commonly used to move liquids through a piping system and are therefore frequently used for handling liquid manure and slurries.

Pressure displacement pumps

For the transport of thick liquid feedstock, with high dry matter content, pressure displacement pumps (rotary pist and eccentric screw pumps) are often used. Displacement pumps are self-sucking and more pressure stable than centrifugal pumps. For this reason, the piping performance is less dependent on difference in height.

Transport of non-pumpable feedstock

Stackable feedstock like grass, maize silage, manure with high straw content, vegetable residues etc. must to be transported from a storage facility (bunker silo) to the digester feed in system. This is usually done by loaders or tractors and the feedstock is fed into the digester using e.g. a screw pipe transporting system.

The feed-in system includes a container, where stackable feedstock is poured by tractor, and a transport system, which feeds the digester. The transport system is controlled automatically and consists of scraper floors, walking floors, pushing rods and conveyor screws.

Scraper floors and overhead push rods are used to transport feedstock to the conveyor screws. They are capable of transporting nearly all stackable feedstock, either horizontally or with a slight incline, and are therefore used in very large, temporary storage containers, but they are not suitable for dosing.

Conveyor screws can transport feedstock in nearly all directions. The only precondition is the absence of large stones and other physical impurities. For optimal function, coarse feedstock should be crushed, in order to be gripped by the screw and to fit into the screw windings.

The insertion of the feedstock into the digester has to be air-tight and should not allow leak of biogas. For this reason, the feed-in system inserts the feedstock below the surface layer of digestate. Three systems are commonly used: wash-in shaft, feed pistons and feed conveyor screws.

Wash-in shaft

Feeding solids to the digester through wash-in shafts or sluices, using front or wheel loaders, allows large quantities of solids to be delivered any time, directly to the digester (Figure xx)

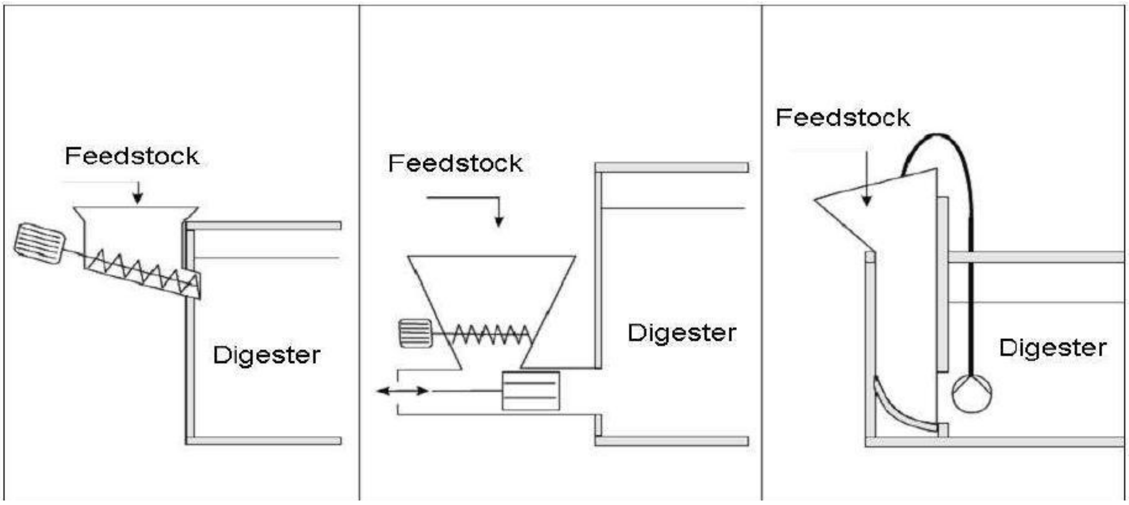

Figure 15 - Wash-in shaft, feed pistons and feed conveyors system for feedstock insertion into the digester. (Source: Biogas Handbook)

Feed pistons

When using feed pistons [Figure 15], the feedstock is inserted directly into the digester by hydraulic cylinders, which push the feedstock through an opening in the wall of the digester.

This ground level insertion means that the feedstock is soaked in the liquid content of the digester, reducing the risk of floating layer formation. This system is equipped with counter rotating mixing rollers, which transport co-substrates to the lower horizontal cylinders and, at the same time, crush long fibre materials.

Feed conveyor screws

Feeding co-substrates to the digester can be done by using feed screws or conveyor screws [Figure 15]. In this case, the material is pressed under the level of the liquid in the digester, using plug screws. The method has the advantage of preventing gas leaking during feeding.

The simplest way to do it is to position a dozer on the digester, so that only one insertion screw is necessary. For feeding the screw, temporary storage containers, with and without crushing tools, are used.

Digesters

The core of a biogas plant is the digester - an air proof reactor tank, where the decomposition of feedstock takes place, in absence of oxygen, and where biogas is produced. Common characteristics of all digesters, apart from being air proof, are that they have a system of feedstock feed-in as well as systems of biogas and digestate output.

There are a various types of biogas digesters, operating in Europe and around the world. The size of digesters determine the scale of biogas plants and varies from few cubic meters in the case of small household installations to several thousands of cubic meters, like in the case of large commercial plants, often with several digesters.

The design of a biogas plant and the type of digestion are determined by the dry matter content of the digested substrate. As mentioned before, AD operates with two basic digestion systems: wet digestion, when the average dry matter content (DM) of the substrate is lower than 15 % and dry digestion, when the DM content of the substrate is above this value, usually between 20-40 %.

Wet digestion involves feedstock like manure and sewage sludge, while dry digestion is applied to biogas production from solid animal manure, with high straw content, household waste and solid municipal biowaste, green cuttings and grass from landscape maintenance or energy crops (fresh or ensiled). Both dry and wet digesters are described in the next subchapters, with emphasis on wet digestion systems.

Batch-type digesters

The specific operation of batch digesters is that they are loaded with a portion (batch) of fresh feedstock, which is allowed to digest and then is completely removed. The digester is fed with a new portion and the process is repeated. Batch-type digesters are the simplest to build and **are usually used for dry digestion**.

An example of batch digesters are the so-called "*garage type*" digesters made of concrete, for the treatment of source separated biowaste from households, grass cuttings, solid manure and energy crops. Treatment capacity ranges from 2 000 to 50 000 toe per year. The feedstock is inoculated with digestate and fed in the digester.

Unlike wet digestion, dry digestion needs no stirring or mixing of the AD substrate during digestion. The temperature of the process and of percolation liquid are regulated by a built-in floor heating system, inside the digester, and by a heat exchanger, which acts as a reservoir for percolation liquid.

Compared to other systems, batch digestion has the advantage of low operation costs and costs of the mechanical technology behind it and the disadvantage of high process energy consumption and maintenance costs.

Batch digesters are also used for combined dry and wet digestion, in case of stackable feedstock types, where additional waste water or percolation liquid is used in larger quantities for flooding or percolation.

Continuous-type digesters

In a continuous-type digester, feedstock is constantly fed into the digester. The material moves through the digester either mechanically or by the pressure of the newly feed substrate, pushing out the digested material. Unlike batch-type digesters, continuous digesters produce biogas without interruption for loading new feedstock and unloading the digested effluent. Biogas production is constant and predictable.

Continuous digesters can be vertical, horizontal or multiple tank systems. Depending on the solution chosen for stirring the substrate, continuous digesters can be completely mixed digesters and plug flow digesters.

Completely mixed digesters	Plug flow digesters
Round, simple tank construction, vertical	Elongated, horizontal tank
Completely mixed	Vertically mixed
Suitable for simple feedstock (liquid manure)	Suitable for difficult feedstock (solid manure)
Fractions of the undigested feedstock can reach the outflow	Normally, no short cut between inflow and outflow; secure sanitation
Process temperature 20° - 37° C	Process temperature 35° - 55° C
Retention time 30 - 90 days	Retention time 15 - 30 days

Figure 16 - Digester type. (Source: Biogas Handbook)

Vertical digesters

In practice, most digesters are vertical digesters. Vertical digesters are generally built on-site, round tanks of steel or reinforced concrete, often with a conic bottom, for easy stirring and removal of sand sediments. They are air proof, insulated, heated and outfitted with stirrers or pumps. The digesters are covered by a roof of concrete, steel or gas proof membrane and the produced biogas is piped and stored in an external storage facility, close to the digester or under the gas proof membrane. The membrane is inflated by the produced biogas or it can be fastened to a central mast.

The advantage of vertical digesters is that the existing manure tanks at the farms can be converted cost effectively into biogas digesters by adding the insulation and the heating system.

The figure below shows the operation of a vertical digester.

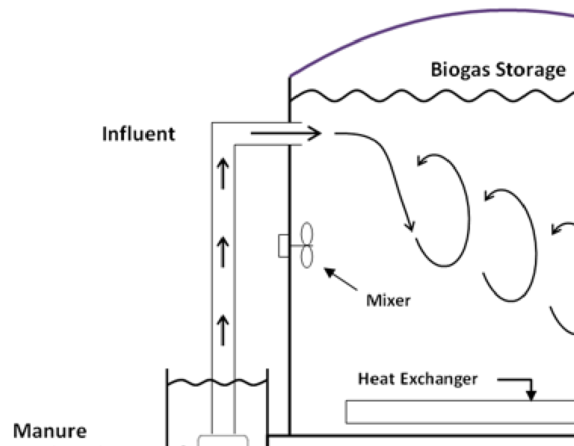

Figure 17 - Operation of a vertical digester. (Source: http://www.anaerobicdigester.com)

Horizontal digesters

Horizontal digesters have a horizontal axis and a cylindrical shape. This type of digesters are usually manufactured and transported to the biogas plant site in one piece, so they are limited in size and volume. The standard type for small scale solutions is a horizontal steel tank of 50-150 m^3, which is used as the main digester for smaller biogas plants or as pre-digesters for larger plants. There is also an alternative of concrete, the channel type digester, which allows a larger digester volume of up to 1 000 m^3.

Horizontal digesters can also run in parallel, in order to achieve larger throughput quantities. Because of their shape, the plug-flow stream is automatically used. The feedstock flows slowly from the entry side to the discharge side, forming a plug-flow, streaming through the digester.

Figure 18 - Horizontal digester, built in Denmark (Nordish Folkecenter 2001). (Source: Biogas Handbook)

Large farm scale co-digestion plants usually consist of several digester tanks. They are normally operated as continuous flow system, including one or several main digesters and post digesters. Like in the case of single digesters, the multiple tank system can consists of vertical digesters only or a combination between vertical and horizontal digesters. The storage tanks for digestate serve also as post-digesters and should always be covered with gas tight membrane.

Maintenance of digesters

Removal of sediments in the digester

Sediments of heavy materials such as sand and other non-digestible materials can accumulate inside continuous-type digesters. Most of these materials can be removed during pre-storage or during the feeding process. Accumulation of sand inside the tanks and digesters reduces their active volume. The presence of sand in the biomass flow is heavily loading the stirring systems, the pumps and the heat exchangers, causing fouling, obstructions and heavy wear. If not removed periodically, sediment layers can become hard and can only be removed with heavy equipment.

If the amount of sediment formation is high, the sediment removal systems may not function and the digester must be taken out of operation and opened in order to remove the sediment layer manually or mechanically, according to the size of the digester. The static pressure of very high digesters (more than 10 m) is considered sufficient to remove sand, scale and sludge.

Sediment formation and the problems caused by it can be minimized by some basic measures:

· Regularly emptying of pre-storage and storage tanks

· Establishing sufficient pre-storage capacity

· Applying adequate stirring method

· Adequate placement of the pumping pipe stubs, in order to avoid sand circulation

· Avoiding feedstock types with high sand content

· Utilization of specially developed methods of sand evacuation from the digesters

Measures against foam layers

Forming of foam and swimming layers can be a sign of process imbalance and their formation is often caused by the types of feedstock supplied. The presence of foam and swimming layers on the surface of biomass, inside the digester, can cause clogging of gas lines. To prevent this, gas lines should be installed as high as possible inside the digester.

Foam traps can prevent penetration of foam in the feedstock pipes and to the post digester or storage basins. A foam sensor can be installed in the gas area of the digester, to start automatically spraying foam retardant inside the digester, if there is too much foam on the surface of the substrate. The foam retardants must be used only in emergency situations, as they usually consist of silicate binders which can damage the CHP plant.

Stirring Technologies

A minimum stirring of biomass inside the digester takes place by *passive stirring*. This occurs by insertion of fresh feedstock and the subsequent thermal convection streams as well as by the up-flow of gas bubbles. As passive stirring is not sufficient for optimal operation of the digester, active stirring must be implemented, using mechanical, hydraulic or pneumatic equipment. Up to 90% of biogas plants use mechanical stirring equipment.

The digester content must be stirred several times per day with the aim of mixing the new feedstock with the existing substrate, inside the digester. Stirring prevents formation of swimming layers and of sediments, brings the micro-organisms in contact with the new feedstock particles, facilitates the up-flow of gas bubbles and homogenizes distribution of heat and nutrients through the whole mass of substrate.

Experience shows that stirring sequences can be empirically optimized and adapted to a specific biogas plant (tank size, feedstock quality, tendency to form floating layers etc.). After the supply of the first feedstock load and the start-up of the plant, the optimum duration and frequency of stirring sequences and adjustment of stirrers will be determined by experience, through continuous monitoring of digester performance.

A better alternative proved to be the continuously, slow rotating stirrers, installed centrally, in the top of the digesters, although their utilization requires a precise adjustment of the level of biomass inside the digester, in order to avoid formation of floating layers.

Mechanical Stirring

According to their rotation speed, mechanical stirrers can be intensive fast running stirrers, medium running stirrers and slow running stirrers.

Submersible motor propeller stirrers are frequently used in vertical digesters. They are completely immersed in the feedstock and usually have two or three winged, geometrically optimized propellers. Due to their guiding tubing system, consisting of gibbet, cable winch and lead profile, the stirrers can usually be adjusted to height, tilt and to the side.

Another possibility for mechanical mixing is axial stirrers. They are often operated continuously. Axial stirrers are usually mounted on shafts that are centrally installed on the digester ceiling. The speed of the engine, which is placed outside of the digester, is reduced to several revolutions per minute, using a transmission. They should create a steady stream in the digester that flows from the bottom, up to the walls.

Figure 19 - Submersible motor propeller stirrer (AGRINZ 2006). (Source: Biogas Handbook)

Pneumatic stirring uses the produced biogas, which is blown from the bottom of the digester through the mass of the feedstock. The bubbles of rising gas cause a vertical movement and stir the feedstock. This system has the advantage that the necessary equipment is placed outside the digester (pumps and compressors), so the wear is lower. Pneumatic stirring not frequently used in agricultural biogas plants, as the technology is not appropriate for destruction of floating layers. Pneumatic stirring can only be used for thin liquid feedstock, with low tendency of forming floating layers.

Hydraulic Stirring

Hydraulically stirred systems have the advantage that the mechanical parts of the stirrers are placed outside the digester, subject to lower wear and can be easily maintained. Hydraulic mixing is only occasionally appropriate for destruction of floating layers and, like the pneumatic stirring, only used for thin liquid feedstock, with low tendency of forming floating layers.

Biogas Storage

Biogas production must be maintained as stable and constant as possible. Inside the digester, biogas is formed in fluctuating quantities and with performance peaks. When biogas is utilized in e.g. a CHP unit, the demand for biogas can vary during the day. To compensate for all these variation, it is necessary to temporarily store the produced biogas, in appropriate storage facilities.

Various types of biogas storage facilities are available today. The simplest solution is the biogas storage established on top of digesters, using a gas tight membrane, which has also the function of digester cover. For larger biogas plants, separate biogas storage facilities are established, either as stand-alone facility or included in storage buildings.

The biogas storage facilities can be operated at low, medium or high pressure. All biogas storage facilities must be gas tight and pressure-resistant, and in case of storage facilities which are not protected by buildings, they must be UV, temperature and weather proof. Before starting-up the biogas plant, the gas storage tanks must be checked for gas tightness. For safety reasons, they must be equipped with safety valves (under-pressure and overpressure) to prevent damages and safety risks. Explosion protection must also be guaranteed and an emergency flare is required. The gas storage facility must have the minimum capacity corresponding to one fourth of the daily biogas production. Normally, a capacity of one or two days gas production is recommended.

Figure 20 - Safety pressure facilities and valves (AGRINZ 2006). (Source: Biogas Handbook)

Low pressure tanks

The frequently used low pressure tanks have an overpressure range of 0,05 to 0,5 mbar and are made of special membranes, which must meet a number of safety requirements. The membrane tanks are installed as external gas reservoirs or as gas domes/covers, in top of the digester.

External low-pressure reservoirs can be designed in the shape of membrane cushions/gas balones [Figure 21]. The membrane cushions are placed in buildings for weather protection or equipped with a second membrane.

Figure 21 - External low pressure gas storage tanks (RUTZ 2007). (Source: Biogas Handbook)

If the digester or the post-digester is used for biogas storage, both must be covered with gas tight membrane domes (double membrane reservoirs) as shown in Figure 22 *left*, fixed on the upper edge of the digester. A supporting frame can be installed in the digester to hold the membrane when it is empty. The membrane expands according to the volume of gas contained. In order to limit the membrane expansion, a special net can be mounted over it [Figure 22 right].

Figure 22 - Digester cover of gas tight membrane, seen from the inside of the tank -*left* (AGRINZ 2006); Digester cover of gas tight membrane, outfitted in exterior with expansion net -*right* (RUTZ 2006). (Source: Biogas Handbook)

This can happen due to extraordinary high gas production rates or through breakdown/maintenance of the energy recovery system. In such cases, back-up solutions are necessary, such as additional biogas storage or additional energy production systems.

Storage of biogas is possible for short periods without compression, but for periods of more than a few hours it is generally not feasible due to the large volume. In situations where there is an excess of biogas, which cannot be stored or used, flaring is the ultimate solution, necessary to eliminate any safety risks and to protect the environment. In exceptional situations, flaring could be the solution for safe disposal of the biogas produced by AD processes, where energy recovery is not feasible.

Irrespective of the type of flare, safe and reliable operation of a flare requires a number of features, in addition to burner and enclosure. Essential safety features include a flamearrestor, failsafe valve and ignition system, incorporating a flame detector. A gas blower is also essential, to raise the pressure of the gas to 3-15 kPa at the burner. The necessity of gas cleaning or conditioning depends on the biogas quality and whether the gas is used in an energy recovery plant, where there is lower tolerance for entrained particulates and for a number of acidic gases formed during combustion. There are two basic types of biogas flares: open flares and enclosed flares.

An ***open flare*** is essentially a burner, with a small windshield to protect the flame. Gas control is rudimentary - in many cases, a coarse manual valve. The rich gas mixture, lack of insulation and poor mixing lead to an incomplete combustion and a luminous flame, which is often seen above the windshield. Radiant heat loss is considerable and this leads to cool areas at the edge of the flame and quenching of combustion reactions to yield many undesirable by products.

Enclosed flares are usually ground based, permanent plants, housing a single or several burners, enclosed within a cylindrical enclosure, lined with refractory material. Designed for purpose, the enclosure prevents quenching and, as a result, the combustion is much more uniform and the emissions are low.

Figure 23 - Modern biogas flares (RUTZ 2007). (Source: Biogas Handbook)

Biogas Cleaning

Gas conditioning

When biogas leaves the digester, it is saturated with water vapours and contains, in addition to methane (CH_4) and carbon dioxide (CO_2), various amounts of hydrogen sulphide (H_2S). Hydrogen sulphide is a toxic gas, with a specific, unpleasant odour, similar to rotten eggs, forming sulphuric acid in combination with the water vapours in biogas. The sulphuric acid is corrosive and can cause damage to the CHP engines, gas pipelines, exhaust pipes etc. To prevent this, biogas must be desulphurizated (removal of H_2S) and dried.

The manufacturers of CHP units have minimum requirements for the properties of the combustible gas (Table xx). The combustion properties must be guaranteed, to prevent damage to the engines. This also applies to the use of biogas. For other utilisations of biogas (e.g. as vehicle fuel or in fuel cells), further gas up-grading and conditioning measures are necessary.

Table 23 - Minimum properties for combustible gases with relative oxygen content of 5%. (Source: Biogas Handbook)

Heat value (lower heat value)	H_u	**≥ 4 kWh/m³**
Sulphur content (total)	S	≤ 2,2 g/m³ CH_4
or H_2S-content	H_2S	≤ 0,15 Vol.- %
Chlorine content (total)	Cl	≤ 100,0 mg/m³ CH_4
Fluoride content (total)	F	≤ 50,0 mg/m³ CH_4
Sum of Chlorine and Fluoride	(Cl + F)	≤ 100,0 mg/m³ CH_4
Dust (3 ... 10 µm)		≤ 10,0 mg/m³ CH_4
Relative humidity (at lowest intake air temperature, i.e. condensation in intake pipe and gas control path	φ	< 90 %
Flow pressure before entry into the gas control path	p_{Gas}	20 ... 100 mbar
Gas pressure fluctuation		< ± 10 % of set value
Gas temperature	T	10 ... 50 °C
Hydrocarbons (> C5)		< 0,4 mg/m³ CH_4
Silicon (at Si > 5 mg/m³ CH_4 oil analysis of metal content < 15 mg/kg oil observed)	Si	< 10,0 mg/m³ CH_4
Methane e count (Biogas MC approx. 135)	MZ	> 135

Desulphurization

The biogas produced by co-digestion of animal manure with other substrates can contain various levels of H_2S. Most of the conventional engines used for CHP generation need biogas with levels of H_2S below 700 ppm, in order to avoid excessive corrosion and rapid and expensive deterioration of lubrication oil.

Removal of H_2S from biogas (desulphurisation) can be done by various methods, either biological or chemical, taking place inside or outside the digester.

Higher biogas production and thus high throughput rates can be observed after insertion of new feedstock into the digester and during stirring.

Biological desulphurization inside the digester

Biological oxidation is one of the most used methods of desulphurisation, based on injection of a small amount of air (2-8%) into the raw biogas. This way, the hydrogen sulphide is biologically oxidised either to solid free sulphur or to liquid sulphurous acid (H_2SO_3).

Biological desulphurization is frequently carried out inside the digester, as a cost-effective method. For this kind of desulphurization, oxygen and *Sulfobacter oxydans* bacteria must be present, to convert hydrogen sulphide into elementary sulphur, in the presence of oxygen. *Sulfobacter oxydans* is present inside the digester (does not have to be added) as the AD substrate contains the necessary nutrients for their metabolism. The oxygen is provided by injection of air in the top of the digester, done with the help of a very small compressor. The process is dependent of the existence of a stable floating layer inside the digester.

Biological desulphurization outside the digester

Biological desulphurization can take place outside the digester in desulphurization tanks or desulphurization columns. This method facilitates the control of desulphurization process and the precise adjustment of oxygen addition.

The H_2S is oxidized through a biological process to acidic products or free sulphur, by upstream injection of a small amount of atmospheric air.

A reactor loading of approx. 10 m^3/h of biogas per m^3 of reactor filling and a process temperature around 35°C can normally be chosen. The process has proven very efficient, provided sufficient air is injected. The sump pH must be maintained at 6,0 ppm or higher. A washing procedure, where the filling elements are showered through with an air/water mixture, has to be carried out at regular intervals in order to prevent free sulphur deposits from closing the reactor filling.

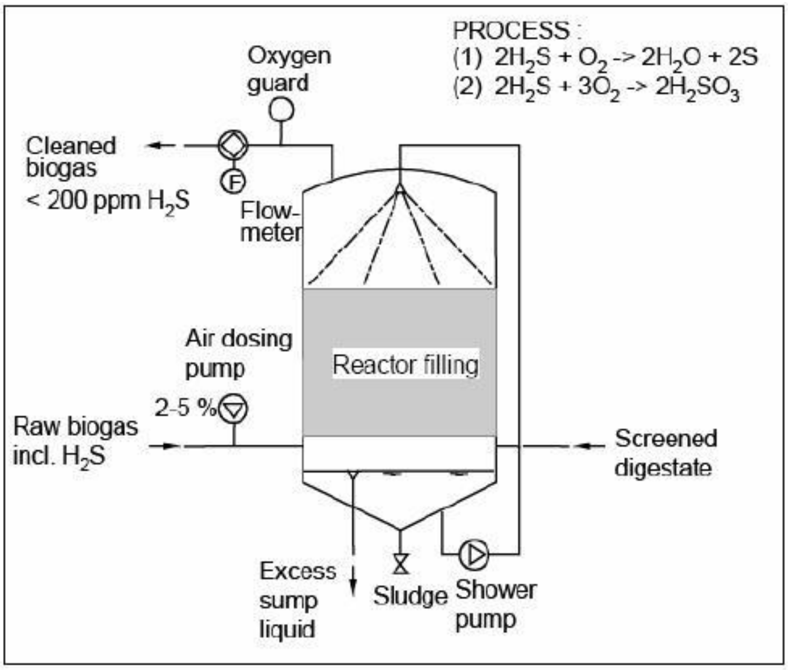

Figure 24 - Schematic diagram of system for biological H2S oxidation (ANGELIDAKI 2004). (Source: Biogas Handbook)

Chemical desulphurization inside the digester

Desulphurisation can also be done by adding a chemical substance to the feedstock mixture, inside the digester. This way, the sulphur is chemically bounded during the AD process, preventing the release of hydrogen sulphide into biogas. Thereby, sulphur is not lost, but remains in the digestate.

Chemical desulphurization outside the digesters

Chemical biogas desulphurisation can take place outside of digester, using e.g. a base (usually sodium hydroxide). The method needs special equipment.

Another chemical method to reduce the content of hydrogen sulphide is to add commercial ferrous solution to the feedstock. Ferrous compounds bind sulphur in an insoluble compound in the liquid phase, preventing the production of gaseous hydrogen sulphide. The method is rather expensive, as the consumption of ferrous material on a stoichiometric basis has proven to be 2-3 times the desired reduction in gaseous hydrogen sulphide (ANGELIDAKI 2004). A cheaper alternative is thus to supply co-substrates (organic wastes) containing ferrous materials and to use the ferrous addition only as a back up.

Biogas Properties

The energy content of biogas from AD is chemically bounded in methane. The composition and properties of biogas varies to some degree depending on feedstock types, digestion systems, temperature, retention time etc. [Table 24] contains some average biogas composition values, found in most of the literature. Considering biogas with the standard methane content of 50%, the heating value is of 21 MJ/Nm³, the density is of 1,22 kg/Nm³ and the mass is similar to air (1.29 kg/Nm³).

Table 24 - Biogas composition. (Source: Biogas Handbook)

Compound	Chemical symbol	Content (Vol.-%)
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-45
Water vapour	H_2O	2 (20°C) -7 (40°C)
Oxygen	O_2	<2
Nitrogen	N_2	<2
Ammonia	NH_3	<1
Hydrogen	H_2	<1
Hydrogen sulphide	H_2S	<1

Drying

The relative humidity of biogas inside the digester is 100%, so the gas is saturated with water vapors. To protect the energy conversion equipment from wear and from eventual damage, water must be removed from the produced biogas.

The quantity of water contained by biogas depends on temperature. A part of the water vapors can be condensed by cooling of the gas. This is frequently done in the gas pipelines transporting biogas from digester to CHP unit. The water condensates on the walls of the sloping pipes and can be collected in a condensation separator, at the lowest point of the pipeline. The condensation separator must be kept frost free and easily accessible, in order to be regularly emptied. In addition to the removed water vapors, condensation also removes some of the undesirable substances such as water soluble gases and aerosols.

Another possibility of biogas drying is by cooling the gas in electrically powered gas coolers, at temperatures below 10°C, which allows a lot of humidity to be removed. In order to minimize the relative humidity, but not the absolute humidity, the gas can be warmed up again after cooling, in order to prevent condensation along the gas pipelines.

Digestate storage

The digested substrate is pumped out of the digester through pumping sequences and transported through pipelines to storage facilities, in the vicinity of the digester, where digestate can be temporarily stored (several days).

When used as fertiliser, digestate is transported away from the biogas plant, through pipelines or with special vacuum tankers, and temporarily stored in storage tanks placed e.g. out in the fields, where the digestate is applied. The total capacity of these facilities must be enough to store the production of digestate for several months.

Digestate can be stored in concrete tanks or in lagoon ponds, covered by natural or artificial floating layers or by membrane covers.

Losses of methane and nutrients from storing and handling of digestate are possible. Up to 20% of the total biogas production can take place outside the digester, in storage tanks for digestate. In order to prevent methane emissions and to collect the extra gas production, storage tanks should always be covered with a gastight membrane for gas recovery. Modern biogas plants have the storage tanks for digestate sealed with a gas-tight membrane.

Figure 25 - Storage tanks covered with natural floating layer (DANISH BIOGAS ASSOCIATION 2008). (Source: Biogas Handbook)

Figure 26 - Open pond lagoons for digestate storage (AGRINZ 2006). (Source: Biogas Handbook)

Application of digestate

As fertiliser – Organic valorization

Digestate is more homogenous, compared to raw slurry, with an improved N-P balance. It has a declared content of plant nutrients, allowing accurate dosage and integration in fertilisation plans of farms. Digestate contains more inorganic nitrogen, easier accessible to the plants, than untreated slurry. N-efficiency will increase considerably and nutrient losses by leaching and evaporation will be minimised if digestate is used as fertiliser in conformity with good agricultural practice.

Due to its higher homogeneity and flow properties, digestate penetrates in soil faster than raw slurry. Nevertheless, application of digestate as fertiliser involves risks of nitrogen losses through ammonia emissions and nitrate leaking. In order to minimise these risks, some simple rules of good agricultural practice must be respected:

- Avoid too much stirring of digestate before application
- Application of cooled digestate, from the post storage tank
- Application with dragging pipes, dragging hoses, direct injection in soil or disk injectors
- Immediate incorporation in soil, if applied on the surface of soil
- Application at the start of the growing season or during vegetative growth
- Application to winter crops should be started with 1/3 of the total N requirement
- Optimum weather conditions for application of digestate are: rainy, high humidity and no wind. Dry, sunny and windy weather reduces the N-efficiency considerably.

Depending on the crop, experience shows that, in Europe, the best time for digestate application is during vigorous vegetative growth.

Degradation of organic matter, which occurs through AD process, includes degradation of carbon bounds, organic acids as well as odoriferous and caustic substances. For this reason, when applied on soil, digestate creates less stress and more suitable environment for soil organisms, compared to application of raw slurry.

Compared to compost and to untreated slurry application, digestate supplies larger portions of carbon, available for the reproduction of organic substances in soils. During AD, decomposable organic bounds such as cellulose and fatty acids are broken down. The lignin bounds, valuable for formation of humus, remain. Methane bacteria themselves produce a whole series of amino acids, which are available for plants and other living organisms in the soil.

As pellets use – Energetic Valorization

The pellets are a clean fuel and CO_2 neutral. The final product is obtained by compressing forestry residues or other related, at high pressures not resorting to the use of additives that may harm the environment later.

This material can be used both domestically and industrially, simply perform the installation of a stove or fireplace, having as ultimate goal the warming.

The pellets are a material easy to store safely and without risk, no danger of explosion. There is the possibility of being supplied in bags of 15 kg to 30 kg, which facilitates transport and storage.

The Control Unit

A biogas plant is a complex installation with close interrelationships between all parts. For this reason, centrally computerized monitoring and controlling is an essential part of the overall plant operation, aiming to guarantee success and avoid failures. Standardization and further development of the AD process technologies is only possible with regular monitoring and documentation of important data.

The ***monitoring process*** includes the collection and analysis of chemical and physical parameters. Regular laboratory tests are required to optimize the biochemical process and to avoid inhibition or collapse of biogas production. Following parameters should be monitored, as a minimum:

- Type and quantity of inserted feedstock (daily)
- Process temperature (daily)
- pH value (daily)
- Gas quantity and composition (daily)

- Short-chain fatty acids content
- Filling level

The ***control of biogas plants*** is increasingly automated through use of specific computer based process control systems. Even wireless remote controlling is possible. The automated control of the following components is state of the art:

- Feedstock feeding
- Sanitation
- Digester heating
- Stirring intensity and frequency
- Sediment removal
- Feedstock transport through the plant
- Solids-liquids separation
- Desulphurization
- Electric and heat output

Biogas Upgrading (Biomethane production)

Biogas can be distributed through the existing natural gas networks and used for the same purposes as natural gas or it can be compressed and used as renewable vehicle fuel. Prior to injection into the natural gas grid or to utilization as vehicle fuel, biogas must undergo an upgrading process, where all contaminants as well as carbon dioxide are removed and the content of methane must is increased from the usual 50-75% to more than 95%. The upgraded biogas is often named biomethane.

Two common methods of removing carbon dioxide from biogas are absorption (water scrubbing, organic solvent scrubbing) and adsorption (pressure swing adsorption, PSA). Less frequently used are membrane separation, cryogenic separation and process internal upgrading, which are relatively new methods currently under development.

The total cost for cleaning and upgrading biogas consists of investment costs and of operation and maintenance costs. In the case of investment costs, an important factor is the size of the plant. The total investment costs increase with increased plant capacity but investment per unit of installed capacity is lower for larger plants, compared to small ones. In the case of operation costs, the most expensive part of the treatment is the removal of carbon dioxide.

Biogas as Vehicle Fuel

Utilization of biogas in the transport sector is a technology with great potential and with important socio-economic benefits. Biogas is already used as vehicle fuel in countries like Sweden, Germany and Switzerland.

The number of private cars, public transportation vehicles and trucks driven on biogas (biomethane) is increasing. **Biomethane can be used as fuel in the same way and by the same vehicles like the natural gas**. An increasing number of European cities are exchanging their diesel buses with biomethane driven ones.

Biomethane vehicles have substantial overall advantages compared to vehicles equipped with petrol or diesel engines. The overall carbon dioxide emissions are drastically reduced, depending on the feedstock substrate and origin of electricity (fossil or renewable) used for gas upgrading and compressing. Emission of particles and soot are also drastically reduced, even compared with very modern diesel engines, equipped with particle filters. Emissions of

NO_x and *Non Methane Hydrocarbons* (NMHC) are also drastically reduced.

Upgraded biogas (biomethane) is considered to have the highest potential as vehicle fuel, even when compared to other biofuels. Figure xx shows a comparison between transport biofuels, in terms of covered distance by an automobile, when running on the respective biofuel, produced on energy crops cultivated on one hectare arable land. The potential of biogas for the transport sector is even higher, if waste is used as feedstock, instead of energy crops.

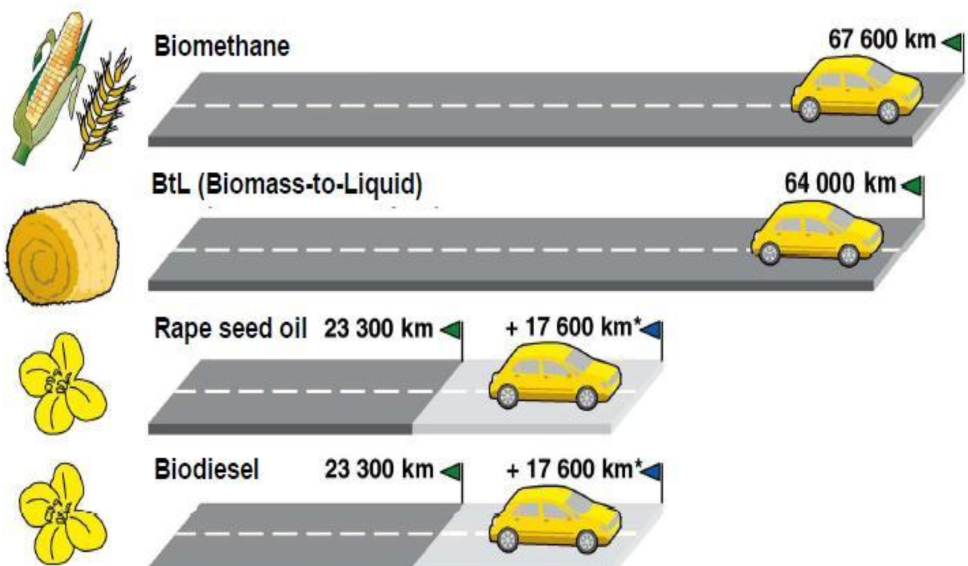

Figure 28 - Biofuels in comparison: Range of personal car, running on biofuels produced on feedstock/energy crops from one hectare arable land. FNR 2008. (Source: Biogas Handbook)

Biomethane for grid injection

Upgraded biogas (biomethane) can be injected and distributed through the natural gas grid, after it has been compressed to the pipeline pressure. In many EU countries, the access to the gas grid is guaranteed for all biogas suppliers.

There are several advantages of using the gas grid for distribution of biomethane. One important advantage is that the grid connects the production site of biomethane, which is usually in rural areas, with more densely populated areas. This enables the gas to reach new customers. It is also possible to increase the biogas production at a remote site, without concerns about utilization of heat excess. Grid injection means that the biogas plant only needs a small CHP unit for the process energy or a biogas burner.

The main barriers for biomethane injection are the high costs of upgrading and grid connection. Grid injection is also limited by location of suitable biomethane production and upgrading sites, which have to be close to the natural gas grid.

Carbon dioxide and methane production as chemical products

Production of pure methane and CO_2 from biogas can be a viable alternative to methane and carbon dioxide production from fossil sources. Both substances are important for the chemical industry. Pure CO_2 is used for production of polycarbonates, of dry ice or for surface treatment (sandblasting with CO_2). CO_2 from biogas can also be used in agriculture, as fertilizer in greenhouses.

Grid Injection in Portugal and Médio Tejo

The existing biomass resources on our planet can give us an idea of the global potential of biogas production. This potential was estimated by different experts and scientists, on the base of various scenarios and assumptions. Regardless the results of these estimations, the overall conclusion was always, that only a very small part of this potential is utilized today, thus there is a real possibility to increase the actual production of biogas significantly. The European Biomass Association (AEBIOM) estimates that the European production of biomass based energy can be increased from the 72 million toe (Mtoe) in 2004 to 220 Mtoe in 2020. The largest potential lies in biomass originating from agriculture, where biogas is an important player. According to AEBIOM, up to 20 to 40 million hectares (Mha) of land can be used for energy production in the European Union alone, without affecting the European food supply.

Then you will see a picture that corresponds to the natural gas network that serves Continental Portugal.

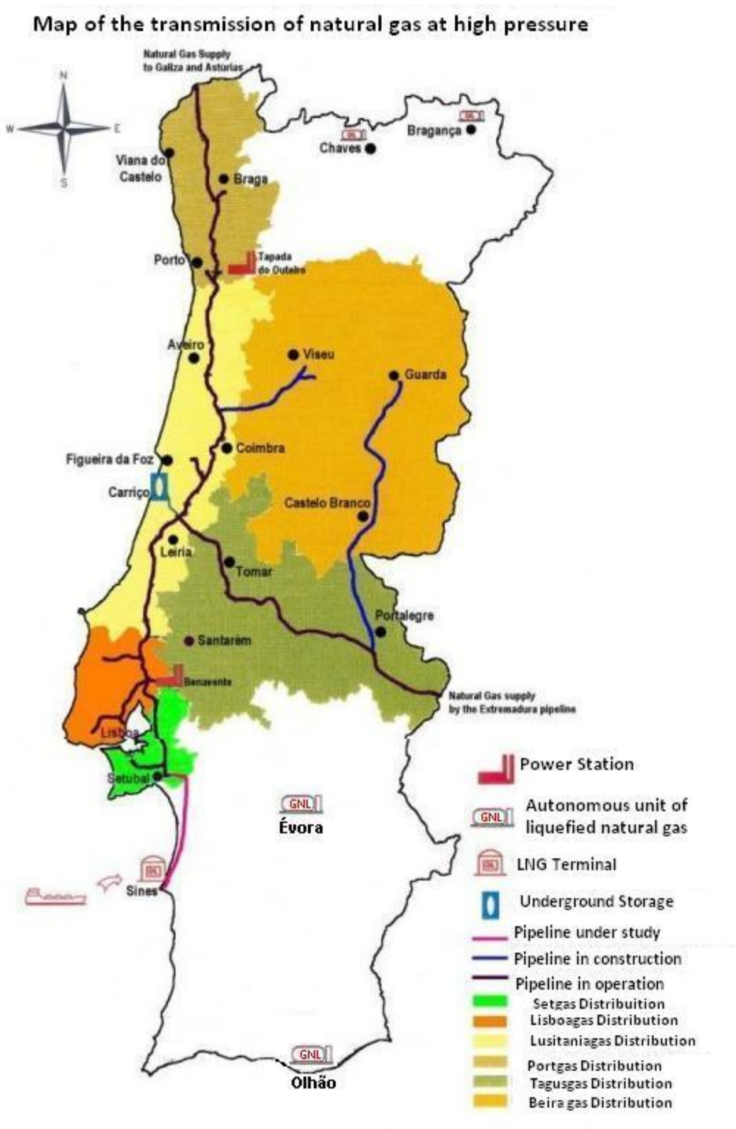

Figure 29 - Map of the transmission of natural gas at high pressure. (Source: www.apvg.pt)

By the image shown above it is possible to see that there is a main line transportation of natural gas that passes through Médio Tejo. This represents an advantage, since it would not be necessary to invest a lot of money in long lengths of pipelines connecting the natural gas network.

Public Transport

As mentioned previously, the public transport network serving the area of the Médio Tejo presents only a fleet powered by fossil fuels. For this happened to be fueled by biomethane would be necessary to implement new engines on existing buses or even proceed to purchase new already adapted to the new conditions.

The initial investment would be expensive, but after a few years this would be amortized, since the price per dm^3 (L) of gas would be lower than the price per liter of fossil fuels.

Production of Biogas and Biomethane

Calculation of prospective biogas and biomethane yield

For the process of calculating the volume of biogas produced through waste were created three steps:

- Step processing input materials

- Step dimensioning

- Step final products

At each step we have associated different important parameters that will be described in the table below:

Table 25 - Important parameters for calculating the volume of biogas

Step	Parameter	Unit
Processing input materials	Population of Medio Tejo	Inhab.
	Amount of waste at the head of the unit	t
Dimensioning	Organic Load	kg oDM/m^3d
	Hidraulic Retention Time	d
	Volume of Digesters (useful)	m^3
	Volume of Digesters (total)	m^3
	Number of digesters	no.
	Methane Content	0,103%
	Net calorific value methane H_i,CH_4	10 kWh/d
Final products	Volume of biogas	m^3/yr
	Electricity produced	kWh/yr
	Volume of biomethane	m^3/yr

Prospective demand, set targets from WP 5

To the present situation we have the quantities that are presented in the table below:

Table 26 - Compilation of all information related to Chapter 3.

Materials	Amount (t/yr)
Sewage Sludge	4.704
Household Waste	73.676
Livestock Waste	218.134
Forest Waste	1.963
Agriculture Waste	25.889
Total	324.366

It is expected that in the future these quantities and demand may vary a bit depending also the variation of the population.

In chapter 7 is going to be done a projection analysis under each scenario created.

Target Cities

Table 27 - Indication of the target cities and the reasons why did we choose those.

Target Cities	Reasons
Bern, Switzerland	This city was chosen because of the amount of waste at the head of the unit is very similar in our case and so some comparisons were made with this target city during the projection. We have found a lot of information about this unit in Bern so it was very useful in the projection analysis.
Madrid, Spain	This city has the amount of waste in the unit's head a little higher than the amount studied for our case but this city was chosen because it has the proximity of Portugal. Temperatures in Portugal and Spain can be said that are slightly similar throughout the year and therefore this factor was also important to have in mind and that had helped us in comparing results.
Lille, France	This city has the amount of waste in the unit's head a little lower than our case but we have chosen this city because of the weather too. This city doesn't have so much information as the others that's why we had to choose other cities to have a better results comparison.

5) Proposal of best solutions of biomethane use in Abrantes

In the previous chapter were addressed all important components for the construction of a biogas production unit, which in this chapter it is suggest the best components that should be adopted to build the same in Abrantes.

Table 28 - Processes involved in the entire chain of biogas production and its components. (Source: Adapted from Biogas Handbook)

Process	Component	Observations
Feedstock Storage	Bunker silos for energy crops (not pumpable feedstock)	Used for storing the energy crops
		One or more tractors are needed to transport the mass to the digester
		Covered with plastic foils, held tight by tyres or sand bags
		When it is not covered this reduces costs with covering but increases energy losses from the silage
	Storage tanks for pumpable feedstock	Generally stored in sealed, water-tight and reinforced concrete tanks in or above the ground
		Tanks should be covered
		Placed on a higher level compered to the digester, the hydraulic incline eliminates the need for transport (pumps) and saves energy
		One or more stirrings are needed
		Pumps
		Equipment with biofilter ventilation (sanitation)
		Sedimentation material have to be removed from the bottom of the tank from time to time
Feedstock Conditioning	Feedstock sorting and separation	Household waste needs that kind of process before getting into the digester
		There are usually separated by sedimentation in storage tanks
		Impurities like plastic, metal, wood, glass, packing and wrapping residues should be removed by a separate collection by mechanical, magnetic and manual methods
		Manpower, mechanical machine for crushing, mashing and homogenising and a magnetic machine are needed
		Pumps
Pumps for transport of pumpable feedstock	Pressure displacement pumps and pipes	Thick liquid feedstock with high dry matter content
		Watch out the diameter of the pipes
		Pumps and pipes should be easily accessible
		Automatically control (in control unit)
		One or two pumps
Transport of	Wash-in shaft	Large quantities of solids directly in the digester

stockable feedstock		A tractor is needed
Armatures and Pipelines	Biomass Pipelines	Biomass transport inside the unit
	Gas Pipelines	Gas transport inside the unit
Heating System - Digester Heating	Pipes for pre-heating during heating	Pre-heating the feedstock during feeding has the advantage of avoiding temperature fluctuations inside the digester
Digester	Continuous type digesters – vertical digesters	System works with a continuous flow and has a high retention time and good gas yields
		Digestate flows into the storage tank which works also as post digester
	Multiple tank system (optional)	Combination between vertical and horizontal digesters
Stirring Technologies	Mechanical stirring	According to their rotation speed, mechanical stirrers can be intensive fast running stirrers, medium running stirrers and slow running stirrers
Biogas Storage	Low pressure tanks	The membrane tanks can be installed as external gas reservoirs or gas covers in the top of the digester
	Biogas flares	In situations where there is an excess of biogas, which cannot be stored or used, flaring is the ultimate solution, necessary to eliminate any safety risks and to protect the environment.
		In exceptional situations, flaring could be the solution for safe disposal of the biogas produced by AD processes, where energy recovery is not feasible
Biogas Cleaning	Desulphurization – Biological desulphurization outside the digester	Can take place outside the digester in desulphurization tanks or desulphurization columns
		H_2S is oxidized through a biological process
		A reactor loading of approx. 10 m^3/h of biogas
Drying	Inside the pipelines	
Digestate Storage	Concrete tanks covered or not covered	Covered tanks are more effective
Machinery Control	Control Unit	The monitoring process includes the collection and analysis of chemical and physical parameters like: Type and quantity of inserted feedstock (daily), Process temperature (daily), pH value (daily), Gas quantity and composition (daily), Short-chain fatty acids content, Filling level

Biogas Production and Upgrading Plant

Biomethane is produced from the biogas however for the initial production of the same is needed to implement an upgrading system. After the implementation of the system the gas can be injected into the network as well as utilized in the fleet.

There are some technologies associated with this improved system:

- Chemical Solvent (e.g. amine process)
- Physical Solvent (other than water)
- Chemical Membrane (low pressure process)
- Physical Membrane (high pressure process)
- Cryogenic Distillation
- PSA/VSA (pressure swing adsorption or molecular sieve)
- Water Scrubbing

There are some advantages and disadvantages associated with each of the technologies mentioned above that will be summarized in the table below.

Table 29 - Advantages and disavantages of various technologies for upgrading plants. (Source: Greenlane, "Experience wih the application of Water Scrubbing Biogas Upgrading Technology")

Process/Technique	Benefits	Disadvantages
Chemical Solvent	1.Cost effective on larger scale 2.Good energy efficiency and operating costs on large scale	1.Safety – solvent is dangerous to handle 2.Risk of pollution by chemical contamination 3.Uneconomic capital and energy costs for gas streams with high CO_2 loadings (> 20%) 4.Does not remove inets (e.g. O_2 and N_2)

Physical Solvent	1.High absorption rate 2.Gas dried during cleaning process	1.Safety – solvent is dangerous to handle 2.Risk of pollution by chemical contamination 3.Not proven technology
Chemical Membrane	1.Reduced compression requirement	1.High energy consumption, steam boiler required 2.Membranes susceptible to failure, requiring replacement of fluid and membranes 3.H_2S not removed
Physical Membrane	1.Low capital cost 2.Simple plan	1.High energy consumption 2.CH_4 > 92% difficult to achieve alone; H_2S not removed 3.Membranes foul and require replacement 4.Does not remove inerts (e.g. O_2 and N_2)
Cryogenic Distillation	1.Very high CH_4 purity achievable 2.Can produce LNG 3.Cost effective on very large scale	1.Complex plant, high capital and operating costs 2.Operational problems due to solid CO_2 formation on heat exchangers 3.Very low temperatures and high pressures create potentially hazardous plants
PSA/VSA	1.Can remove some inert gases but sometimes requires an additional process module 2.Very simple version of the process can be cost effective on small scale	1.Media becomes poisoned and needs replacement 2.Process difficult to control – problems maintaining high CH_4 recovery 3.Bed fluidization causes “dusting” of media 4.Upstream H_2S removal required
Water Scrubbing	1.Excellent safety; proven performance 2.Reliable, simple and easy to maintain 3.Low capital and operation cost 4.Siloxanes effectively removed 5.No chemical uses	1.Practical capacity limit ~2200 Nm^3/h per unit 2.Does not remove inerts

Table 30 - Comparison prices, yield and purity of the different techniques. (Source: L.Binni, M. Sc. et all; "Comparing different biogas upgrading techniques", Eidhoven University of Technology, 2008)

Technique	Price per Nm^3 of biogas (€)	Yield (%)	Purity (%)
Chemical Absorption	0.28	90	98
High Pressure Water Scrubbing	0.15	94	98
Pressure Swing Adsorption	0.26	91	98
Cryogenic separation	0.40	98	91
Membrane separation	0.22	78	89

Table 30 shows that high pressure water scrubbing seems to be the cheapest technique to upgrade biogas. Also this technique gives quite high yield and purity. Cryogenics is the most expensive way of upgrading biogas but it gives the highest possible yield.

In this study was concluded that high pressure water scrubbing has the best performing. With the low cost price, high purity and yield it is a promising upgrading technique. Though one waste stream needs treatment, it is a continuous process which operates almost on itself. (Source: “Comparing different biogas upgrading techniques”)

Technology and Operation

There are some technologies related with biomethane production as it was shown before but, in this case we will only focus on Water Scrubbing Technology.

Water scrubbing is used to remove carbon dioxide but also hydrogen sulphides from biogas since these gases are more soluble in water than methane. The absorption process is purely physical. Usually the biogas is pressurized and fed to the bottom of a packed column where water is fed on the top and so the absorption process is operated counter-currently.

Water scrubbing can also be used for selective removal of hydrogen sulphide since hydrogen sulphide is more soluble than carbon dioxide in water. The water which exits the column with absorbed carbon dioxide and/or hydrogen sulphide can be regenerated and re-circulated back to the absorption column. The regeneration is made by de-pressurizing or by stripping with air in a similar column. Stripping with air is not recommended when high levels of hydrogen sulphide are handled since the water will soon be contaminated with elementary sulphur which causes operational problems. The most cost efficient method is not to re-circulate the water if cheap water can be used, for example, outlet water from a sewage treatment plant.

Plant location – Where to locate the biogas plant?

The next planning step in a biogas project idea is to find a suitable site for the establishment of the plant. The list below shows some important considerations to be made, before choosing the location of the future plant:

- The site should be located at suitable distance from residential areas in order to avoid inconveniences, nuisance and thereby conflicts related to odors and increased traffic to and from the biogas plant;

- The direction of the dominating winds must be considered in order to avoid wind born odors reaching residential areas;

- The site should have easy access to infrastructure such as to the electricity grid, in order to facilitate the sale of electricity and to the transport roads in order to facilitate transport of feedstock and digestate;

- The soil of the site should be investigated before starting the construction;

- The chosen site should not be located in a potential flood affected area;

- The site should be located relatively close (central) to the agricultural feedstock production (manure, slurry, energy crops) aiming to minimize distances, time and costs of feedstock transportation;

- For cost efficiency reasons, the biogas plant should be located as close as possible to potential users of the produced heat. Alternatively, other potential heat users such as heat demanding industry, greenhouses etc. can be brought closer to the biogas plant site.

- The size of the site must be suitable for the activities performed and for the amount of biomass supplied.

The required site space for a biogas plant cannot be estimated in a simple way. Experience shows that e.g. a biogas plant of 500 kW_{el} needs an area of approximate 8 000 m^2.

Economy

Each technology as seen previously has associated advantages and disadvantages. The main goal is to get the final product with the best quality at the lowest price you can get. The water scrubbing technology has some studies that show that in large-scale farms this is the most cost-effective.

The following table will show a comparison of investment among all technologies considered previously.

Table 31 - Comparing the efficiency, flexibility, operational and investment costs of different technologies. (Source: R. Lems M. Sc., R&D Manager, "Making pressurized water scrubbing the ultimate biogas upgrading technology with the DMT TS-PWS system")

	Unit	PSA	Membrane Separation	Cryogenic Liquefaction	Catalytic Absorption (Physical Solvent)	PWS – Pressurized Water Scrubbing	DMT TS-PWS – Direct catalytic regenerative oxidation and PWS
Energy efficiency	%	96-97	80-85	91-92	91-92	95-96	100
Flexibility	-,+/-,+,++	-	+/-	+/-	+	++	++
Operational costs	€/m^3	0,26	0,3-0,5	0,4	0,35	0,25	0,18
Investment	Million €	1,3-1,4	>1,5	1,4-1,5	1,1-1,3	0,8	1,2-1,3

By analyzing the above table it is possible to ascertain that the system pressurized water scrubbing has best benefits in financial terms than all other technologies under consideration. In this case some caution in the analysis is needed because the data was taking out from a presentation from a company that sells a system that can see under "TS-PWS - Direct regenerative catalytic oxidation and PWS" so you have to keep in mind because there may be an overestimation of values relating to technology that is being presented.

6) Legal requirements for biomethane use

Licensing of Production Facilities

According to the Decree-Law n º 312/2001, 10/12, this establishes the rules for administering the capacity of reception of electrical energy in the networks of the Electricity System of Public Service (SEP), to enable the reception and delivery of electricity from new power plants of the Independent Electricity System (SEI). According to this you must start the licensing process through a request prior information (PIP) within Directorate General for Energy and Geology (DGEG), ending with obtaining the Establishment License. This decree law applies to the management of the reception capacity of electricity networks in the SEP from:

a) The production of electricity in hydroelectric plants up to 10 MVA of installed apparent power;

b) The generation of electricity from renewable energy or industrial waste, agricultural or urban, with the exception of hydropower, without prejudice to the preceding paragraph;

c) The generation of electricity in co-generation facilities;

d) The generation of electricity by the Non-Binding Electricity System (SENV).

This same process covers cogeneration installations framed in Decree-Law 313/2001 of 10/12, this establishes provisions relating to the activity of co-generation, meaning by co-generation process combined production of electricity and thermal energy and is designed for both the consumer himself or others regulated by Decree 399/2002 of 18/04.

(Source: edpdistribuicao.pt)

According to continuous dispatch no. 51/2004 on the promotion of electricity produced from renewable energy sources (RES) in the domestic market electricity, which enshrined the recognition of the priority allocated by the European Union and the member states to promote increasing the contribution of such sources to produce electricity.

Whereas the guidelines of this order are as a reinforcement for the development of effective and harmonious duties and responsibilities of assessment environmental impact assessment (EIA) and other agencies involved, providing increased efficiency and rationality of work Evaluation Committees (EC), also contributing to the essential and strict compliance with the statutory time limits and for more clarity and transparency of procedures in order to foster trust and investment on the part of economic agents, and as a continuous improvement of the relationship between them and public Directors:

Accordingly, it is determined:

1 - The present order shall apply, unless otherwise specified, the production of electricity from the following renewable energy: wind, water, biomass, biogas, wave and photovoltaic, and in the case of hydroelectric hydropower with installed capacity up to 10MW (small hydro or PCH) only applies to everything not contradict the Ordinance 295/2002 of 19 March

3 - In the case of projects for producing electricity from RES covered by Decree-Law No 69/2000 of 3 May, the environmental impact statement (EIA) issuing a favorable or favorable conditionally determines compulsorily and immediately to the respective project.

The installation is intended to be built within the DL 69/2000 and this establishes the legal regime the environmental impact assessment of public projects and Private likely to have a significant effect on environment.

Thus, prior to its construction will be necessary to make an Environmental Impact Study to where the facilities will be implemented, followed by an Environmental Impact Assessment. If this is accepted, carry out proposed Environmental Impact Statement.

Grid injection and recommended amendments

After obtaining the license Establishment of DGEG, the promoter shall request EDP Distribution Energy, SA, the connection requirements of production facility to the RESP (Public Service Electric Network).

The request for connection conditions must be accompanied by the location of the plant production facility on an appropriate scale and it's Connection Point, including their geographic coordinates. This connection point is in the network of SEP (Public Electricity System) which will connect the extension of the co-generation facility.

(Source: edpdistribuicao.pt)

Infrastructures Network Connection

Made the request of the conditions of connection to the RESP, the promoter receives EDP Distribution the technical solution and pricing for the establishment of infrastructure connection, and other relevant information.

(Source: edpdistribuicao.pt)

Interface of Production Facilities with RESP

In the production facility must be installed protection systems and metering/telemetry energy.

(Source: edpdistribuicao.pt)

Protection Systems Interconnection

Protective systems interconnection should take into account the "Technical Guide of Production Facilities Independent Electricity", the Directorate General for Energy - Part 5 - Conditions Technical Network Connection Recipient with the amendments approved by Order of 3 August 2007. The inspection and commissioning of these protections are the responsibility of the promoter, which, before the time of connection must submit a report to EDP Distribution prepared by Certified Entity and endorsed by Technical Responsible Exploration.

(Source: edpdistribuicao.pt)

Energy counting systems

The energy metering systems shall be in accordance with the "Guide for Measuring, Reading and Availability of Data", approved by the Energy Services Regulatory Authority, by Order No. 459-A/2007, published in Diário da Républica - Series II March 13, 2007.

For the case of Special Regime Producers calling for Low Voltage (LV PRE) must also conform to the specifications in effect at EDP Distribution.

The cabinet needed to count and telemetry equipment to install energy inspection and commissioning of the equipment are the responsibility of the Promoter, so prior to the first parallel should be submitted to Directorate Management Count of EDP Distribution, said the inspection report prepared by a certified entity, equivalent to Type 1 Audit of LABELEC - Activities Laboratory, SA

(Source: edpdistribuicao.pt)

Design elements of the production plant

With the objective of analyzing its insertion in RESP, the Prosecutor must proceed to issue the following project elements of the production plant in applicable:

- Single line diagram of insertion into the RESP and any changes to be made in it.

- Constitution of the generating sets, with their main characteristics.

- Electrification Schemes Panel Interconnection, including the links and the interconnection of the protections of the measuring equipment, metering/telemetry energy, and even the technical characteristics of the equipment, including its measurement transformers.

- Features generators for modeling.

- Plan Regulatory protections own Setup Production, including generators, for studies of selectivity of the protections of interconnection.

- Label signaling Producer Special Regime Low Voltage, as specified in the EDP force Distribution.

(Source: edpdistribuicao.pt)

Specific conditions for the act of connecting the Production Installation to the RESP

Completed the establishment of a manufacturing facility and Extension Connection and to achieve the first parallel to the RESP, the Promoter shall request and execute, submit, in advance, the following applies in:

- Exploration License of production facilities and infrastructure interconnection, passed by the Competent Authority.

- Checking the label signaling LV PRE.

- Inspection Systems to Measure, Energy Metering and Telemetering.

- Ensuring smooth functioning of the communication channel for Telemetering.

- Regulation and Inspection for the Protection of Interconnection.

- Preparation and signing of automobiles and automobiles Delivery Receiving relating to infrastructure, including the provision of relevant guarantees (if infrastructure built by the Promoter, for integration into RESP).

- Preparation and signing of the Purchase and Supply of Energy.

(Source: edpdistribuicao.pt)

Biomethane conditions for injection into the natural gas grid

The Decree-Law n. º 230/2012 of October 26 establishes the general bases the organization and functioning of the National System Natural Gas (NSNG) as well as the general basis applicable to the practice of the receipt, storage and regasification of liquefied natural gas (LNG), underground storage of natural gas, transportation, distribution and marketing of natural gas and organization of their respective markets.

In the same decree law describes the characteristics that natural gas should be so it can be transported and used. In accordance with Article 18. º:

1 - Natural gas aired on NSNG must guarantee the correct functioning of infrastructure and equipment, as well as the safety of their use.

2 - Monitoring the characteristics of natural gas must be performed by operators infrastructure in which there was a reception in NSNG natural gas, gas delivery natural entry points of RNTGN (National Network of Natural Gas Transportation) and natural gas mixture of different provenances.

3 - Natural gas at entry points of national network of transport natural gas (RNTGN), must meet the following ranges allowable variation for features:

a) Wobbe Index, calculated at reference conditions:

i) minimal IW = 48.17 MJ/m3 (n).

ii) maximum IW = 57.66 MJ/m3 (n).

b) Relative density, calculated at reference conditions:

i) minimum d = 0.5549.

ii) d max = 0.7001.

4 - Natural gas at entry points of RNTGN, shall meet the following limits for maximum features:

a) Dew point of water = -5 º C to maximum working pressure.

b) Hydrogen sulphide = 5 mg/m3 (n).

c) Total sulfur = 50 mg/m3 (n).

5 - Will be monitored for the following characteristics of natural gas:

a) Concentration of oxygen.

b) Hydrocarbon Dewpoint for pressures up to the maximum operating pressure.

c) Concentration of carbonyl sulphide.

d) Minimum concentration of methane

Public transport

According to the Decree-Law no. 77/2011 of June 20 introduces new rules in this organizational framework for the natural gas system. According to the same decree of law, you can read up on Article 72. º-A as follows: "The provisions of this decree law on access to transmission and distribution and other infrastructure SNGN (National System Natural Gas) as well as marketing, are generally applicable to biogas and gas from biomass or other gases, as these gases may be, from the standpoint of technical and security networks injected of natural gas. "

REN is incumbent upon the management of pipelines interconnecting RNTGN with international networks and infrastructure with underground storage and LNG terminal, as well as control the formation and maintenance of stocks of natural gas.

Actors involved in the biomethane supply chain in Abrantes

The chain of biogas production has several stages. In the following figures will be presented the various chains associated with the production of biogas, namely the process chain and material flow chain associated with the process of biomethane production.

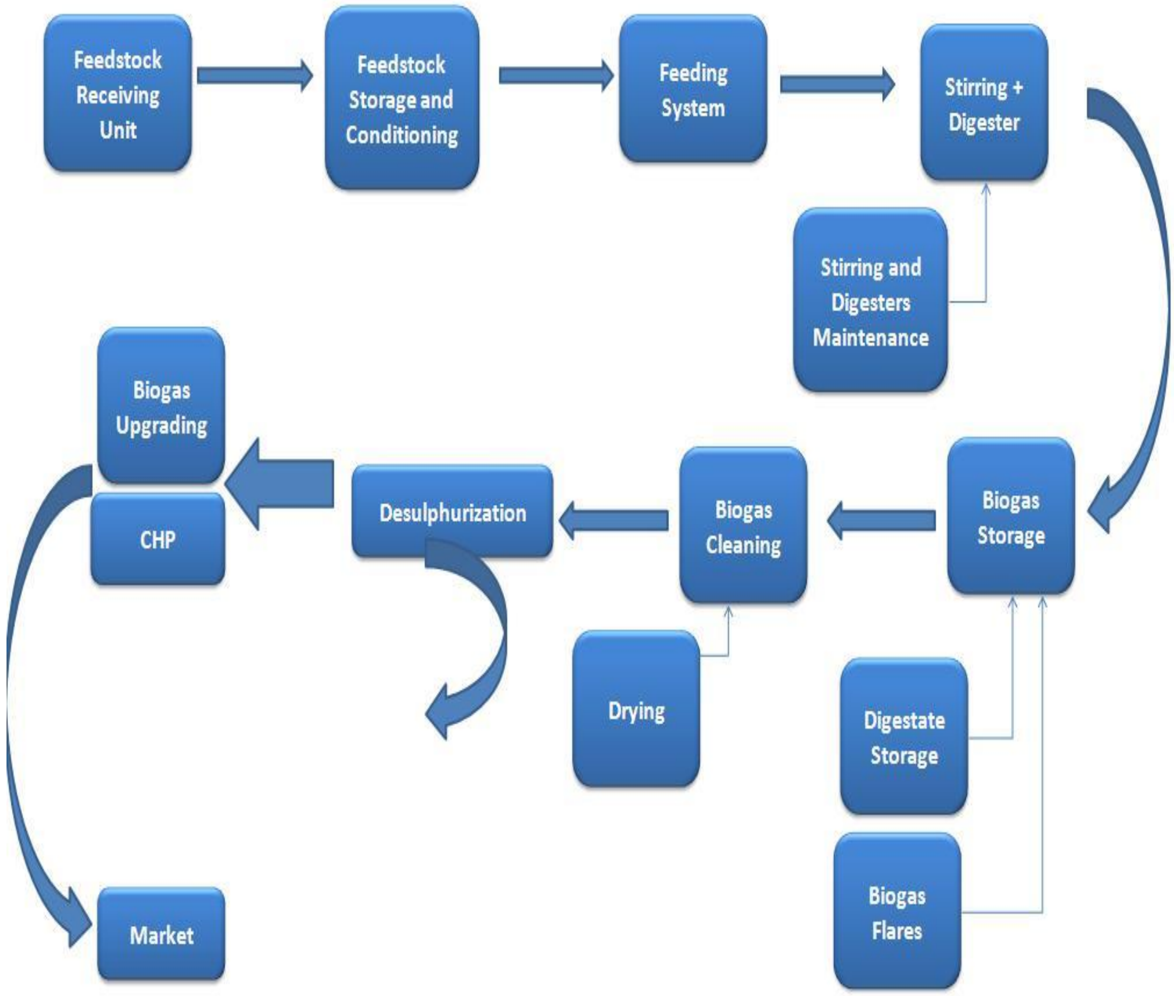

Figure 30 - Process chain for biomethane production. (Source: IrRADIARE, Science for Evolution, 2013)

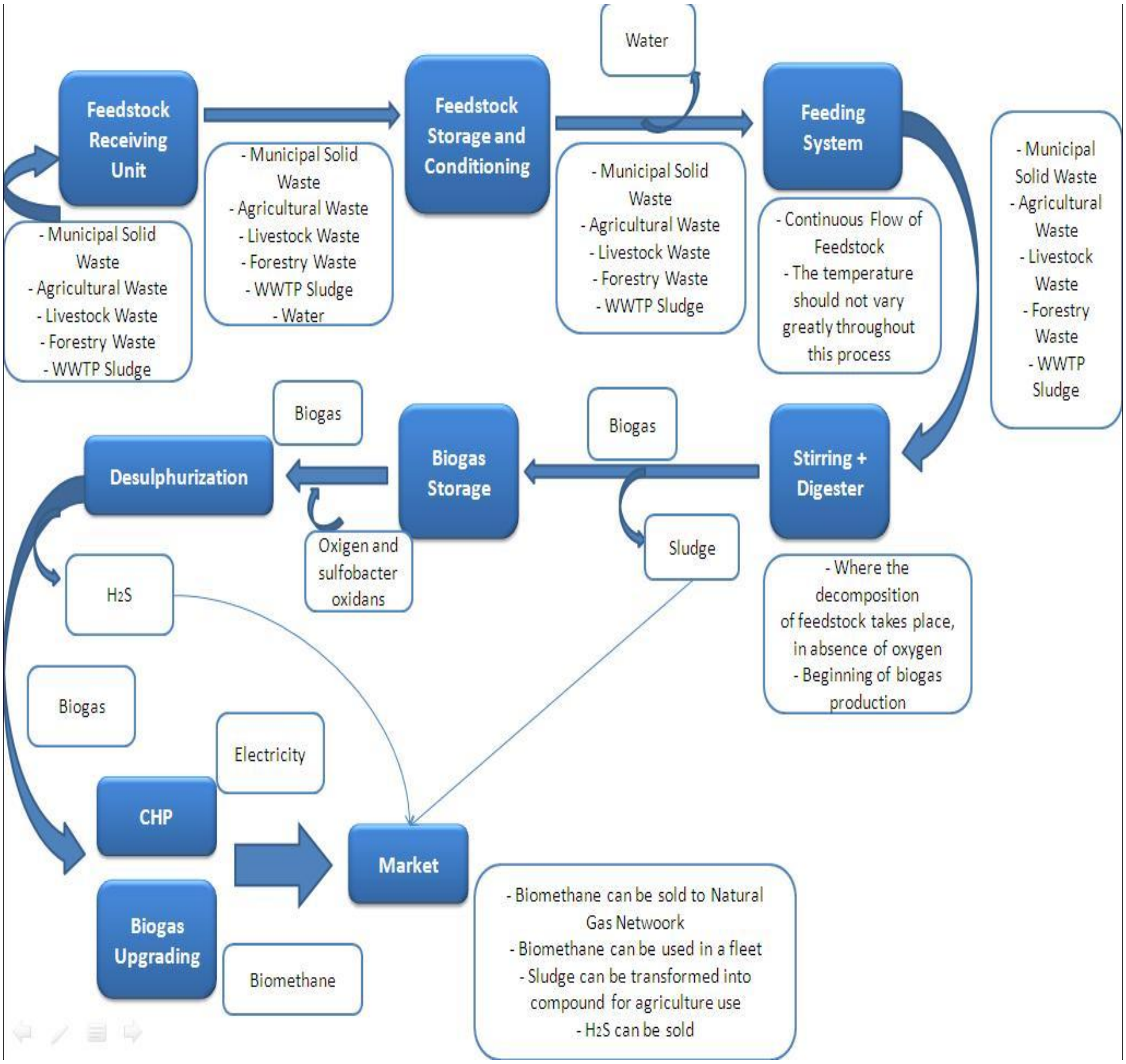

Figure 31 –Biomethane production chain – Materials flow. (Source: IrRADIARE, Science for Evolution, 2013)

7) Strategies for a successful biomethane production in Abrantes

Creating and maintaining a sustainable demand for biomethane

One of the strategies adopted for a success production of biomethane in Abrantes was the creation of three distinct scenarios that present three different ways of waste management approach in the region. These scenarios are based on some cases of studies (which are in annexes). Then the three scenarios are presented and detailed.

Scenario 1

"User-Pays" Scenario – Payment for all produced waste

Summary - Among the basic principles of environmental policy, it includes the "principle of responsibility" that "points to the assumption by polluters for the consequences in others for their action, direct or indirect, over natural resources". Thus, the consumer (polluter) is forbidden to pollute, so the consumer should pay the costs of waste disposal and if don't, the consumer will have the responsibility of paying the "social" cost of a pollutant action (through fines, damages, etc.).

<table>
<tr><th>Before</th><th>After</th></tr>
<tr><td>Green containers system for mixed waste deposit</td><td rowspan="2">Creating a single container that includes a scale (where you can weigh the waste), a payment system (e.g. ATM) and an opening that only opens if the person makes their waste payment.</td></tr>
<tr><td>Selective Deposition: Yellow container is used for plastic deposition, blue container is used for deposition of paper and similar, green container is used for deposition of glass, red container is used for deposition of batteries and cells and orange container is used for deposition of cooking oils.</td></tr>
<tr><td>Mixed waste is processed in a transfer station, but most are sent to landfill</td><td rowspan="2">At the transfer station should be done the separation of mixed waste that will join already separated waste by people in the single container (on the street).</td></tr>
<tr><td>Selective waste are sent directly to the transfer station and treated according their type (paper, plastic or glass)</td></tr>
</table>

Payment of a waste fee that comes along with water invoice	The fee that comes along with water invoice disappears and a fee would be applied to mixed waste and selective waste. This fee would have different values for each of cases; it would be assigned a higher value in case of mixed waste, thus forcing people to make separation of their waste.
Scenario Principle	“User-Pays” Principle
Food distribution companies, eg, use unnecessary plastic packaging – it produces too many waste	Make an effort to minimize the production of plastic packaging - Involvement of companies that are responsible for packaging product.
Plastic bags utilization	Remove the habit of plastic bags using in shopping and introduce a new technology that consists in bags with easy degradation or biodegradables bags. It may be used cloth or paper bags.
Plastic packaging utilization	Place on market organic biodegradable packages or lighter packages that are easily biodegradable. Avoid as much as possible plastics use and replace plastic packaging for packaging with a specific expiration date (past the expiration date, the package will begin to degrade itself – new technology).
Bulky waste, scrap metal, end of life cars and garden leftover are free removed. You should make a call for the entity who is responsible for the collection and combine a day and time to be collected	The collection of such waste should be carried in the same way however the service should be charged.
Waste collection in Abrantes is made up of two entities, VALNOR (selective waste) and SMA (mixed waste).	The collection could now be done only by one company to save resources.
Use of used cooking oil for biodiesel production and use of it in their equipment	Sale of over produced biodiesel
Existence of an unit which allows to obtain	Make a connection between Anaerobic

Anaerobic Digestion gains in energy production.	Digestion and Cogeneration thus achieving energy savings
	Create a partnership with wastewater treatment plants in the area to use their sludge in anaerobic digestion
	Create optimal conditions within anaerobic digester for digestion becomes faster and more efficient
	Use of biomethane in vehicles
Energy production	Injection of excess energy in the network and use of produced energy
Indicators 2010	
Number of residents covered by VALNOR	167.771
Total MSW (t)	126.467
Capitation of MSW (kg/inhab.year)	461
Total selective collection (t)	8.638,9
Capitation of selective collection (kg/inhab.year)	45
Amount of waste sent to landfill (t)	107.509
Municipal waste sent to units of organic recovery (t)	7.508
Municipal waste sent for recycling (t)	11.450
Number of ecopoints	1.060
Amount of waste exported for recovery operations and disposal (t)	56.109
Expenditure of Local Government per capita in waste management field (€/inhabitant)	25 - 50
Number of campaigns characterization of MSW (No/year)	10

Expense of Public Administration with Waste Management (10^3 Euros)	552.927	
	Before	After
Capitation of MSW (kg/inhab.year)	461	+
Capitation of selective collection (kg/inhab.year)	45	+
Inhabitants/Ecopoints	158	++
% Mixed Waste		0
% Selected Waste (by people)		++
Average rate charged for the services of waste disposal (€)		++
% Recycling of plastic packaging		-
Use of plastic bags/capita		--
Quantity of biodiesel /year (L/year)		+
Energy produced in anaerobic digestion		+
% Energy injected into the network		++
Legend: ++ ➔ Great growth + ➔ Smooth growth 0 ➔ Stabilization - ➔ Decrease -- ➔ Abrupt decrease		

SWOT Analysis	
Strengths	**Weaknesses**
Policy and regulatory framework positive to the implementation of measures to promote energy efficiency; Policy and regulatory framework positive to the implementation of measures to reduce dependence on fossil fuels, particularly for renewable generation; Local dynamism and entrepreneurship of community; Waste reduction by the population; Increased conditioning of waste produced.	Limitations on the ability of public investment, which leads to the implementation of measures occur predominantly based on structural funds or private investment; This limitation leads to greater dispersion in leadership processes and introduces greater weakness in waste management; Objection by the population of the implementation of the new measures
Opportunities	**Threats**
Existence of funding opportunities for energy efficiency measures in private investment (VALNOR); Global political context favors the action at local level; Awareness of people for the amount of waste produced; Actions of awareness that allows the minimization of waste production in their homes; Opportunity for packing companies to show new technologies and expansion in international market, these same technologies	Existence and perception of a serious economic crisis may make it difficult to implement measures with investment; Natural resistance to change may dictate the use of traditionally used solutions; Difficulties in obtaining financing; Vandalism of containers; Waste disposing in inappropriate places; Waste accumulation in people's homes

Integration with Covenant of Mayors	
Measure	**Impact**
ACTIVE MONITORING Provide technologies that enable smart metering energy data collection like water use, electricity and gas, in order to create a more efficient management of resources analyzed.	The introduction of appropriate waste management, consumption monitoring and adoption of good practice in equipment use allows minimizing energy waste. Monitoring lets you analyze and receive all data collected in real time, ie, checks the entire system and where there is something irregular on system it generates an alert that allows a correction in real-time.
DOMESTIC EQUIPMENT RENEWAL Promote a gradual household renewal that are energy inefficient, especially appliances.	Due technological advances growing consumers have at their disposal equipment more efficient and therefore should be promoted more or less regular replacement of existing household equipment in housing with more efficient models. However this will have consequences in terms of waste production. The old equipment should be sent to appropriate locations, dismantled and the parts that can be grasped should be seized.
MODERNIZATION EQUIPMENT Gradually renew the equipment, replacing equipment by more efficient equipment in particular driving forces equipment.	All equipment has a life time. With the passage of the "year" equipment begin to be less efficient, i.e., begin to spend more energy resources for the same function, and this increases the waste production. However, as the domestic equipment renewal, the old equipment should be referred to appropriate locations, dismantled and parts that can still be reused should be exploited in new equipment.
BIODIESEL Biodiesel use as a main fuel for the fleet for cars with internal combustion engine of diesel type.	Currently transport sector is almost entirely dependent on petroleum products, which makes it a major contributor to greenhouse gases emissions. As the biodiesel produced from oils, used or new, of vegetable or animal

	origin, this biofuel is a sustainable energy source alternative to using diesel so there is a reduction of greenhouse gases emissions and waste recovery.
WASTE MANAGEMENT Designing or improving waste management model, achieving maximum efficiency in energy use.	The organic recovery is a strategic measure to reduce GHG emissions. The separation, collection and routing of organic matter to a treatment station allows biogas production which can be used to produce energy and for producing a "compound" of high quality for agriculture. The waste sector is responsible for direct and indirect emissions that can be reduced using a waste management model. Direct emissions arise primarily from support activities, such as the consumption of fossil fuels in incineration and composting operation and collection fleets and mobile machinery existing in landfills. Indirect emissions are associated with electricity consumed on facilities.
GREEN PUBLIC PROCUREMENT Designing a tool to measure ecologically all purchases as energy using equipment, vehicles and contracts.	The purchase of ecological products or services by public bodies gives a positive image to the market, serving as an example to other identities, and encourages companies to seek innovate their products so that these products are truly sustainable. Comes the need to develop a tool that takes into consideration ecological criteria to be applied under new public procurement policy and to measure ecologically all products and services to be contracted by municipal services.

Projection for scenario 1

For scenario 1 was made a projection of the functioning of the biogas production plant. The results of the projection are presented in the table shown below [Table 32].

Table 32 - Projection for scenario 1.

Scenario 1 - Payment for all produced waste						
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Inputs (Amount)	**Units**					
Population	Inhab.		260.434,04	259.482,46	258.529,82	257.577,14
Process (Amount)						
Sewage Sludge	ton		3.531,80	3.884,98	4.273,48	4.700,83
Municipal Solid Waste	ton		39.875,20	40.672,70	41.079,43	41.490,23
Livestock Waste	ton		9.755,00	12.681,50	19.022,25	24.728,93
Forest Waste	ton		1.350,00	1.377,00	1.404,54	1.432,63
Agricultural Waste	ton		8.978,00	9.157,56	11.904,83	12.142,92
Total Waste	ton		63.490,00	67.773,74	77.684,53	84.495,53
% send to landfill - Sewage Sludge	%		25,61	18,17	9,99	0,99
% send to landfill - Municipal Solid Waste	%		45,22	44,12	43,56	43,00
% send to landfill - Livestock Waste	%		94,38	92,69	89,04	85,75
% send to landfill - Forest Waste	%		14,65	12,94	11,20	9,43
% send to landill - Agricultural Waste	%		65,17	64,47	53,82	52,89
Dimensioning						
Substrate_volume_load - Sewage Sludge	[kg oDM/d]		2.419,04	2.660,95	2.927,04	3.219,74
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]		7.756,55	7.911,68	7.990,79	8.070,70
Substrate_volume_load - Livestock Waste	[kg oDM/d]		6.681,51	8.685,96	13.028,94	16.937,62
Substrate_volume_load - Forest Waste	[kg oDM/d]		406,85	414,99	423,29	431,75
Substrate_volume_load - Agricultural Waste	[kg oDM/d]		983,89	1.003,57	1.304,64	1.330,73
Substrate_volume_load - TOTAL	[kg oDM/d]		18.247,83	20.677,14	25.674,70	29.990,55
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**

Required Volume in the Digesters	m^3		5.914,14	6.313,17	7.236,37	7.870,82
Hidraulic Retention Time	days		34	34	34	34
Organic load	[kg oDM/m³d]		3,0855	3,2752	3,5480	3,8103
Number of digestors	nº	1	1	1	2	2
Digesters Selected Volume	m^3	6000	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	6000	7000	7000	14000	14000
Outputs						
Biogas Volume - Sewage sludge	m^3/d		1.524,00	1.676,40	1.844,04	2.028,44
Biogas Volume - Municipal Solid Waste	m^3/d		5.437,34	5.546,09	5.601,55	5.657,56
Biogas Volume - Livestock Waste	m^3/d		2.111,36	2.744,76	4.117,14	5.352,29
Biogas Volume - Forest Waste	m^3/d		183,08	186,74	190,48	194,29
Biogas Volume - Agricultural Waste	m^3/d		645,43	658,34	855,84	872,96
Biogas Volume - Total	m^3/d		9.901,20	10.812,33	12.609,05	14.105,54
Biogas Volume - Total	m^3/yr		3.613.939,80	3.946.499,88	4.602.302,31	5.148.520,71
Electricity produced	kWh/yr		3.722.357,99	4.064.894,87	4.740.371,38	5.302.976,33
Upgrading - Biomethane Production						
Chemical Absortion	m^3/yr		3.252.545,82	3.551.849,89	4.142.072,08	4.633.668,64
High Pressure Water Scrubbing	m^3/yr		3.397.103,41	3.709.709,88	4.326.164,18	4.839.609,47
Pressure Swing Adsorption	m^3/yr		3.288.685,22	3.591.314,89	4.188.095,11	4.685.153,85
Cryogenic separation	m^3/yr		3.541.661,00	3.867.569,88	4.510.256,27	5.045.550,30
Membrane separation	m^3/yr		2.818.873,04	3.078.269,90	3.589.795,80	4.015.846,15

		Year 5	Year 6	Year 7	Year 8
Inputs (Amount)	**Units**				
Population	Inhab.	256.618,33	255.664,77	254.711,47	253.758,18
Process (Amount)					
Sewage Sludge	ton	4.700,83	4.700,83	4.747,83	4.747,83
Municipal Solid Waste	ton	43.564,74	45.742,97	54.891,57	71.359,04
Livestock Waste	ton	37.093,39	48.221,40	72.332,11	115.731,37
Forest Waste	ton	1.461,28	1.490,51	1.520,32	1.550,73
Agricultural Waste	ton	12.750,07	13.770,08	16.524,09	21.481,32
Total Waste	ton	99.570,30	113.925,79	150.015,92	214.870,29
% send to landfill - Sewage Sludge	%	0,99	0,99	0,00	0,00
% send to landfill - Municipal Solid Waste	%	40,15	37,15	24,59	1,96
% send to landfill - Livestock Waste	%	78,63	72,22	58,33	33,33
% send to landfill - Forest Waste	%	7,62	5,77	3,88	1,96
% send to landill - Agricultural Waste	%	50,54	46,58	35,90	16,67
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.219,74	3.219,74	3.251,94	3.251,94
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	8.474,24	8.897,95	10.677,54	13.880,80
Substrate_volume_load - Livestock Waste	[kg oDM/d]	25.406,43	33.028,36	49.542,54	79.268,06
Substrate_volume_load - Forest Waste	[kg oDM/d]	440,39	449,19	458,18	467,34
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	1.397,27	1.509,05	1.810,86	2.354,12
Substrate_volume_load - TOTAL	[kg oDM/d]	38.938,06	47.104,29	65.741,05	99.222,26
Required Volume in the Digesters	m^3	9.820,63	12.485,02	16.440,10	25.902,17
Hidraulic Retention Time	days	36	40	40	44
Organic load	[kg oDM/m³d]	3,9649	3,7729	3,9988	3,8307
Number of digestors	nº	2	2	3	4

		Year 5	Year 6	Year 7	Year 8
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	14000	14000	21000	28000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.028,44	2.028,44	2.048,72	2.048,72
Biogas Volume - Municipal Solid Waste	m^3/d	5.940,44	6.237,46	7.484,95	9.730,44
Biogas Volume - Livestock Waste	m^3/d	8.028,43	10.436,96	15.655,44	25.048,71
Biogas Volume - Forest Waste	m^3/d	198,17	202,14	206,18	210,30
Biogas Volume - Agricultural Waste	m^3/d	916,61	989,94	1.187,92	1.544,30
Biogas Volume - Total	m^3/d	17.112,09	19.894,94	26.583,22	38.582,48
Biogas Volume - Total	m^3/yr	6.245.913,57	7.261.651,50	9.702.876,42	14.082.603,46
Electricity produced	kWh/yr	6.433.290,98	7.479.501,04	9.993.962,71	14.505.081,57
Upgrading - Biomethane Production					
Chemical Absorption	m^3/yr	5.621.322,21	6.535.486,35	8.732.588,78	12.674.343,12
High Pressure Water Scrubbing	m^3/yr	5.871.158,75	6.825.952,41	9.120.703,83	13.237.647,25
Pressure Swing Adsorption	m^3/yr	5.683.781,35	6.608.102,86	8.829.617,54	12.815.169,15
Cryogenic separation	m^3/yr	6.120.995,30	7.116.418,47	9.508.818,89	13.800.951,39
Membrane separation	m^3/yr	4.871.812,58	5.664.088,17	7.568.243,61	10.984.430,70

		Year 9	Year 10	Year 11	Year 12
Inputs (Amount)	**Units**				
Population	Inhab.	252.804,89	251.852,13	250.898,70	249.945,22
Process (Amount)					
Sewage Sludge	ton	4.747,83	4.747,83	4.795,31	4.843,27
Municipal Solid Waste	ton	72.786,22	54.589,66	40.942,25	30.706,69
Livestock Waste	ton	173.597,05	178.804,97	184.169,11	189.694,19
Forest Waste	ton	1.581,74	1.550,11	1.550,11	1.550,11
Agricultural Waste	ton	25.777,58	26.035,36	26.295,71	26.295,71
Total Waste	ton	278.490,43	265.727,93	257.752,49	253.089,96
% send to landfill - Sewage Sludge	%	0,00	0,00	-1,00	-2,01
% send to landfill - Municipal Solid Waste	%	0,00	25,00	43,75	57,81
% send to landfill - Livestock Waste	%	0,00	-3,00	-6,09	-9,27
% send to landfill - Forest Waste	%	0,00	2,00	2,00	2,00
% send to landill - Agricultural Waste	%	0,00	-1,00	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.251,94	3.251,94	3.284,46	3.317,31
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	14.158,42	10.618,81	7.964,11	5.973,08
Substrate_volume_load - Livestock Waste	[kg oDM/d]	118.902,09	122.469,15	126.143,23	129.927,53
Substrate_volume_load - Forest Waste	[kg oDM/d]	476,69	467,16	467,16	467,16
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.824,94	2.853,19	2.881,72	2.881,72
Substrate_volume_load - TOTAL	[kg oDM/d]	139.614,08	139.660,25	140.740,67	142.566,79
Required Volume in the Digesters	m^3	35.097,42	36.401,09	35.308,56	38.136,84
Hidraulic Retention Time	days	46	50	50	55
Organic load	[kg oDM/m^3d]	3,9779	3,8367	3,9860	3,7383
Number of digestors	nº	6	6	6	6

		Year 9	Year 10	Year 11	Year 12
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	42000	35000	35000	35000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.048,72	2.048,72	2.069,21	2.089,90
Biogas Volume - Municipal Solid Waste	m^3/d	9.925,05	7.443,79	5.582,84	4.187,13
Biogas Volume - Livestock Waste	m^3/d	37.573,06	38.700,25	39.861,26	41.057,10
Biogas Volume - Forest Waste	m^3/d	214,51	210,22	210,22	210,22
Biogas Volume - Agricultural Waste	m^3/d	1.853,16	1.871,69	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	51.614,50	50.274,67	49.613,94	49.434,76
Biogas Volume - Total	m^3/yr	18.839.293,93	18.350.256,33	18.109.088,07	18.043.687,33
Electricity produced	kWh/yr	19.404.472,75	18.900.764,02	18.652.360,71	18.584.997,95
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	16.955.364,54	16.515.230,70	16.298.179,26	16.239.318,59
High Pressure Water Scrubbing	m^3/yr	17.708.936,30	17.249.240,95	17.022.542,79	16.961.066,09
Pressure Swing Adsorption	m^3/yr	17.143.757,48	16.698.733,26	16.479.270,14	16.419.755,47
Cryogenic separation	m^3/yr	18.462.508,05	17.983.251,21	17.746.906,31	17.682.813,58
Membrane separation	m^3/yr	14.694.649,27	14.313.199,94	14.125.088,69	14.074.076,11
Inputs (Amount)	**Units**				
Population	Inhab.	248.991,74	248.038,27	247.092,38	246.139,14
Process (Amount)					
Sewage Sludge	ton	4.843,27	4.843,27	4.843,27	4.843,27
Municipal Solid Waste	ton	23.030,01	17.272,51	12.954,38	9.715,79
Livestock Waste	ton	195.385,01	201.246,56	207.283,96	213.502,48
Forest Waste	ton	1.550,11	1.550,11	1.550,11	1.550,11
Agricultural Waste	ton	26.295,71	26.295,71	26.295,71	26.295,71
Total Waste	ton	251.104,11	251.208,16	252.927,43	255.907,35
% send to landfill - Sewage Sludge	%	-2,01	-2,01	-2,01	-2,01
% send to landfill - Municipal Solid Waste	%	68,36	76,27	82,20	86,65

		Year 13	Year 14	Year 15	Year 16
% send to landfill - Livestock Waste	%	-12,55	-15,93	-19,41	-22,99
% send to landfill - Forest Waste	%	2,00	2,00	2,00	2,00
% send to landill - Agricultural Waste	%	-2,01	-2,01	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.317,31	3.317,31	3.317,31	3.317,31
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	4.479,81	3.359,86	2.519,89	1.889,92
Substrate_volume_load - Livestock Waste	[kg oDM/d]	133.825,35	137.840,11	141.975,32	146.234,57
Substrate_volume_load - Forest Waste	[kg oDM/d]	467,16	467,16	467,16	467,16
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.881,72	2.881,72	2.881,72	2.881,72
Substrate_volume_load - TOTAL	[kg oDM/d]	144.971,34	147.866,15	151.161,39	154.790,68
Required Volume in the Digesters	m^3	37.837,61	37.853,28	38.112,35	40.664,73
Hidraulic Retention Time	days	55	55	55	58
Organic load	[kg oDM/m³d]	3,8314	3,9063	3,9662	3,8065
Number of digestors	nº	6	6	6	6
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	35000	35000	35000	35000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.089,90	2.089,90	2.089,90	2.089,90
Biogas Volume - Municipal Solid Waste	m^3/d	3.140,35	2.355,26	1.766,45	1.324,83
Biogas Volume - Livestock Waste	m^3/d	42.288,81	43.557,48	44.864,20	46.210,13
Biogas Volume - Forest Waste	m^3/d	210,22	210,22	210,22	210,22
Biogas Volume - Agricultural Waste	m^3/d	1.890,41	1.890,41	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	49.619,69	50.103,27	50.821,18	51.725,49
		Year 13	**Year 14**	**Year 15**	**Year 16**
Biogas Volume - Total	m^3/yr	18.111.186,93	18.287.692,70	18.549.729,51	18.879.804,35

Electricity produced	kWh/yr	18.654.522,54	18.836.323,48	19.106.221,40	19.446.198,48
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	16.300.068,24	16.458.923,43	16.694.756,56	16.991.823,91
High Pressure Water Scrubbing	m^3/yr	17.024.515,71	17.190.431,13	17.436.745,74	17.747.016,09
Pressure Swing Adsorption	m^3/yr	16.481.180,11	16.641.800,35	16.880.253,86	17.180.621,96
Cryogenic separation	m^3/yr	17.748.963,19	17.921.938,84	18.178.734,92	18.502.208,26
Membrane separation	m^3/yr	14.126.725,81	14.264.400,30	14.468.789,02	14.726.247,39

Table 33 - Tabled constants used in the model.

Tabled Constants		
Materials	**Biogas yield (L/kg oDM) - Biomax final**	**% oDM - Biomax final**
Sewage Sludge	630	25
Municipal Solid Waste	701	7,1
Livestock Waste	316	25
Forest Waste	450	11
Agricultural Waste	656	4
c CH4 (%) - methane content	0,103 %	
Hi CH4 (kWh/d)	10 kWh/d	
Upgrading	Yields (%)	
Chemical Absortion	90 %	
High Pressure Water Scrubbing	94 %	
Pressure Swing Adsorption	91 %	
Cryogenic separation	98 %	
Membrane separation	78 %	

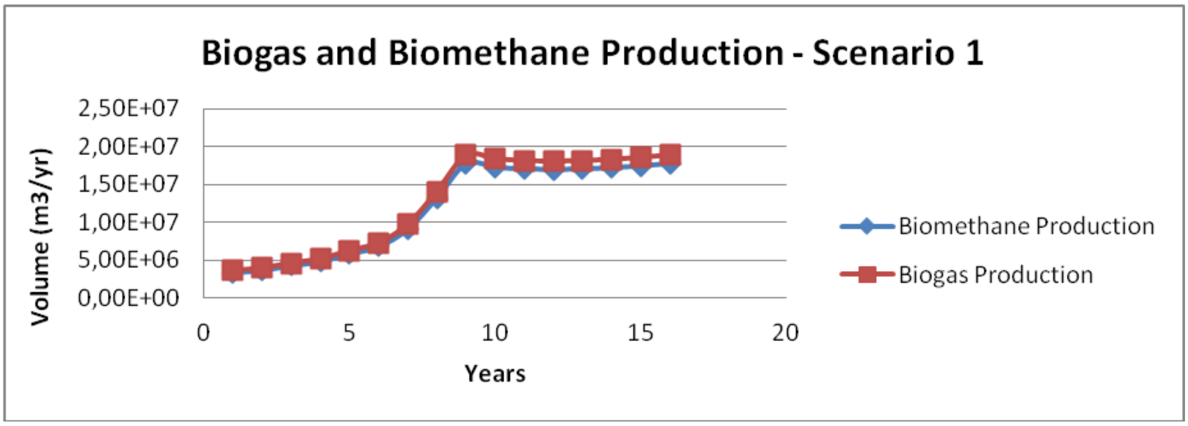

Figure 32 – Biogas and Biomethane production – Scenario 1.

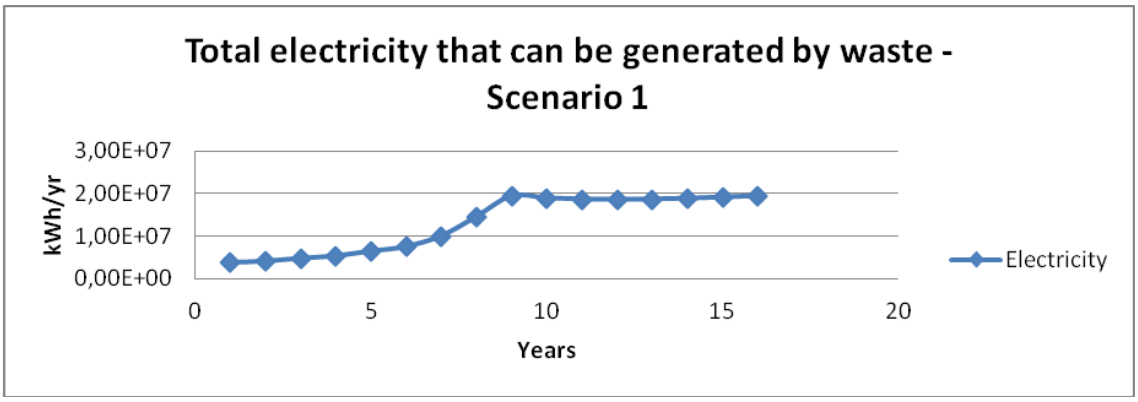

Figure 33 – Total electricity that can be generated by waste – Scenario 1.

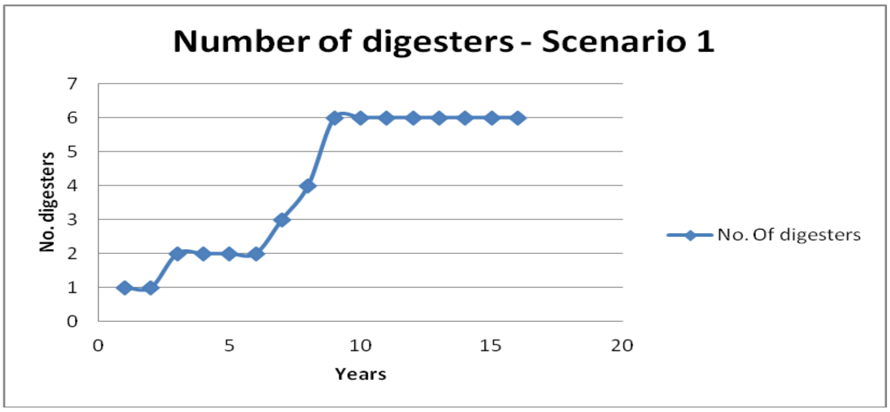

Figure 34 - Number of digesters needed to meet the needs - Scenario 1.

Projection explanations – Scenario 1

This scenario has the principle "The payment for all the waste produced."

For the creation of the projection presented above [Table 32] is only possible to observe a stabilization of input quantities at the biogas production unit from the year 9.

Was idealized a concept of perfection, if all waste quantities were sent to the production biogas unit, so we witness the effectively amount of biogas produced.

Also in the above table [Table 32] it can be seen the percentage of residues that are sent to landfill. When you have positive percentages it means that amount of waste is still sent to landfill and negative percentages means the amounts that could save their way to landfill.

For this scenario will be necessary to construct 6 digesters with 7,000 m^3 each. Each digester will be built in different years depending on the examination table [Table 32].

The electricity produced is the total electricity could be drawn from the total amount of biogas produced.

Each upgrading technology has different yields and so thought the table [Table 32] it is possible to analyze the amount produced by each of the technologies that can be implemented.

Economic projection for scenario 1

According to the materials flow projection made earlier for scenario 1 it was also made an economic projection for the same scenario that is going to be presented as follow:

Table 34 - Economic projection for scenario 1

		Year 0	Year 1	Year 2	Year 3	Year 4
Investment (€)	.	**4325083**	**0**	**3589420**	**0**	**0**
Intallations (digesters)	€	2550000	0	2550000	0	0
Machinery Technology	€	450000	0	450000	0	0
Other investments (infrastruture)	€	1325083	0	589420		0
Overhead expenses for approval and planning (10% of total investment)	€	43251	0	35894	0	0
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Revenues (€)	.		**3087258**	**3320542**	**3828128**	**4218281**
Material that can't be digested (metals)	€		139	149	171	185
Electricity	€		580688	634124	739498	827264
Digesters Waste	€		31428	33548	38454	41825
Consulting and Methods	€		1000	1000	1000	1000
Technical Training	€		700	700	700	15000
Biomethane	€		441623	482262	562401	629149
Cost does not go to landfill	€		1396780	1491022	1709060	1858902
Sludge	€		634900	677737	776845	844955
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Expenses (€)		**9323588**	**9323588,1**	**9757243**	**9323588,1**	**9323588**
Amortization	€	2168276	2168276,3	2168276	2168276,3	2168276
Operation and maintenance costs	€	7155312	7155311,8	7588967	7155311,8	7155312
Balance	€	-9323588	-6236330	-6436701	-5495460	-5105307

		Year 5	Year 6	Year 7	Year 8	Year 9
Investment (€)	.	**0**	**3589420**	**3589420**	**6589420**	**0**
Intallations (digesters)	€	0	2550000	2550000	5100000	0
Machinery Technology	€	0	450000	450000	900000	0
Other investments (infrastruture)	€	**0**	589420	589420	589420	0
Overhead expenses for approval and planning (10% of total investment)	€	0	35894	35894	65894	0
		Year 5	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Revenues (€)	.	**5018600**	**5772445**	**7635847**	**10982370**	**14395420**
Material that can't be digested (metals)	€	219	250	329	472	611
Electricity	€	1003593	1166802	1559058	2262793	3027098
Digesters Waste	€	49287	56393	74258	106361	137853
Consulting and Methods	€	1000	1000	1000	1000	1000
Technical Training	€	15000	15000	15001	15002	15003
Biomethane	€	763251	887374	1185691	1720894	2302162
Cost does not go to landfill	€	2190547	2506367	3300350	4727146	6126789
Sludge	€	995703	1139258	1500159	2148703	2784904
		Year 5	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Expenses (€)		**9323588**	**10190899**	**10841382**	**11058209**	**11058209**
Amortization	€	2168276	2168276	2168276	2168276	2168276
Operation and maintenance costs	€	7155312	8022622	8673105	8889933	8889933
Balance	€	-4304988	-4418454	-3205534	-75838,7	3337211

		Year 10	Year 11	Year 12	Year 13
Investment (€)	.	**0**	**0**	**0**	**0**
Intallations (digesters)	€	0	0	0	0
Machinery Technology	€	0	0	0	0
Other investments (infrastruture)	€	0	0	0	0
Overhead expenses for approval and planning (10% of total investment)	€	0	0	0	0
		Year 10	**Year 11**	**Year 12**	**Year 13**
Revenues (€)	.	**13842337**	**13514937**	**13344918**	**13299479**
Material that can't be digested (metals)	€	583	566	555	551
Electricity	€	2948519	2909768	2899260	2910106
Digesters Waste	€	131535	127587	125280	124297
Consulting and Methods	€	1000	1000	1000	1000
Technical Training	€	15004	15005	15006	15007
Biomethane	€	2242401	2212931	2204939	2213187
Cost does not go to landfill	€	5846014	5670555	5567979	5524290
Sludge	€	2657279	2577525	2530900	2511041
		Year 10	**Year 11**	**Year 12**	**Year 13**
Expenses (€)		**11058209**	**8889933**	**8889933**	**8889933**
Amortization	€	2168276	0	0	0
Operation and maintenance costs	€	8889933	8889933	8889933	8889933
Balance	€	2784128	4625004	4454985	4409546

		Year 14	Year 15	Year 16
Investment (€)	.	**0**	**0**	**0**
Intallations (digesters)	€	0	0	0
Machinery Technology	€	0	0	0
Other investments (infrastruture)	€	0	0	0
Overhead expenses for approval and planning (10% of total investment)	€	0	0	0
		Year 14	**Year 15**	**Year 16**
Revenues (€)	.	**13352791**	**13482788**	**13673000**
Material that can't be digested (metals)	€	551	555	562
Electricity	€	2938466	2980571	3033607
Digesters Waste	€	124348	125199	126674
Consulting and Methods	€	1000	1000	1000
Technical Training	€	15008	15009	15010
Biomethane	€	2234756	2266777	2307112
Cost does not go to landfill	€	5526579	5564403	5629962
Sludge	€	2512082	2529274	2559074
		Year 14	**Year 15**	**Year 16**
Expenses (€)		**8889933**	**8889933**	**8889933**
Amortization	€	0	0	0
Operation and maintenance costs	€	8889933	8889933	8889933
Balance	€	4462858	4592856	4783067

Table 35 - Data used in the calculations of economic projection - Scenario 1

Material that can't be digested - 7% of the Total	**by ton**	**0,236**	**€**
Electricity	by kWh	0,156	€
Digesters Waste - 1% of the Total	by ton	50	€
Consulting and Methods	annual	1000	€
Technical Training	annual	700	€
Biomethane	by m^3	0,13	€
Sludge	by ton	100	€
Investment			
Approximate cost of each digester	€	2.550.000	
Technology cost	€	450.000	

Economic projection conclusions – Scenario 1

By analyzing the table [Table 34] can be concluded that:

Table 36 - Economic projection conclusions - Scenario 1

Payback	**Year 9**
Total Investment	21.682.763
Years of big investments	Year 0
	Year 2
	Year 6
	Year 7
	Year 8

Scenario 2

Waste separation incentive scenario

Summary - In terms of waste prevention policy, it is important to raise awareness and involvement of all stakeholders in order to develop promotional activities that contribute to waste production prevention. It can therefore be considered monetary incentive a promotional action for waste separation in source.

<table>
<tr><th>Before</th><th>After</th></tr>
<tr><td>Green containers system for mixed waste deposit</td><td rowspan="2">Separation is performed in respective houses, waste delivery is done in transfer stations and reception of a monetary incentive for waste produced. People only receive monetary incentives for separated waste (paper, plastic, glass, batteries and oils).</td></tr>
<tr><td>Selective Deposition: Yellow container is used for plastic deposition, blue container is used for deposition of paper and similar, green container is used for deposition of glass, red container is used for deposition of batteries and cells and orange container is used for deposition of cooking oils.</td></tr>
<tr><td>Mixed waste is processed in a transfer station, but most are sent to landfill</td><td rowspan="2">At the transfer station should be done the separation of mixed waste that will join the waste already separated and delivered by people at transfer station</td></tr>
<tr><td>Selective waste are sent directly to the transfer station and treated according their type (paper, plastic or glass)</td></tr>
<tr><td>Payment of a waste fee that comes along with water invoice</td><td>Should keep up the fee on waste production since there is waste that can’t be delivered on transfer station (mixed waste)</td></tr>
<tr><td>Scenario Principle</td><td>Prevention Principle</td></tr>
</table>

Food distribution companies, eg, use unnecessary plastic packaging – it produces too many waste	Make an effort to minimize the production of plastic packaging - Involvement of companies that are responsible for packaging product.
Plastic bags utilization	Remove the habit of plastic bags using in shopping and introduce a new technology that consists in bags with easy degradation or biodegradables bags. It may be used cloth or paper bags.
Plastic packaging utilization	Place on market organic biodegradable packages or lighter packages that are easily biodegradable. Avoid as much as possible plastics use and replace plastic packaging for packaging with a specific expiration date (past the expiration date, the package will begin to degrade itself – new technology).
Bulky waste, scrap metal, end of life cars and garden leftover are free removed. You should make a call for the entity who is responsible for the collection and combine a day and time to be collected	The collection of such waste should be carried in the same way however the service should be charged.
Waste collection in Abrantes is made up of two entities, VALNOR (selective waste) and SMA (mixed waste).	The collection could now be done only by one company to save resources.
Use of used cooking oil for biodiesel production and use of it in their equipment	Sale of over produced biodiesel
Existence of an unit which allows to obtain Anaerobic Digestion gains in energy production.	Make a connection between Anaerobic Digestion and Cogeneration thus achieving energy savings
	Create a partnership with wastewater treatment plants in the area to use their sludge in anaerobic digestion
	Create optimal conditions within anaerobic digester for digestion becomes faster and more efficient
	Use of biomethane in vehicles

Energy production	Injection of excess energy in the network and use of produced energy	
Indicadors 2010		
Number of residents covered by VALNOR	167.771	
Total MSW (t)	126.467	
Capitation of MSW (kg/inhab.year)	461	
Total selective collection (t)	8.638,9	
Capitation of selective collection (kg/inhab.year)	45	
Amount of waste sent to landfill (t)	107.509	
Municipal waste sent to units of organic recovery (t)	7.508	
Municipal waste sent for recycling (t)	11.450	
Number of ecopoints	1.060	
Amount of waste exported for recovery operations and disposal (t)	56.109	
Expenditure of Local Government per capita in waste management field (€/inhabitant)	25 - 50	
Number of campaigns characterization of MSW (No./year)	10	
Expense of Public Administration with Waste Management (10^3 Euros)	552.927	
	Before	**After**
Capitation of MSW (kg/inhab.year)	461	+
Capitation of selective collection (kg/inhab.year)	45	++

Inhabitants/Ecopoints		+
% Mixed Waste	158	-
% Selected Waste (by people)		++
Average rate charged for the services of waste disposal (€)		++
% Recycling of plastic packaging		++
Use of plastic bags/capita		-
Quantity of biodiesel /year (L/year)		++
Energy produced in anaerobic digestion		+
% Energy injected into the network		++
Legend: ++ ➔ Great growth + ➔ Smooth growth 0 ➔ Stabilization - ➔ Decrease -- ➔ Abrupt decrease		

SWOT Analysis	
Strengths	**Weaknesses**
Policy and regulatory framework positive to the implementation of measures to promote energy efficiency; Policy and regulatory framework positive to the implementation of measures to reduce dependence on fossil fuels, particularly for renewable generation; Local dynamism and entrepreneurship of community; Lower costs associated with moving from companies in waste collection	Limitations on the ability of public investment, which leads to the implementation of measures occur predominantly based on structural funds or private investment; This limitation leads to greater dispersion in leadership processes and introduces greater weakness in waste management

Opportunities	**Threats**
Existence of funding opportunities for energy efficiency measures in private investment (VALNOR); Global political context favors the action at local level; Awareness of people for the amount of waste produced; Actions of awareness that allows the minimization of waste production in their homes; Opportunity for packing companies to show new technologies and expansion in international market, these same technologies; Save money in collecting waste and investment in another areas	Existence and perception of a serious economic crisis may make it difficult to implement measures with investment; Natural resistance to change may dictate the use of traditionally used solutions; Difficulties in obtaining financing; Vandalism of containers; May have little adhesion due to the movement that people have to make
Integration with Covenant of Mayors	
Measure	**Impact**
ACTIVE MONITORING Provide technologies that enable smart metering energy data collection like water use, electricity and gas, in order to create a more efficient management of resources analyzed.	The introduction of appropriate waste management, consumption monitoring and adoption of good practice in equipment use allows minimizing energy waste. Monitoring lets you analyze and receive all data collected in real time, ie, checks the entire system and where there is something irregular on system it generates an alert that allows a correction in real-time.
DOMESTIC EQUIPMENT RENEWAL Promote a gradual household renewal that are energy inefficient, especially appliances.	Due technological advances growing consumers have at their disposal equipment more efficient and therefore should be promoted more or less regular replacement of existing household equipment in housing with more efficient models. However this will have consequences in terms of waste production. The old equipment should be sent to appropriate locations, dismantled and the parts that can be grasped should be seized.

MODERNIZATION EQUIPMENT Gradually renew the equipment, replacing equipment by more efficient equipment in particular driving forces equipment.	All equipment has a life time. With the passage of the "year" equipment begin to be less efficient, ie, begin to spend more energy resources for the same function, and this increases the waste production. However, as the domestic equipment renewal, the old equipment should be referred to appropriate locations, dismantled and parts that can still be reused should be exploited in new equipment.
BIODIESEL Biodiesel use as a main fuel for the fleet for cars with internal combustion engine of diesel type.	Currently transport sector is almost entirely dependent on petroleum products, which makes it a major contributor to greenhouse gases emissions. As the biodiesel produced from oils, used or new, of vegetable or animal origin, this biofuel is a sustainable energy source alternative to using diesel so there is a reduction of greenhouse gases emissions and waste recovery.
WASTE MANAGEMENT Designing or improving waste management model, achieving maximum efficiency in energy use.	The organic recovery is a strategic measure to reduce GHG emissions. The separation, collection and routing of organic matter to a treatment station allows biogas production which can be used to produce energy and for producing a "compound" of high quality for agriculture. The waste sector is responsible for direct and indirect emissions that can be reduced using a waste management model. Direct emissions arise primarily from support activities, such as the consumption of fossil fuels in incineration and composting operation and collection fleets and mobile machinery existing in landfills. Indirect emissions are associated with electricity consumed on facilities.

GREEN PUBLIC PROCUREMENT Designing a tool to measure ecologically all purchases as energy using equipment, vehicles and contracts.	The purchase of ecological products or services by public bodies gives a positive image to the market, serving as an example to other identities, and encourages companies to seek innovate their products so that these products are truly sustainable. Comes the need to develop a tool that takes into consideration ecological criteria to be applied under new public procurement policy and to measure ecologically all products and services to be contracted by municipal services.

Projection for Scenario 2

For scenario 2 it was also made a projection of the functioning of the biogas production plant. The results of the projection are presented in the table shown below [Table 37].

Table 37 - Projection for Scenario 2.

Scenario 2 - Waste separation incentive scenario						
		Year 0	Year 1	Year 2	Year 3	Year 4
Inputs (Amount)	Units					
Population	Inhab.		260.434,04	259.482,46	258.529,82	257.577,14
Process (Amount)						
Sewage Sludge	ton		3.531,80	3.884,98	4.273,48	4.700,83
Municipal Solid Waste	ton		39.875,20	40.672,70	41.079,43	41.490,23
Livestock Waste	ton		9.755,00	12.681,50	19.022,25	24.728,93
Forest Waste	ton		1.350,00	1.377,00	1.404,54	1.432,63
Agricultural Waste	ton		8.978,00	9.157,56	11.904,83	12.142,92
Total Waste	ton		63.490,00	67.773,74	77.684,53	84.495,53
% send to landfill - Sewage Sludge	%		25,61	18,17	9,99	0,99
% send to landfill - Municipal Solid Waste	%		45,22	44,12	43,56	43,00
% send to landfill - Livestock Waste	%		94,38	92,69	89,04	85,75
% send to landfill - Forest Waste	%		14,65	12,94	11,20	9,43
% send to landill - Agricultural Waste	%		65,17	64,47	53,82	52,89
Dimensioning						
Substrate_volume_load - Sewage Sludge	[kg oDM/d]		2.419,04	2.660,95	2.927,04	3.219,74
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]		7.756,55	7.911,68	7.990,79	8.070,70
Substrate_volume_load - Livestock Waste	[kg oDM/d]		6.681,51	8.685,96	13.028,94	16.937,62

		Year 0	Year 1	Year 2	Year 3	Year 4
Substrate_volume_load - Forest Waste	[kg oDM/d]		406,85	414,99	423,29	431,75
Substrate_volume_load - Agricultural Waste	[kg oDM/d]		983,89	1.003,57	1.304,64	1.330,73
Substrate_volume_load - TOTAL	[kg oDM/d]		18.247,83	20.677,14	25.674,70	29.990,55
Required Volume in the Digesters	m^3		5.566,25	5.941,81	7.236,37	7.870,82
Hidraulic Retention Time	days		32	32	34	34
Organic load	[kg oDM/m³d]		3,2783	3,4799	3,5480	3,8103
Number of digestors	nº	1	1	1	2	2
Digesters Selected Volume	m^3	7000	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	7000	7000	7000	14000	14000
Outputs						
Biogas Volume - Sewage sludge	m^3/d		1.524,00	1.676,40	1.844,04	2.028,44
Biogas Volume - Municipal Solid Waste	m^3/d		5.437,34	5.546,09	5.601,55	5.657,56
Biogas Volume - Livestock Waste	m^3/d		2.111,36	2.744,76	4.117,14	5.352,29
Biogas Volume - Forest Waste	m^3/d		183,08	186,74	190,48	194,29
Biogas Volume - Agricultural Waste	m^3/d		645,43	658,34	855,84	872,96
Biogas Volume - Total	m^3/d		9.901,20	10.812,33	12.609,05	14.105,54
Biogas Volume - Total	m^3/yr		3.613.939,80	3.946.499,88	4.602.302,31	5.148.520,71
Electricity produced	kWh/yr		3.722.357,99	4.064.894,87	4.740.371,38	5.302.976,33
Upgrading - Biomethane Production						
Chemical Absortion	m^3/yr		3.252.545,82	3.551.849,89	4.142.072,08	4.633.668,64
High Pressure Water Scrubbing	m^3/yr		3.397.103,41	3.709.709,88	4.326.164,18	4.839.609,47
Pressure Swing Adsorption	m3/yr		3.288.685,22	3.591.314,89	4.188.095,11	4.685.153,85
Cryogenic separation	m3/yr		3.541.661,00	3.867.569,88	4.510.256,27	5.045.550,30
Membrane separation	m3/yr		2.818.873,04	3.078.269,90	3.589.795,80	4.015.846,15

		Year 5	Year 6	Year 7	Year 8
Inputs (Amount)	**Units**				
Population	Inhab.	256.618,33	255.664,77	254.711,47	253.758,18
Process (Amount)					
Sewage Sludge	ton	4.700,83	4.700,83	4.747,83	4.747,83
Municipal Solid Waste	ton	43.564,74	45.742,97	54.891,57	71.359,04
Livestock Waste	ton	37.093,39	48.221,40	72.332,11	115.731,37
Forest Waste	ton	1.461,28	1.490,51	1.520,32	1.550,73
Agricultural Waste	ton	12.750,07	13.770,08	16.524,09	21.481,32
Total Waste	ton	99.570,30	113.925,79	150.015,92	214.870,29
% send to landfill - Sewage Sludge	%	0,99	0,99	0,00	0,00
% send to landfill - Municipal Solid Waste	%	40,15	37,15	24,59	1,96
% send to landfill - Livestock Waste	%	78,63	72,22	58,33	33,33
% send to landfill - Forest Waste	%	7,62	5,77	3,88	1,96
% send to landill - Agricultural Waste	%	50,54	46,58	35,90	16,67
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.219,74	3.219,74	3.251,94	3.251,94
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	8.474,24	8.897,95	10.677,54	13.880,80
Substrate_volume_load - Livestock Waste	[kg oDM/d]	25.406,43	33.028,36	49.542,54	79.268,06
Substrate_volume_load - Forest Waste	[kg oDM/d]	440,39	449,19	458,18	467,34
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	1.397,27	1.509,05	1.810,86	2.354,12
Substrate_volume_load - TOTAL	[kg oDM/d]	38.938,06	47.104,29	65.741,05	99.222,26
Required Volume in the Digesters	m^3	10.366,22	11.860,77	17.262,11	25.902,17
Hidraulic Retention Time	days	38	38	42	44
Organic load	[kg oDM/m^{3}d]	3,7562	3,9714	3,8084	3,8307
Number of digestors	nº	2	2	3	4
Digesters Selected Volume	m^3	7000	7000	7000	7000

		Year 5	Year 6	Year 7	Year 8
Total Volume of the Digesters Available	m^3	14000	14000	21000	28000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.028,44	2.028,44	2.048,72	2.048,72
Biogas Volume - Municipal Solid Waste	m^3/d	5.940,44	6.237,46	7.484,95	9.730,44
Biogas Volume - Livestock Waste	m^3/d	8.028,43	10.436,96	15.655,44	25.048,71
Biogas Volume - Forest Waste	m^3/d	198,17	202,14	206,18	210,30
Biogas Volume - Agricultural Waste	m^3/d	916,61	989,94	1.187,92	1.544,30
Biogas Volume - Total	m^3/d	17.112,09	19.894,94	26.583,22	38.582,48
Biogas Volume - Total	m^3/yr	6.245.913,57	7.261.651,50	9.702.876,42	14.082.603,46
Electricity produced	kWh/yr	6.433.290,98	7.479.501,04	9.993.962,71	14.505.081,57
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	5.621.322,21	6.535.486,35	8.732.588,78	12.674.343,12
High Pressure Water Scrubbing	m^3/yr	5.871.158,75	6.825.952,41	9.120.703,83	13.237.647,25
Pressure Swing Adsorption	m3/yr	5.683.781,35	6.608.102,86	8.829.617,54	12.815.169,15
Cryogenic separation	m3/yr	6.120.995,30	7.116.418,47	9.508.818,89	13.800.951,39
Membrane separation	m3/yr	4.871.812,58	5.664.088,17	7.568.243,61	10.984.430,70

		Year 9	Year 10	Year 11	Year 12
Inputs (Amount)	**Units**				
Population	Inhab.	252.804,89	251.852,13	250.898,70	249.945,22
Process (Amount)					
Sewage Sludge	ton	4.747,83	4.700,36	4.653,35	4.606,82
Municipal Solid Waste	ton	72.786,22	76.425,53	80.246,81	84.259,15
Livestock Waste	ton	173.597,05	178.804,97	184.169,11	189.694,19
Forest Waste	ton	1.581,74	1.597,56	1.597,56	1.597,56
Agricultural Waste	ton	25.777,58	26.035,36	26.295,71	26.295,71
Total Waste	ton	278.490,43	287.563,77	296.962,54	306.453,42
% send to landfill - Sewage Sludge	%	0,00	1,00	1,99	2,97

		Year 9	Year 10	Year 11	Year 12
% send to landfill - Municipal Solid Waste	%	0,00	-5,00	-10,25	-15,76
% send to landfill - Livestock Waste	%	0,00	-3,00	-6,09	-9,27
% send to landfill - Forest Waste	%	0,00	-1,00	-1,00	-1,00
% send to landill - Agricultural Waste	%	0,00	-1,00	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.251,94	3.219,42	3.187,23	3.155,36
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	14.158,42	14.866,34	15.609,65	16.390,14
Substrate_volume_load - Livestock Waste	[kg oDM/d]	118.902,09	122.469,15	126.143,23	129.927,53
Substrate_volume_load - Forest Waste	[kg oDM/d]	476,69	481,46	481,46	481,46
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.824,94	2.853,19	2.881,72	2.881,72
Substrate_volume_load - TOTAL	[kg oDM/d]	139.614,08	143.889,56	148.303,29	152.836,19
Required Volume in the Digesters	m^3	38.149,37	39.392,30	40.679,80	41.979,92
Hidraulic Retention Time	days	50	50	50	50
Organic load	[kg oDM/m³d]	3,6597	3,6527	3,6456	3,6407
Number of digestors	nº	6	6	6	6
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	35000	35000	35000	35000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.048,72	2.028,24	2.007,95	1.987,87
Biogas Volume - Municipal Solid Waste	m^3/d	9.925,05	10.421,30	10.942,37	11.489,48
Biogas Volume - Livestock Waste	m^3/d	37.573,06	38.700,25	39.861,26	41.057,10
Biogas Volume - Forest Waste	m^3/d	214,51	216,66	216,66	216,66

		Year 9	Year 10	Year 11	Year 12
Biogas Volume - Agricultural Waste	m^3/d	1.853,16	1.871,69	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	51.614,50	53.238,14	54.918,64	56.641,52
Biogas Volume - Total	m^3/yr	18.839.293,93	19.431.920,26	20.045.305,40	20.674.155,36
Electricity produced	kWh/yr	19.404.472,75	20.014.877,86	20.646.664,56	21.294.380,02
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	16.955.364,54	17.488.728,23	18.040.774,86	18.606.739,82
High Pressure Water Scrubbing	m^3/yr	17.708.936,30	18.266.005,04	18.842.587,07	19.433.706,04
Pressure Swing Adsorption	m3/yr	17.143.757,48	17.683.047,43	18.241.227,91	18.813.481,37
Cryogenic separation	m3/yr	18.462.508,05	19.043.281,85	19.644.399,29	20.260.672,25
Membrane separation	m3/yr	14.694.649,27	15.156.897,80	15.635.338,21	16.125.841,18

		Year 13	Year 14	Year 15	Year 16
Inputs (Amount)	**Units**				
Population	Inhab.	248.991,74	248.038,27	247.092,38	246.139,14
Process (Amount)					
Sewage Sludge	ton	4.560,75	4.515,14	4.469,99	4.425,29
Municipal Solid Waste	ton	88.472,10	92.895,71	97.540,50	102.417,52
Livestock Waste	ton	195.385,01	201.246,56	207.283,96	207.283,96
Forest Waste	ton	1.597,56	1.597,56	1.597,56	1.597,56
Agricultural Waste	ton	26.295,71	26.295,71	26.295,71	26.295,71
Total Waste	ton	316.311,14	326.550,69	337.187,72	342.020,04
% send to landfill - Sewage Sludge	%	3,94	4,90	5,85	6,79
% send to landfill - Municipal Sold Waste	%	-21,55	-27,63	-34,01	-40,71
% send to landfill - Livestock Waste	%	-12,55	-15,93	-19,41	-19,41
% send to landfill - Forest Waste	%	-1,00	-1,00	-1,00	-1,00
% send to landill - Agricultural Waste	%	-2,01	-2,01	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.123,80	3.092,56	3.061,64	3.031,02

		Year 13	Year 14	Year 15	Year 16
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	17.209,64	18.070,12	18.973,63	19.922,31
Substrate_volume_load - Livestock Waste	[kg oDM/d]	133.825,35	137.840,11	141.975,32	141.975,32
Substrate_volume_load - Forest Waste	[kg oDM/d]	481,46	481,46	481,46	481,46
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.881,72	2.881,72	2.881,72	2.881,72
Substrate_volume_load - TOTAL	[kg oDM/d]	157.521,97	162.365,98	167.373,76	168.291,83
Required Volume in the Digesters	m^3	43.330,29	44.732,97	46.190,10	46.852,06
Hidraulic Retention Time	days	50	50	50	50
Organic load	[kg oDM/m³d]	3,6354	3,6297	3,6236	3,5920
Number of digestors	nº	7	7	7	7
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	35000	35000	35000	35000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	1.968,00	1.948,32	1.928,83	1.909,54
Biogas Volume - Municipal Solid Waste	m^3/d	12.063,96	12.667,16	13.300,52	13.965,54
Biogas Volume - Livestock Waste	m^3/d	42.288,81	43.557,48	44.864,20	44.864,20
Biogas Volume - Forest Waste	m^3/d	216,66	216,66	216,66	216,66
Biogas Volume - Agricultural Waste	m^3/d	1.890,41	1.890,41	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	58.427,83	60.280,01	62.200,61	62.846,35
Biogas Volume - Total	m^3/yr	21.326.157,94	22.002.204,50	22.703.223,12	22.938.917,28
Electricity produced	kWh/yr	21.965.942,68	22.662.270,63	23.384.319,82	23.627.084,80
Upgrading - Biomethane Production					
Chemical Absorption	m^3/yr	19.193.542,15	19.801.984,05	20.432.900,81	20.645.025,56
High Pressure Water Scrubbing	m^3/yr	20.046.588,47	20.682.072,23	21.341.029,73	21.562.582,25
Pressure Swing Adsorption	m3/yr	19.406.803,73	20.022.006,09	20.659.933,04	20.874.414,73

Cryogenic separation	m3/yr	20.899.634,78	21.562.160,41	22.249.158,66	22.480.138,94
Membrane separation	m3/yr	16.634.403,20	17.161.719,51	17.708.514,03	17.892.355,48

Table 38 - Tabled constants used in the model.

Tabled Constants		
Materials	**Biogas yield (L/kg oDM) - Biomax final**	**% oDM - Biomax final**
Sewage Sludge	630	25
Municipal Solid Waste	701	7,1
Livestock Waste	316	25
Forest Waste	450	11
Agricultural Waste	656	4
c CH4 (%) - methane content	0,103 %	
Hi CH4 (kWh/d)	10 kWh/d	
Upgrading	**Yields (%)**	
Chemical Absortion	90 %	
High Pressure Water Scrubbing	94 %	
Pressure Swing Adsorption	91 %	
Cryogenic separation	98 %	
Membrane separation	78 %	

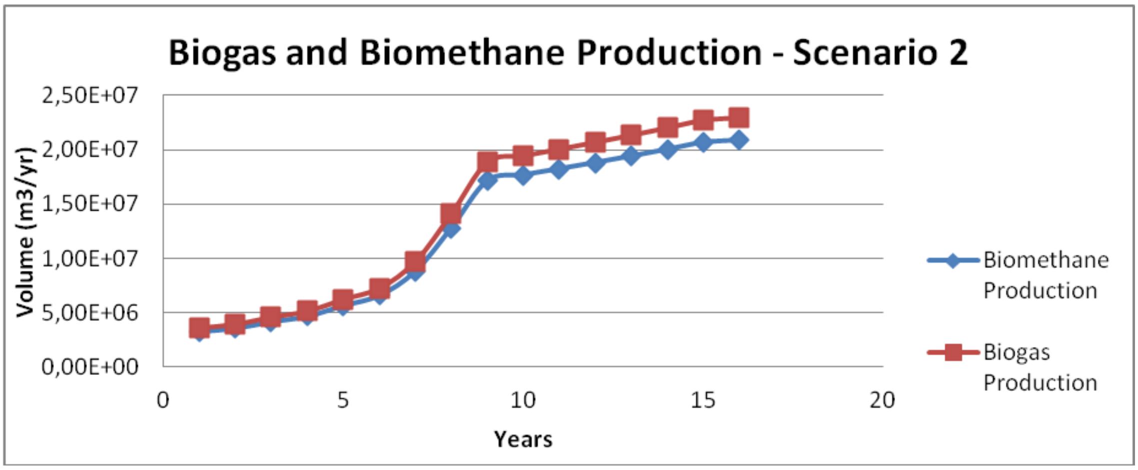

Figure 35 - Biogas and Biomethane production - Scenario 2.

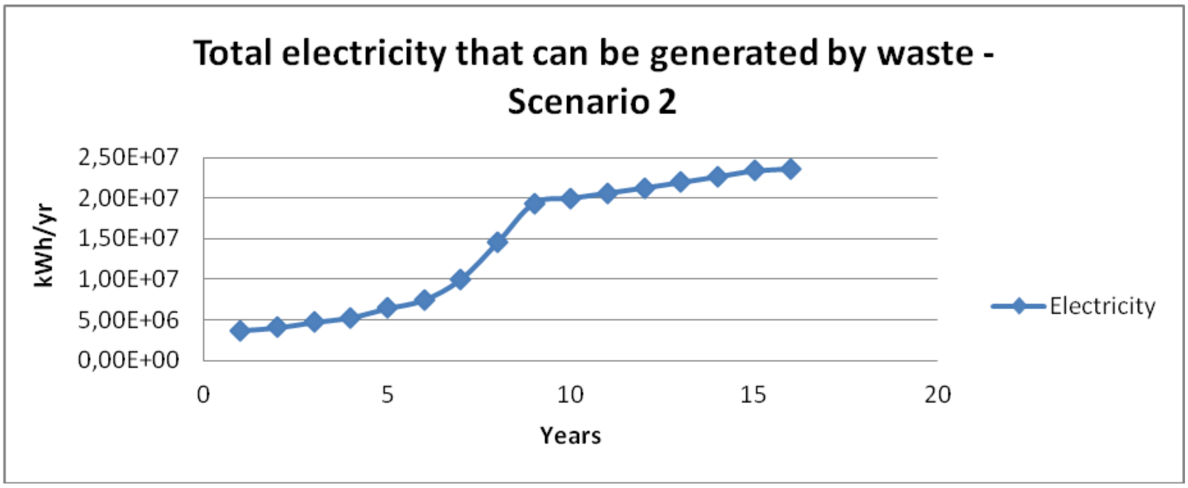

Figure 36 - Total electricity that can be generated by waste - Scenario 2.

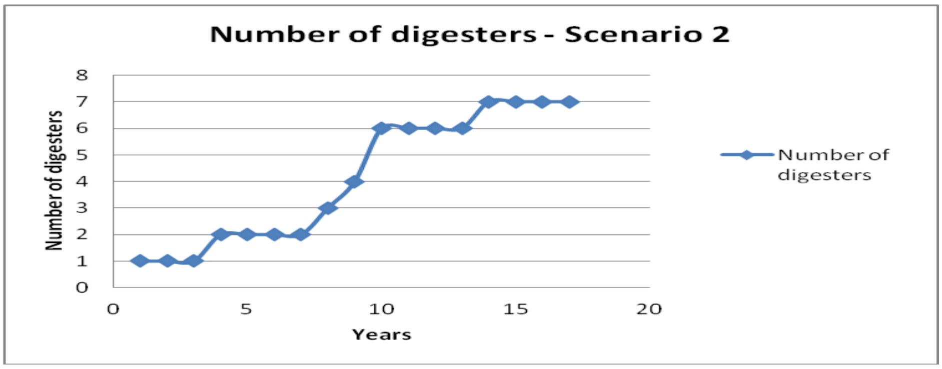

Figure 37 - Number of digesters needed to meet the needs - Scenario 2.

Projection explanations – Scenario 2

This scenario has the principle "Waste separation incentive scenario."

For the creation of the projection presented above [Table 37] is only possible to observe a stabilization of input quantities at the biogas production unit from the year 9.

Was idealized a concept of perfection, if all waste quantities were sent to the production biogas unit, so we witness the effectively amount of biogas produced.

Also in the above table [Table 37] it can be seen the percentage of residues that are sent to landfill. When you have positive percentages it means that amount of waste is still sent to landfill and negative percentages means the amounts that could save their way to landfill.

For this scenario will be necessary to construct 7 digesters with 7,000 m^3 each. Each digester will be built in different years depending on the examination table [Table 37].

The electricity produced is the total electricity could be drawn from the total amount of biogas produced.

Each upgrading technology has different yields and so thought the table [Table 37] it is possible to analyze the amount produced by each of the technologies that can be implemented.

Economic projection for scenario 2

According to the materials flow projection made earlier for scenario 2 it was also made an economic projection for the same scenario that is going to be presented as follow:

Table 39 - Economic projection for scenario 2.

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Investment (€)	.	**4325083**	**0**	**0**	**4325083**	**0**	**0**
Intallations (digesters)	€	2550000	0	0	2550000	0	0
Machinery Technology	€	450000	0	0	450000	0	0
Other investments (infrastruture)	€	1325083	0	0	1325083	0	**0**
Overhead expenses for approval and planning (10% of total investment)	€	43251	0	0	43251	0	0
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Revenues (€)	.		**3073164**	**3305151**	**3810180**	**4198202**	**4994241**
Material that can't be digested (metals)	€		139	149	171	185	219
Electricity	€		580688	634124	739498	827264	1003593
Digesters Waste	€		31428	33548	38454	41825	49287
Consulting and Methods	€		1000	1000	1000	1000	1000
Technical Training	€		700	700	700	15000	15000
Biomethane	€		427529	466871	544452	609070	738892
Cost does not go to landfill	€		1396780	1491022	1709060	1858902	2190547
Sludge	€		634900	677737	776845	844955	995703
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Expenses (€)		**13465384**	**13465384**	**14091681**	**13465384**	**13465384**	**13465384**
Amortization	€	3131485	3131485	3131485	3131485	3131485	3131485
Operation and maintenance costs	€	10333899	10333899	10960196	10333899	10333899	10333899
Balance	€	-1,3E+07	-1E+07	-1,1E+07	-9655204	-9267182	-8471143

		Year 6	Year 7	Year 8	Year 9	Year 10
Investment (€)	.	**0**	**3589420**	**3589420**	**6589420**	**0**
Intallations (digesters)	€	0	2550000	2550000	5100000	0
Machinery Technology	€	0	450000	450000	900000	0
Other investments (infrastruture)	€	0	589420	589420	589420	0
Overhead expenses for approval and planning (10% of total investment)	€	0	35894	35894	65894	0
		Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Revenues (€)	.	**5744124**	**7598006**	**10927448**	**14321947**	**14782137**
Material that can't be digested (metals)	€	250	329	472	611	631
Electricity	€	1166802	1559058	2262793	3027098	3122321
Digesters Waste	€	56393	74258	106361	137853	142344
Consulting and Methods	€	1000	1000	1000	1000	1000
Technical Training	€	15000	15001	15002	15003	15004
Biomethane	€	859053	1147850	1665972	2228688	2298796
Cost does not go to landfill	€	2506367	3300350	4727146	6126789	6326403
Sludge	€	1139258	1500159	2148703	2784904	2875638
		Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Expenses (€)		**14717978**	**15657423**	**15970571**	**15970571**	**15970571**
Amortization	€	3131485	3131485	3131485	3131485	3131485
Operation and maintenance costs	€	11586493	12525938	12839087	12839087	12839087
Balance	€	-8973854	-8059417	-5043123	-1648624	-1188435

		Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Investment (€)	.	**0**	**0**	**8896420**	**0**	**0**	**0**
Intallations (digesters)	€	0	0	2550000	0	0	0
Machinery Technology	€	0	0	450000	0	0	0
Other investments (infrastruture)	€	0	0	5896420	0	0	0
Overhead expenses for approval and planning (10% of total investment)	€	0	0	88964	0	0	0
		Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**
Revenues (€)	.	**15258694**	**15742558**	**16244803**	**16766164**	**17307409**	**17530201**
Material that can't be digested (metals)	€	652	673	694	717	740	751
Electricity	€	3220880	3321923	3426687	3535314	3647954	3685825
Digesters Waste	€	146996	151694	156574	161643	166908	169300
Consulting and Methods	€	1000	1000	1000	1000	1000	1000
Technical Training	€	15005	15006	15007	15008	15009	15010
Biomethane	€	2371360	2445753	2522884	2602861	2685791	2713674
Cost does not go to landfill	€	6533176	6741975	6958845	7184115	7418130	7524441
Sludge	€	2969625	3064534	3163111	3265507	3371877	3420200
		Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**
Expenses (€)		**12839087**	**12839087**	**12839087**	**12839087**	**12839087**	**12839087**
Amortization	€	0	0	0	0	0	0
Operation and maintenance costs	€	12839087	12839087	12839087	12839087	12839087	12839087
Balance	€	2419607	2903472	3405716	3927077	4468322	4691114

Table 40 - Data used in the calculations of economic projection - Scenario 2.

Material that can't be digested - 7% of the Total	**by ton**	**0.236**	**€**
Electricity	by kWh	0.156	€
Digesters Waste - 1% of the Total	by ton	50	€
Consulting and Methods	annual	1,000	€
Technical Training	annual	700	€
Biomethane	by m3	0.13	€
Sludge	by ton	100	€
Investment			
Approximate cost of each digester	€	2,550,000	
Technology cost	€	450,000	

Economic projection conclusions – Scenario 2

By analyzing the table [Table 39] can be concluded that:

Table 41 - Economic projection conclusions - Scenario 2

Payback	**Year 11**
Total Investment	31,314,846 €
Years of big investments	Year 0
	Year 3
	Year 7
	Year 8
	Year 9
	Year 13

Scenario 3

Technological development of transfer stations scenario

Summary - Waste Recovery is currently a popular subject. Most companies are dealing with waste management strives his best in forefront of technological development of their business. It is important in this scenario that technologies used are high because just in this case it is possible to maximize efficiency process and have good success rates.

Before	After
Green containers system for mixed waste deposit	People have to put their waste into one bag containing only: paper, cardboard, glass, batteries and used cooking oil. In another bag they should put mixed waste.
Selective Deposition: Yellow container is used for plastic deposition, blue container is used for deposition of paper and similar, green container is used for deposition of glass, red container is used for deposition of batteries and cells and orange container is used for deposition of cooking oils.	
Mixed waste is processed in a transfer station, but most are sent to landfill	At transfer station should be done a separation of all waste using high technology equipment.
Selective waste are sent directly to the transfer station and treated according their type (paper, plastic or glass)	
Payment of a waste fee that comes along with water invoice	Should keep up or increase the fee on waste production.
Scenario Principle	Recovery and Waste Treatment Principle

Food distribution companies, eg, use unnecessary plastic packaging – it produces too many waste	Make an effort to minimize the production of plastic packaging - Involvement of companies that are responsible for packaging product – High Technology
Plastic bags utilization	Remove the habit of plastic bags using in shopping and introduce a new technology that consists in bags with easy degradation or biodegradables bags. It may be used cloth or paper bags.
Plastic packaging utilization	Place on market organic biodegradable packages or lighter packages that are easily biodegradable. Avoid as much as possible plastics use and replace plastic packaging for packaging with a specific expiration date (past the expiration date, the package will begin to degrade itself – new technology) – High Technology
Bulky waste, scrap metal, end of life cars and garden leftover are free removed. You should make a call for the entity who is responsible for the collection and combine a day and time to be collected	The collection of such waste should be carried in the same way however the service should be charged.
Waste collection in Abrantes is made up of two entities, VALNOR (selective waste) and SMA (mixed waste).	The collection could now be done only by one company to save resources.
Use of used cooking oil for biodiesel production and use of it in their equipment	Sale of over produced biodiesel
Existence of an unit which allows to obtain Anaerobic Digestion gains in energy production.	Make a connection between Anaerobic Digestion and Cogeneration thus achieving energy savings
	Create a partnership with wastewater treatment plants in the area to use their sludge in anaerobic digestion
	Create optimal conditions within anaerobic digester for digestion becomes faster and more efficient

	Biomethane use in vehicles
Energy production	Injection of excess energy in the network and use of produced energy – High Technology
Indicadors 2010	
Number of residents covered by VALNOR Total MSW (t)	167.771 126.467
Capitation of MSW (kg/inhab.year)	461
Total selective collection (t)	8.638,9
Capitation of selective collection (kg/inhab.year)	45
Amount of waste sent to landfill (t)	107.509
Municipal waste sent to units of organic recovery (t)	7.508
Municipal waste sent for recycling (t)	11.450
Number of ecopoints	1.060
Amount of waste exported for recovery operations and disposal (t)	56.109
Expenditure of Local Government per capita in waste management field (€/inhabitant)	25-50
Number of campaigns characterization of MSW (No/year)	10
Expense of Public Administration with Waste Management (10^3 Euros)	552.927

	Before	**After**
Capitation of MSW (kg/inhab.year)	461	++
Capitation of selective collection (kg/inhab.year)	45	++

Inhabitants/Ecopoints	158	+
% Mixed Waste		-
% Selected Waste (by people)		++
Average rate charged for the services of waste disposal (€)		+
% Recycling of plastic packaging		+
Use of plastic bags/capita		-
Quantity of biodiesel /year (L/year)		++
Energy produced in anaerobic digestion		++
% Energy injected into the network		++
Legend: ++ ➔ Great growth + ➔ Smooth growth 0 ➔ Stabilization - ➔ Decrease -- ➔ Abrupt decrease		

SWOT Analysis

Strengths	**Weaknesses**
Policy and regulatory framework positive to the implementation of measures to promote energy efficiency; Policy and regulatory framework positive to the implementation of measures to reduce dependence on fossil fuels, particularly for renewable generation; Local dynamism and entrepreneurship of community; Strong adherence by the population because the effort implicit in this case the separation is not very significant	Limitations on the ability of public investment, which leads to the implementation of measures occur predominantly based on structural funds or private investment; This limitation leads to greater dispersion in leadership processes and introduces greater weakness in waste management

<table>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>Existence of funding opportunities for energy efficiency measures in private investment (VALNOR);

Global political context favors the action at local level;
Awareness of people for the amount of waste produced;
Actions of awareness that allows the minimization of waste production in their homes;
Opportunity for packing companies to show new technologies and expansion in international market, these same technologies;

Creating more jobs in transfer stations (would require more hand labor to do the waste separation);

More effective waste recycling because of high technology used.</td><td>Existence and perception of a serious economic crisis may make it difficult to implement measures with investment;
Natural resistance to change may dictate the use of traditionally used solutions;
Difficulties in obtaining financing;
Waste contamination (if we mix liquids with wet paper, this will be contaminated).</td></tr>
<tr><td colspan="2">Integration with Covenant of Mayors</td></tr>
<tr><td>Measure</td><td>Impact</td></tr>
<tr><td>ACTIVE MONITORING
Provide technologies that enable smart metering energy data collection like water use, electricity and gas, in order to create a more efficient management of resources analyzed.</td><td>The introduction of appropriate waste management, consumption monitoring and adoption of good practice in equipment use allows minimizing energy waste. Monitoring lets you analyze and receive all data collected in real time, ie, checks the entire system and where there is something irregular on system it generates an alert that allows a correction in real-time.</td></tr>
</table>

DOMESTIC EQUIPMENT RENEWAL Promote a gradual household renewal that are energy inefficient, especially appliances.	Due technological advances growing consumers have at their disposal equipment more efficient and therefore should be promoted more or less regular replacement of existing household equipment in housing with more efficient models. However this will have consequences in terms of waste production. The old equipment should be sent to appropriate locations, dismantled and the parts that can be grasped should be seized.
MODERNIZATION EQUIPMENT Gradually renew the equipment, replacing equipment by more efficient equipment in particular driving forces equipment.	All equipment has a life time. With the passage of the "year" equipment begin to be less efficient, ie, begin to spend more energy resources for the same function, and this increases the waste production. However, as the domestic equipment renewal, the old equipment should be referred to appropriate locations, dismantled and parts that can still be reused should be exploited in new equipment.
BIODIESEL Biodiesel use as a main fuel for the fleet for cars with internal combustion engine of diesel type.	Currently transport sector is almost entirely dependent on petroleum products, which makes it a major contributor to greenhouse gases emissions. As the biodiesel produced from oils, used or new, of vegetable or animal origin, this biofuel is a sustainable energy source alternative to using diesel so there is a reduction of greenhouse gases emissions and waste recovery.

WASTE MANAGEMENT Designing or improving waste management model, achieving maximum efficiency in energy use.	The organic recovery is a strategic measure to reduce GHG emissions. The separation, collection and routing of organic matter to a treatment station allows biogas production which can be used to produce energy and for producing a "compound" of high quality for agriculture. The waste sector is responsible for direct and indirect emissions that can be reduced using a waste management model. Direct emissions arise primarily from support activities, such as the consumption of fossil fuels in incineration and composting operation and collection fleets and mobile machinery existing in landfills. Indirect emissions are associated with electricity consumed on facilities.
GREEN PUBLIC PROCUREMENT Designing a tool to measure ecologically all purchases as energy using equipment, vehicles and contracts.	The purchase of ecological products or services by public bodies gives a positive image to the market, serving as an example to other identities, and encourages companies to seek innovate their products so that these products are truly sustainable. Comes the need to develop a tool that takes into consideration ecological criteria to be applied under new public procurement policy and to measure ecologically all products and services to be contracted by municipal services.

Projection for Scenario 3

For scenario 3 it was also made a projection of the functioning of the biogas production plant. The results of the projection are presented in the table shown below [**Erro! A origem da referência não foi encontrada.**].

Table 42 - Projection for Scenario 3.

Scenario 3 - Technological development of transfer stations scenario						
		Year 0	Year 1	Year 2	Year 3	Year 4
Inputs (Amount)	**Units**					
Population	Inhab.		260.434,04	259.482,46	258.529,82	257.577,14
Process (Amount)						
Sewage Sludge	ton		3.531,80	3.884,98	4.273,48	4.700,83
Municipal Solid Waste	ton		39.875,20	40.672,70	41.079,43	41.490,23
Livestock Waste	ton		9.755,00	12.681,50	19.022,25	24.728,93
Forest Waste	ton		1.350,00	1.377,00	1.404,54	1.432,63
Agricultural Waste	ton		8.978,00	9.157,56	11.904,83	12.142,92
Total Waste	ton		63.490,00	67.773,74	77.684,53	84.495,53
% send to landfill - Sewage Sludge	%		25,61	18,17	9,99	0,99
% send to landfill - Municipal Sold Waste	%		45,22	44,12	43,56	43,00
% send to landfill - Livestock Waste	%		94,38	92,69	89,04	85,75
% send to landfill - Forest Waste	%		14,65	12,94	11,20	9,43
% send to landill - Agricultural Waste	%		65,17	64,47	53,82	52,89
Dimensioning						
Substrate_volume_load - Sewage Sludge	[kg oDM/d]		2.419,04	2.660,95	2.927,04	3.219,74
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]		7.756,55	7.911,68	7.990,79	8.070,70
Substrate_volume_load - Livestock Waste	[kg oDM/d]		6.681,51	8.685,96	13.028,94	16.937,62
Substrate_volume_load - Forest Waste	[kg oDM/d]		406,85	414,99	423,29	431,75
Substrate_volume_load - Agricultural Waste	[kg oDM/d]		983,89	1.003,57	1.304,64	1.330,73
Substrate_volume_load - TOTAL	[kg oDM/d]		18.247,83	20.677,14	25.674,70	29.990,55

		Year 0	Year 1	Year 2	Year 3	Year 4
Required Volume in the Digesters	m^3		5.566,25	5.941,81	6.810,70	7.870,82
Hidraulic Retention Time	days		32	32	32	34
Organic load	[kg oDM/m^3d]		3,2783	3,4799	3,7698	3,8103
Number of digestors	nº	1	1	1	2	2
Digesters Selected Volume	m^3	7000	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	7000	7000	7000	14000	14000
Outputs						
Biogas Volume - Sewage sludge	m^3/d		1.524,00	1.676,40	1.844,04	2.028,44
Biogas Volume - Municipal Solid Waste	m^3/d		5.437,34	5.546,09	5.601,55	5.657,56
Biogas Volume - Livestock Waste	m^3/d		2.111,36	2.744,76	4.117,14	5.352,29
Biogas Volume - Forest Waste	m^3/d		183,08	186,74	190,48	194,29
Biogas Volume - Agricultural Waste	m^3/d		645,43	658,34	855,84	872,96
Biogas Volume - Total	m^3/d		9.901,20	10.812,33	12.609,05	14.105,54
Biogas Volume - Total	m^3/yr		3.613.939,80	3.946.499,88	4.602.302,31	5.148.520,71
Electricity produced	kWh/yr		3.722.357,99	4.064.894,87	4.740.371,38	5.302.976,33
Upgrading - Biomethane Production						
Chemical Absortion	m^3/yr		3.252.545,82	3.551.849,89	4.142.072,08	4.633.668,64
High Pressure Water Scrubbing	m^3/yr		3.397.103,41	3.709.709,88	4.326.164,18	4.839.609,47
Pressure Swing Adsorption	m^3/yr		3.288.685,22	3.591.314,89	4.188.095,11	4.685.153,85
Cryogenic separation	m^3/yr		3.541.661,00	3.867.569,88	4.510.256,27	5.045.550,30
Membrane separation	m^3/yr		2.818.873,04	3.078.269,90	3.589.795,80	4.015.846,15

		Year 5	Year 6	Year 7	Year 8
Inputs (Amount)	**Units**				
Population	Inhab.	256.618,33	255.664,77	254.711,47	253.758,18
Process (Amount)					
Sewage Sludge	ton	4.700,83	4.700,83	4.747,83	4.747,83
Municipal Solid Waste	ton	43.564,74	45.742,97	54.891,57	71.359,04
Livestock Waste	ton	37.093,39	48.221,40	72.332,11	115.731,37
Forest Waste	ton	1.461,28	1.490,51	1.520,32	1.550,73
Agricultural Waste	ton	12.750,07	13.770,08	16.524,09	21.481,32
Total Waste	ton	99.570,30	113.925,79	150.015,92	214.870,29
% send to landfill - Sewage Sludge	%	0,99	0,99	0,00	0,00
% send to landfill - Municipal Sold Waste	%	40,15	37,15	24,59	1,96
% send to landfill - Livestock Waste	%	78,63	72,22	58,33	33,33
% send to landfill - Forest Waste	%	7,62	5,77	3,88	1,96
% send to landill - Agricultural Waste	%	50,54	46,58	35,90	16,67
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.219,74	3.219,74	3.251,94	3.251,94
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	8.474,24	8.897,95	10.677,54	13.880,80
Substrate_volume_load - Livestock Waste	[kg oDM/d]	25.406,43	33.028,36	49.542,54	79.268,06
Substrate_volume_load - Forest Waste	[kg oDM/d]	440,39	449,19	458,18	467,34
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	1.397,27	1.509,05	1.810,86	2.354,12
Substrate_volume_load - TOTAL	[kg oDM/d]	38.938,06	47.104,29	65.741,05	99.222,26
Required Volume in the Digesters	m^3	9.820,63	12.485,02	16.440,10	25.902,17
Hidraulic Retention Time	days	36	40	40	44
Organic load	[kg oDM/m³d]	3,9649	3,7729	3,9988	3,8307
Number of digestors	nº	2	3	3	5
Digesters Selected Volume	m^3	7000	7000	7000	7000

		Year 5	Year 6	Year 7	Year 8
Total Volume of the Digesters Available	m^3	14000	21000	21000	35000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.028,44	2.028,44	2.048,72	2.048,72
Biogas Volume - Municipal Solid Waste	m^3/d	5.940,44	6.237,46	7.484,95	9.730,44
Biogas Volume - Livestock Waste	m^3/d	8.028,43	10.436,96	15.655,44	25.048,71
Biogas Volume - Forest Waste	m^3/d	198,17	202,14	206,18	210,30
Biogas Volume - Agricultural Waste	m^3/d	916,61	989,94	1.187,92	1.544,30
Biogas Volume - Total	m^3/d	17.112,09	19.894,94	26.583,22	38.582,48
Biogas Volume - Total	m^3/yr	6.245.913,57	7.261.651,50	9.702.876,42	14.082.603,46
Electricity produced	kWh/yr	6.433.290,98	7.479.501,04	9.993.962,71	14.505.081,57
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	5.621.322,21	6.535.486,35	8.732.588,78	12.674.343,12
High Pressure Water Scrubbing	m^3/yr	5.871.158,75	6.825.952,41	9.120.703,83	13.237.647,25
Pressure Swing Adsorption	m^3/yr	5.683.781,35	6.608.102,86	8.829.617,54	12.815.169,15
Cryogenic separation	m^3/yr	6.120.995,30	7.116.418,47	9.508.818,89	13.800.951,39
Membrane separation	m^3/yr	4.871.812,58	5.664.088,17	7.568.243,61	10.984.430,70

		Year 9	Year 10	Year 11	Year 12
Inputs (Amount)	Units				
Population	Inhab.	252.804,89	251.852,13	250.898,70	249.945,22
Process (Amount)					
Sewage Sludge	ton	4.747,83	4.700,36	4.653,35	4.606,82
Municipal Solid Waste	ton	72.786,22	74.241,94	75.726,78	77.241,32
Livestock Waste	ton	173.597,05	178.804,97	184.169,11	189.694,19
Forest Waste	ton	1.581,74	1.597,56	1.597,56	1.597,56
Agricultural Waste	ton	25.777,58	26.035,36	26.295,71	26.295,71
Total Waste	ton	278.490,43	285.380,18	292.442,52	299.435,59
% send to landfill - Sewage Sludge	%	0,00	1,00	1,99	2,97
% send to landfill -	%	0,00	-2,00	-4,04	-6,12

Municipal Solid Waste					
		Year 9	**Year 10**	**Year 11**	**Year 12**
% send to landfill - Livestock Waste	%	0,00	-3,00	-6,09	-9,27
% send to landfill - Forest Waste	%	0,00	-1,00	-1,00	-1,00
% send to landill - Agricultural Waste	%	0,00	-1,00	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.251,94	3.219,42	3.187,23	3.155,36
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	14.158,42	14.441,58	14.730,42	15.025,02
Substrate_volume_load - Livestock Waste	[kg oDM/d]	118.902,09	122.469,15	126.143,23	129.927,53
Substrate_volume_load - Forest Waste	[kg oDM/d]	476,69	481,46	481,46	481,46
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.824,94	2.853,19	2.881,72	2.881,72
Substrate_volume_load - TOTAL	[kg oDM/d]	139.614,08	143.464,81	147.424,05	151.471,08
Required Volume in the Digesters	m^3	35.097,42	35.965,72	38.458,19	39.377,83
Hidraulic Retention Time	days	46	46	48	48
Organic load	[kg oDM/m³d]	3,9779	3,9889	3,8334	3,8466
Number of digestors	nº	6	6	7	7
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	37000	37000	37000	37000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	2.048,72	2.028,24	2.007,95	1.987,87
Biogas Volume - Municipal Solid Waste	m^3/d	9.925,05	10.123,55	10.326,02	10.532,54
Biogas Volume - Livestock Waste	m^3/d	37.573,06	38.700,25	39.861,26	41.057,10
Biogas Volume - Forest Waste	m^3/d	214,51	216,66	216,66	216,66
Biogas Volume - Agricultural Waste	m^3/d	1.853,16	1.871,69	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	51.614,50	52.940,39	54.302,30	55.684,58
		Year 9	**Year 10**	**Year 11**	**Year 12**
Biogas Volume - Total	m^3/yr	18.839.293,93	19.323.240,97	19.820.339,27	20.324.870,99

Electricity produced	kWh/yr	19.404.472,75	19.902.938,20	20.414.949,45	20.934.617,12
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	16.955.364,54	17.390.916,87	17.838.305,34	18.292.383,89
High Pressure Water Scrubbing	m^3/yr	17.708.936,30	18.163.846,51	18.631.118,91	19.105.378,73
Pressure Swing Adsorption	m^3/yr	17.143.757,48	17.584.149,28	18.036.508,74	18.495.632,60
Cryogenic separation	m^3/yr	18.462.508,05	18.936.776,15	19.423.932,48	19.918.373,57
Membrane separation	m^3/yr	14.694.649,27	15.072.127,96	15.459.864,63	15.853.399,38

		Year 13	**Year 14**	**Year 15**	**Year 16**
Inputs (Amount)	**Units**				
Population	Inhab.	248.991,74	248.038,27	247.092,38	246.139,14
Process (Amount)					
Sewage Sludge	ton	4.560,75	4.515,14	4.469,99	4.425,29
Municipal Solid Waste	ton	78.786,14	80.361,87	81.969,10	83.608,49
Livestock Waste	ton	195.385,01	201.246,56	207.283,96	207.283,96
Forest Waste	ton	1.597,56	1.597,56	1.597,56	1.597,56
Agricultural Waste	ton	26.295,71	26.295,71	26.295,71	26.295,71
Total Waste	ton	306.625,18	314.016,84	321.616,33	323.211,01
% send to landfill - Sewage Sludge	%	3,94	4,90	5,85	6,79
% send to landfill - Municipal Solid Waste	%	-8,24	-10,41	-12,62	-14,87
% send to landfill - Livestock Waste	%	-12,55	-15,93	-19,41	-19,41
% send to landfill - Forest Waste	%	-1,00	-1,00	-1,00	-1,00
% send to landfill - Agricultural Waste	%	-2,01	-2,01	-2,01	-2,01
Dimensioning					
Substrate_volume_load - Sewage Sludge	[kg oDM/d]	3.123,80	3.092,56	3.061,64	3.031,02
Substrate_volume_load - Municipal Solid Waste	[kg oDM/d]	15.325,52	15.632,03	15.944,68	16.263,57
Substrate_volume_load - Livestock Waste	[kg oDM/d]	133.825,35	137.840,11	141.975,32	141.975,32
Substrate_volume_load - Forest Waste	[kg oDM/d]	481,46	481,46	481,46	481,46
Substrate_volume_load - Agricultural Waste	[kg oDM/d]	2.881,72	2.881,72	2.881,72	2.881,72

		Year 13	Year 14	Year 15	Year 16
Substrate_volume_load - TOTAL	[kg oDM/d]	155.637,85	159.927,89	164.344,81	164.633,08
Required Volume in the Digesters	m^3	39.483,24	40.435,05	41.413,61	41.618,95
Hidraulic Retention Time	days	47	47	47	47
Organic load	[kg oDM/m³d]	3,9419	3,9552	3,9684	3,9557
Number of digestors	nº	7	7	7	7
Digesters Selected Volume	m^3	7000	7000	7000	7000
Total Volume of the Digesters Available	m^3	37000	37000	37000	37000
Outputs					
Biogas Volume - Sewage sludge	m^3/d	1.968,00	1.948,32	1.928,83	1.909,54
Biogas Volume - Municipal Solid Waste	m^3/d	10.743,19	10.958,06	11.177,22	11.400,76
Biogas Volume - Livestock Waste	m^3/d	42.288,81	43.557,48	44.864,20	44.864,20
Biogas Volume - Forest Waste	m^3/d	216,66	216,66	216,66	216,66
Biogas Volume - Agricultural Waste	m^3/d	1.890,41	1.890,41	1.890,41	1.890,41
Biogas Volume - Total	m^3/d	57.107,06	58.570,91	60.077,31	60.281,57
Biogas Volume - Total	m^3/yr	20.844.078,03	21.378.382,64	21.928.219,45	22.002.772,90
Electricity produced	kWh/yr	21.469.400,37	22.019.734,11	22.586.066,03	22.662.856,09
Upgrading - Biomethane Production					
Chemical Absortion	m^3/yr	18.759.670,23	19.240.544,37	19.735.397,51	19.802.495,61
High Pressure Water Scrubbing	m^3/yr	19.593.433,35	20.095.679,68	20.612.526,28	20.682.606,53
Pressure Swing Adsorption	m^3/yr	18.968.111,01	19.454.328,20	19.954.679,70	20.022.523,34
Cryogenic separation	m^3/yr	20.427.196,47	20.950.814,98	21.489.655,06	21.562.717,44
Membrane separation	m^3/yr	16.258.380,87	16.675.138,46	17.104.011,17	17.162.162,86

Table 43 - Tabled constants use in the model.

Tabled Constants		
Materials	**Biogas yield (L/kg oDM) - Biomax final**	**% oDM - Biomax final**
Sewage Sludge	630	25
Municipal Solid Waste	701	7,1
Livestock Waste	316	25
Forest Waste	450	11
Agricultural Waste	656	4
c CH4 (%) - methane content	0,103 %	
Hi CH4 (kWh/d)	10 kWh/d	
Upgrading	Yields (%)	
Chemical Absortion	90 %	
High Pressure Water Scrubbing	94 %	
Pressure Swing Adsorption	91 %	
Cryogenic separation	98 %	
Membrane separation	78 %	

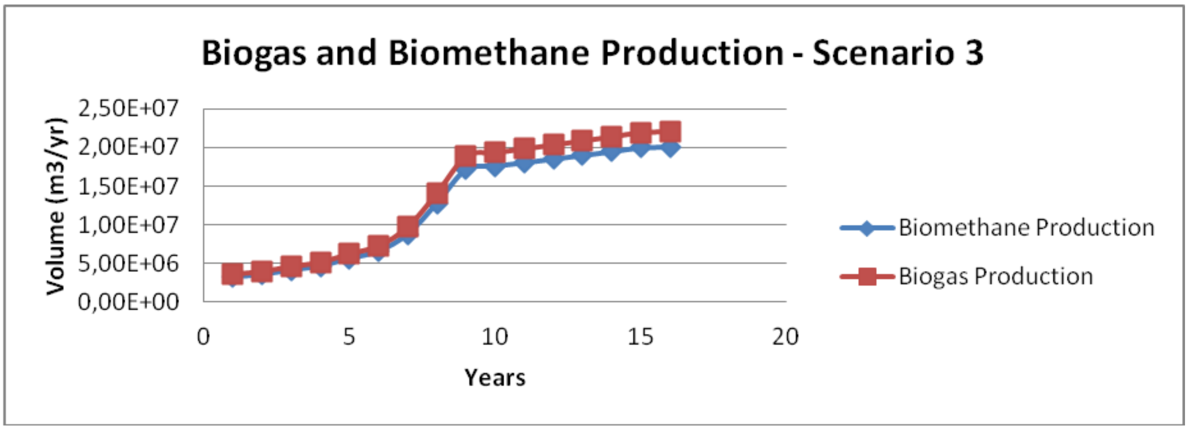

Figure 38 - Biogas and Biomethane production - Scenario 3.

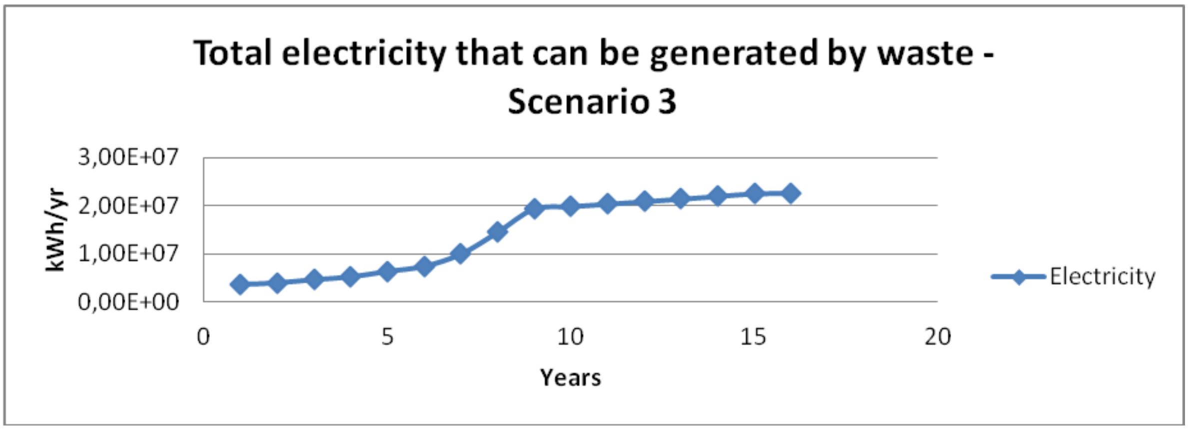

Figure 39 - Total electricity that can be generated by waste - Scenario 3.

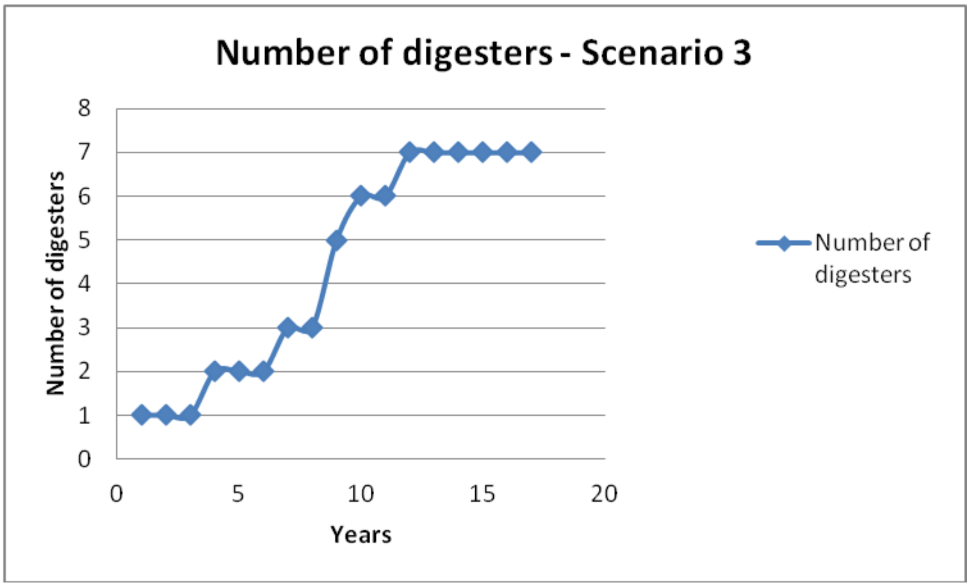

Figure 40 - Number of digesters needed to meet the needs - Scenario 3.

Projection explanations – Scenario 3

This scenario has the principle "Technological development of transfer stations scenario".

For the creation of the projection presented above [Table 42] is only possible to observe a stabilization of input quantities at the biogas production unit from the year 9.

Was idealized a concept of perfection, if all waste quantities were sent to the production biogas unit, so we witness the effectively amount of biogas produced.

Also in the above table [Table 42] it can be seen the percentage of residues that are sent to landfill. When you have positive percentages it means that amount of waste is still sent to landfill and negative percentages means the amounts that could save their way to landfill.

For this scenario will be necessary to construct 7 digesters with 7,000 m^3 each. Each digester will be built in different years depending on the examination table [Table 42].

The electricity produced is the total electricity could be drawn from the total amount of biogas produced.

Each upgrading technology has different yields and so thought the table [Table 42] it is possible to analyze the amount produced by each of the technologies that can be implemented.

Economic projection for Scenario 3

According to the materials flow projection made earlier for scenario 3 it was also made an economic projection for the same scenario that is going to be presented as follow:

Table 44 - Economic projection for scenario 3.

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Investment (€)	.	**4525083**	**0**	**0**	**4525083**	**0**	**0**
Intallations (digesters)	€	2550000	0	0	2550000	0	0
Machinery Technology	€	650000	0	0	650000	0	0
Other investments (infrastruture)	€	1325083	0	0	1325083	0	**0**
Overhead expenses for approval and planning (10% of total investment)	€	45251	0	0	45251	0	0
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Revenues (€)	.		**3073164**	**3305151**	**3810180**	**4198202**	**4994241**
Material that can't be digested (metals)	€		139	149	171	185	219
Electricity	€		580688	634124	739498	827264	1003593
Digesters Waste	€		31428	33548	38454	41825	49287
Consulting and Methods	€		1000	1000	1000	1000	1000
Technical Training	€		700	700	700	15000	15000
Biomethane	€		427529	466871	544452	609070	738892
Cost does not go to landfill	€		1396780	1491022	1709060	1858902	2190547
Sludge	€		634900	677737	776845	844955	995703
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Expenses (€)		**14067384**	**14067384**	**14721681**	**14067384**	**14067384**	**14067384**
Amortization	€	3271485	3271485	3271485	3271485	3271485	3271485
Operation and maintenance costs	€	10795899	10795899	11450196	10795899	10795899	10795899
Balance	€	-1,4E+07	-1,1E+07	-1,1E+07	-1E+07	-9869182	-9073143

		Year 6	Year 7	Year 8	Year 9	Year 10
Investment (€)	.	**3789420**	**0**	**6989420**	**3789420**	**0**
Intallations (digesters)	€	2550000	0	5100000	2550000	0
Machinery Technology	€	650000	0	1300000	650000	0
Other investments (infrastruture)	€	589420	0	589420	589420	0
Overhead expenses for approval and planning (10% of total investment)	€	37894	0	69894	37894	0
		Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Revenues (€)	.	**5744124**	**7598006**	**10927448**	**14321947**	**14728896**
Material that can't be digested (metals)	€	250	329	472	611	626

Electricity	€	1166802	1559058	2262793	3027098	3104858
Digesters Waste	€	56393	74258	106361	137853	141263
Consulting and Methods	€	1000	1000	1000	1000	1000
Technical Training	€	15000	15001	15002	15003	15004
Biomethane	€	859053	1147850	1665972	2228688	2285939
Cost does not go to landfill	€	2506367	3300350	4727146	6126789	6326403
Sludge	€	1139258	1500159	2148703	2784904	2853802
		Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Expenses (€)		**15375978**	**16357423**	**16684571**	**16684571**	**16684571**
Amortization	€	3271485	3271485	3271485	3271485	3271485
Operation and maintenance costs	€	12104493	13085938	13413087	13413087	13413087
Balance	€	-9631854	-8759417	-5757123	-2362624	-1955675

		Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Investment (€)	.	**9096420**	**0**	**0**	**0**	**0**	**0**
Intallations (digesters)	€	2550000	0	0	0	0	0
Machinery Technology	€	650000	0	0	0	0	0
Other investments (infrastruture)	€	5896420	0	0	0	0	0
Overhead expenses for approval and planning (10% of total investment)	€	90964	0	0	0	0	0
		Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**
Revenues (€)	.	**15148485**	**15571448**	**16008637**	**16460560**	**16927743**	**17071593**
Material that can't be digested (metals)	€	642	657	673	689	706	709
Electricity	€	3184732	3265800	3349226	3435079	3523426	3535406
Digesters Waste	€	144759	148221	151779	155438	159200	159989
Consulting and Methods	€	1000	1000	1000	1000	1000	1000
Technical Training	€	15005	15006	15007	15008	15009	15010
Biomethane	€	2344746	2404432	2465854	2529063	2594108	2602928
Cost does not go to landfill	€	6533176	6741975	6958845	7184115	7418130	7524441
Sludge	€	2924425	2994356	3066252	3140168	3216163	3232110
		Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**
Expenses (€)		**13413087**	**13413087**	**13413087**	**13413087**	**13413087**	**13413087**
Amortization	€	0	0	0	0	0	0
Operation and maintenance costs	€	13413087	13413087	13413087	13413087	13413087	13413087
Balance	€	1735398	2158361	2595550	3047473	3514656	3658507

Table 45 - Data used in the calculations of economic projection - Scenario 3

Material that can't be digested - 7% of the Total	**by ton**	**0,236**	**€**
Electricity	by kWh	0,156	€
Digesters Waste - 1% of the Total	by ton	50	€
Consulting and Methods	annual	1000	€
Technical Training	annual	700	€
Biomethane	by m^3	0,13	€
Sludge	by ton	100	€
Investment			
Approximate cost of each digester	€	2550000	
Technology cost	€	650000	

Economic projections conclusions – Scenario 3

By analyzing the table [Table 39] can be concluded that:

Table 46 - Economic projection conclusions - Scenario 3.

Payback	Year 11
Total Investment	32.714.846 €
Years of big investments	Year 0
	Year 3
	Year 6
	Year 8
	Year 9
	Year 11

Implementation of each scenario

Scenario 1

Special containers implementation

A previous study evaluation of strategic points for covering the largest number of people in the city. After certain strategic points should proceed to the emplacement previously agreed.

Waste disposal procedure

Put your bag with waste in the balance available in special container, it will appear on container screen multiple options and that means the type of waste that can be deposited, then you choose the type of waste to be deposited, the machine calculates the weight with the type of waste and will appear on the screen the amount you have to pay. Payment can be made via ATM or notes and coins.

After you made the payment of their respective waste you can put the bag in the groove now open.

Applied rates

The rates to be applied are different depending on type of waste. For mixed waste and batteries have a higher rate compared to other types of waste.

Special containers characteristics

The containers shall contain:

- Scales for people to weigh their waste;
- A digital system that provides information about kind of waste (paper, cardboard, plastic, organic, batteries and used cooking oil), weigh and amount to pay;
- A system of payment by ATM or notes and coins;

- An opening to the outside that opens only if the person makes payment of their respective waste;
- The system must be prepared to recognize what kind of waste is being deposited, so there are no mistakes in fees;
- The containers must be large since it will accommodate almost any type of waste (all in one);
- Containers must have multiple partitions for the various wastes listed. These can't be mixed to avoid contamination.

Waste transportation

Transportation must be made by SMA or VALNOR also in special vehicles with partitions so there is no mixing of waste or contamination.

Waste arrival into transfer station

The waste arriving at the transfer station are removed separately for further treatment The waste considered undifferentiated still have to go through a sorting station (separation process).

Bulky waste, scrap metal, end of life cars and garden leftover

The collection of these waste types should be combined with involved entity (VALNOR or SMA). Citizens should call involved entity and must combine a date and time to make the collection. This collection should also be taxed because the entity has to expend resources on travel.

The waste must be deposited in the appropriate places in the transfer station for further treatment.

Awareness to reduce the use of plastic bags and packaging

Must be performed some workshops to raise awareness of reducing the use of plastic bags and packaging because their treatment when compared with paper and glass processing, is expensive.

It should indicate the alternatives of plastics use such as: use of cloth bags, paper bags, or even those with simple degradation (new technology).

Involve distributors and packers in actions to decrease the number of packages.

Biodiesel purchase

VALNOR through used cooking oil can produce biodiesel and simultaneously integrate it into the company's own fleet. If collection of used cooking oil increases, there will be an even bigger production and the excess can be sold on market.

Energy production

Energy production through anaerobic digestion is a great investment that VALNOR must do to satisfy their energy needs. To maximize energy it could link anaerobic digestion process to cogeneration.

By creating optimal conditions inside anaerobic digestion digester it becomes faster and more effective. Biomethane use in vehicles is also an alternative, as if there were eg biodiesel enough to "feed" the entire company fleet, this could be a viable option to avoid fossil fuels using.

It should be created a partnership with wastewater treatment plants to use its sludge in anaerobic digestion.

Thus, with so many alternatives, it would be possible that VALNOR's installations become energetically self-sufficient and it would still be possible to sell some of its energy produced to network having profits. Over the years the investment made initially begins to be amortized.

Scenario 2

Containers

Study evaluating feasibility of already existing containers. If they are well distributed it must be properly maintained.

Waste disposal procedure

The waste may take two forms of deposition:

• In selective or undifferentiated containers next dwellings (traditional way of deposition)
• The waste can be taken by people themselves to transfer station

Existing containers should be maintained in the future so that people can continue to separate their waste.

The innovation of this scenario comes from the fact that people have the opportunity to take their waste to transfer station closest to their houses (selective and undifferentiated). In the waste transfer station are weighed according to their category (paper, glass, plastic, used cooking oil, batteries) or mixed waste. After weighing the person is given a small amount corresponding to the weight of the waste delivered to the transfer station.

Monetary incentives

The monetary incentive given to people depends on the type of waste delivered and its weight. It offered a higher value when delivered selective waste it encourages the selection of waste in the respective houses.

Waste transportation

Waste transportation containers next dwellings should be done by SMA or VALNOR in special vehicles with partitions to avoid contamination of the waste mixture.

The waste can also be transported by private way (people who go to the transfer station to deliver their waste).

Scenario application

This scenario should be applied for a short period of time. It serves for people to learn to separate their waste. After application of this scenario people should continue to separate their waste without need for incentives to do so.

Bulky waste, scrap metal, end of life cars and garden leftover

The collection of these waste types should be combined with involved entity (VALNOR or SMA). Citizens should call involved entity and must combine a date and time to make the collection. This collection should also be taxed because the entity has to expend resources on travel.

The waste must be deposited in the appropriate places in the transfer station for further treatment.

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Thus, with so many alternatives, it would be possible that VALNOR's installations become energetically self-sufficient and it would still be possible to sell some of its energy produced to network having profits. Over the years the investment made initially begins to be amortized.

Scenario 3

Containers

Study evaluating feasibility of already existing containers. If they are well distributed it must be properly maintained.

Waste disposal procedure

The separation of waste is carried out in respective houses.

People should put a bag with selective waste (paper, glass, plastic, used cooking oil, batteries). In another bag separately should put the mixed waste.

The waste must be placed on selective blue containers suitable for the purpose. The mixed waste should be placed in green containers.

People should take some care in the selective separation of waste before disposal. Should have to wash some packages (such as packages of yogurt, milk, etc.) to avoid waste contamination.

Blue containers characteristics

This form of separation is used in some municipalities in country. Currently blue containers have a capacity of about 60L/90L (small containers). Applying this scenario these containers must have the ability to 800L/1000L (large containers).

There should be a balance between blue and green containers. Ecopoints may remain nevertheless it would be expected to have less demand.

Applied rates

Fees for waste production should remain or increase. This rate should come along with water bill as is done currently.

Waste transportation

All waste (selective and undifferentiated) from the collection must go through a sorting process. It would be necessary labor, as well as machines with high technology. These machines should be prepared to assist in sorting process and make it faster and more effective.

Bulky waste, scrap metal, end of life cars and garden leftover

The collection of these waste types should be combined with involved entity (VALNOR or SMA). Citizens should call involved entity and must combine a date and time to make the collection. This collection should also be taxed because the entity has to expend resources on travel.

The waste must be deposited in the appropriate places in the transfer station for further treatment.

Awareness to reduce the use of plastic bags and packaging

Must be performed some workshops to raise awareness of reducing the use of plastic bags and packaging because their treatment when compared with paper and glass processing, is expensive.

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It should be created a partnership with wastewater treatment plants to use its sludge in anaerobic digestion.

Thus, with so many alternatives, it would be possible that VALNOR’s installations become energetically self-sufficient and it would still be possible to sell some of its energy produced to network having profits. Over the years the investment made initially begins to be amortized.

Inspiring investors

Biogas production from waste has a potential contribution to the objectives of the waste and renewable energy.

Improving quality of biomethane adjacent to the distribution network of natural gas is an opportunity for the efficient use of renewable energy in urban areas. The approach Waste-to-biomethane (WtB) is promoted by the project Urbanbiogas. The main objective of the project is the development of five concepts WtB ("Waste to biomethane" / waste to biomethane) for viable five European cities.

In several European regions waste management is still a major problem and only few biogas plants using organic waste to produce biogas. The waste management practices are insufficient especially dominant in urban areas. Many countries have dump large amounts of municipal solid waste in landfill, instead of being used as a source of energy and nutrients. The simultaneous use of energy organic waste such as municipal solid waste and food waste from catering or the creation of a closed cycle of nutrients is one of the major advantages of anaerobic digestion to biogas by plants in that transforms raw waste materials press "desirable."

In this way European countries have to comply with Directive 1999/31/EC (waste disposal) and Directive 2006/12/EC of the waste in order to reduce land filling for the part of Biodegradable Municipal Solid Waste 35% for next 5-10 years. Also have to comply with the Directive 2009/28/EC of renewable energy.

Biogas production from waste has the potential to contribute to the objectives of the European directives mentioned above. Improving the quality of adjacent natural gas (biomethane) and injection into the distribution network of natural gas represents an opportunity to efficiently use renewable energy in urban areas. This approach Waste-to-biomethane (WtB) is promoted by Urbanbiogas

Convincing authorities and oppositional groups

The objective of the UrbanBiogas project (Urban waste for biomethane grid injection and transport in urban areas) is to prepare 5 European target cities for the production of biomethane from urban bio-waste which will be fed into the natural gas grids or optionally used for transport: City of Zagreb (Croatia), Municipality of Abrantes (Portugal), City of Graz (Austria), City of Rzeszów (Poland), and North Vidzeme Region including the City of Valmiera (Latvia). The UrbanBiogas project promotes the energetic use of urban bio-waste by AD.

Successfully investing on renewable energy production from residues, wastes and sludge requires knowledge, opportunity, technology, equity and alignment with public interest at local, regional and national level. Thus, integration is the key word for success also on waste-to-energy.

The Covenant of Mayors emergence, the evolution of European guiding and programming framework, the local concerns on environment quality, the recent Committee of regions recommendations for 2014-2020, the approved National residues strategy and the underlining priority to the use of new energy sources, turned waste-to-energy projects a multidimensional response.

Solid investment in environment management utilities are appealing alternatives to volatile markets and moving business environments. Waste-to-energy projects, often anchored on long term contracts, proven technology and concrete community needs tend to be more and more priority options for private equity and specialized funds investment. The demand wideness for new energy solutions and new waste treatment routes when combined throughout Europe, gave waste-to-energy the required scale to rank among the premium investment opportunities.

Portugal is a key global player on renewables. The recent top international stakeholders interest on EDP, the Portuguese Electricity utility, privatization (EDP is the third global player in wind energy) has demonstrated it. Additionally, the vigorous growth of renewables that placed the Portuguese energy system among one of greenest in Europe, the proficiency of local energy research centres and agencies and the strong municipal presence in the Covenant of Mayors, makes this market an interesting one to invest in energy sustainability and innovation.

In the present report, a number of key figures are delivered on the business environment, the energy system and the waste and water flows. Supporting a first overview on the Portuguese market is the main objective of gathering the delivered data. Further detailed and sectoral analysis may be delivered under the scope of specific agreements and on the view of on-planning investments.

8) References

APA (2012). Portuguese Agency for Environment portal. Consulted in December 2012, http://www.apambiente.pt/

APVGN (2013). Portuguese Natural Gas Vehicle Association portal. Consulted in January 2013, http://www.apvgn.pt/

Cabeças, A. (October 2011). *Calibration of the theoretical model based on field data.* 7th International technical waste conferences.

Carvalho, Alda de C. (2012). *Statistical Yearbook of Centro Region 2011.* INE.

DGEG (2013). General Direction of Energy and Geology portal. Consulted in March 2013, http://www.dgeg.pt/

CHARACTERISTICS OF NATURAL GAS SECTOR IN PORTUGAL. (January 2007). ERSE

DESCRIPTION OF GAS NATURAL DEMAND IN THE YEARS 2012-2013. (June 2012). ERSE

Duarte, Elizabeth d'Almeida et al. *Optimization of sludge management: processing, storage and final destination.* Department of Agricultural and Environmental Chemistry, Institute of Agronomy and AgroGes

EDP (2013). EDP Portugal energies portal. Consulted in February 2013, http://www.edp.pt/pt/Pages/homepage.aspx

EDP Distribuição (2013). Energy distribution. Consulted in March 2013, http://www.edpdistribuicao.pt/pt/Pages/homepage.aspx

ERSE (2012). Regulatory Authority of Energy Services portal. Consulted in February 2013, http://www.erse.pt/pt/Paginas/home.aspx

EuroStat (2013). European statistics. Consulted in January and February 2013, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Environment Statistics 2011. (2012). INE

FloreStat – IFN5. *Application to consulting the results of the 5th National Forest Inventory.* Ministry of agriculture, rural development and fisheries

Foresty Energy Crops. (June, 2010). National rows forest management

GALP (2012). GALP Energy portal. Consulted in March 2013, http://www.galpenergia.com/PT/INVESTIDOR/CONHECERGALPENERGIA/OS-NOSSOS-NEGOCIOS/GAS-POWER/GAS-NATURAL/Paginas/Distribuicao.aspx

Gonçalves, M. S. (2005). *ORGANIC WASTE MANAGEMENT.* SPI

Hahn, H. and Hoffstede, U. (November 2010). *Assessment report on operational experience.* Biogasmax

IEA Bioenergy. *Biogas Ugrading and utilization.* Task 24: Energy from biological conversion of organic waste

INE (2012). National Statistical Institute portal. Consulted during November, December 2012, January and February 2013, http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main

Knitter, T. (7th and 8th September 2011). SEAI Worshop. *Anaerobic Digestion – a technical overview.* Sustainable Energy Authority of Ireland Renewable Energy Information Office

L. Bini, M.Sc. et al. (July 3, 2008). *Comparing different biogas upgrading techniques.* Eindhoven University of Technology

List of Landfills in operation. (December 2011). APA

Natural gas setor. (September 2008). Portugal Information

PNPRI - National Plan for the Prevention of Industrial Waste. (Lisbon, November 2000). INETI

Seadi, Teodorita Al et al. (October 2008). Biogas Handbook. University of Southern Denmark Esbjerg. Big>East – Biogas for Eastern Europe.

REN (2012). National Energy Network portal. Consulted in February 2013, http://www.ren.pt/o_que_fazemos/gas_natural/o_setor_do_gas_natural/

Renewable Energies (2012). Portal of renewable energy in Portugal. Consulted in December 2012, http://www.energiasrenovaveis.com/

Rodotejo (2013). Road Tagus portal. Consulted in March 2013, http://www.rodotejo.pt/

The biomethane pathway. Biogasmax Training. Biogasmax – A drivinng force

VALNOR (2012). Valorisation and Treatment of Solid Waste North Alentejo, SA portal. Consulted in November 2012, http://www.egf.pt/content/index.php?action=detailfo&rec=1800&t=VALNOR

VALNOR (2012). Data acquisition. Consulted in November and December 2012, http://www.valnor.pt/

Zinn, E. (October 2010). *Guidelines on technical, economical, and legal aspects of grid injection and possible strategies for different local conditions.* Biogasmax – A driving force

Annexes

The Models

For a closer quantitive analysis of the created scenarios it was we used a process model that principal aim is the calculation of the total annual volume of biogas. Then this process model will be explained.

Accompanying this process model was also designed an economic model that could realize the economic viability of the scenarios created.

Functioning of the process model calculation of biogas production

The created model has as main objective to calculate the volume of biogas produced through a certain amount of waste.

Next will be explained all the steps that led to the construction of the same.

Before its construction had to do an analysis of which the most important parameters for the calculations. So will summarize what the fixed parameters (constants tabulated) and which variable parameters were considered.

The formulas used in the model associated with variable parameters are also included in the table below.

Table Annexes 1 - Fixed support parameters for the calculation of biogas volume.

Fixed Parameters	Unit	Value
Substrate oDM (Source: Big East)	%	Sewage Sludge = 80
		Household Waste = 92
		Forest Waste = 85
		Agricultural Waste = 85
Y_{Gas} (Source: Biomax Pathway)	m^3/t	Sewage Sludge = 95
		Household Waste = 144
		Forest Waste = 60
		Agricultural Waste = 110
Methane Content (Source: UrbanBiogas)	%	0,103
Net Calorific Value Methane H_i CH_4 (Source: UrbanBiogas)	kWh/m^3	10
Digester Volume	m^3	7.000

Table Annexes 2 - Variable support parameters for the calculation of biogas volume.

Variable Parameters	Unit	Formula
Input quantities	t	Entered by the user
Hydraulic Retention Time	days	Entered by the user
Substrate Volume Load (support the calculation of organic load)	kg oDM/.d	Substrate Volume Load = (substrate amount [t] * substrate oDM[%] / 100) X 1000 / 365
Organic Load	kg $oDM/m^3.d$	Organic Load = TOTAL Substrate Volume Load / digester volume [m³]
Required Volume in the Digesters	m^3	Required Volume in the Digesters = TOTAL Substrate amount [t] / 365 * hydraulic retention time [days]
Biogas Volume	m^3	Biogas Volume = TOTAL Substrate Volume Load * Organic Load / 1000
Produced Electricity	kWh	Produced Electricity = Biogas Volume * Methane Content * Net Calorific Value Methane

		H_i CH_4

The organic load parameter must be controlled. This should not exceed 4 kg oDM/m^3.d, if it does, the hydraulic retention time should be increased.

The model is prepared to say how many digesters are needed to meet the needs.

Model Validation

As a way of validating the model created there were made some comparisons between the variables in question. That is, in the following graphs will watch the behavior of the model in cases where minimal amounts and maximum.

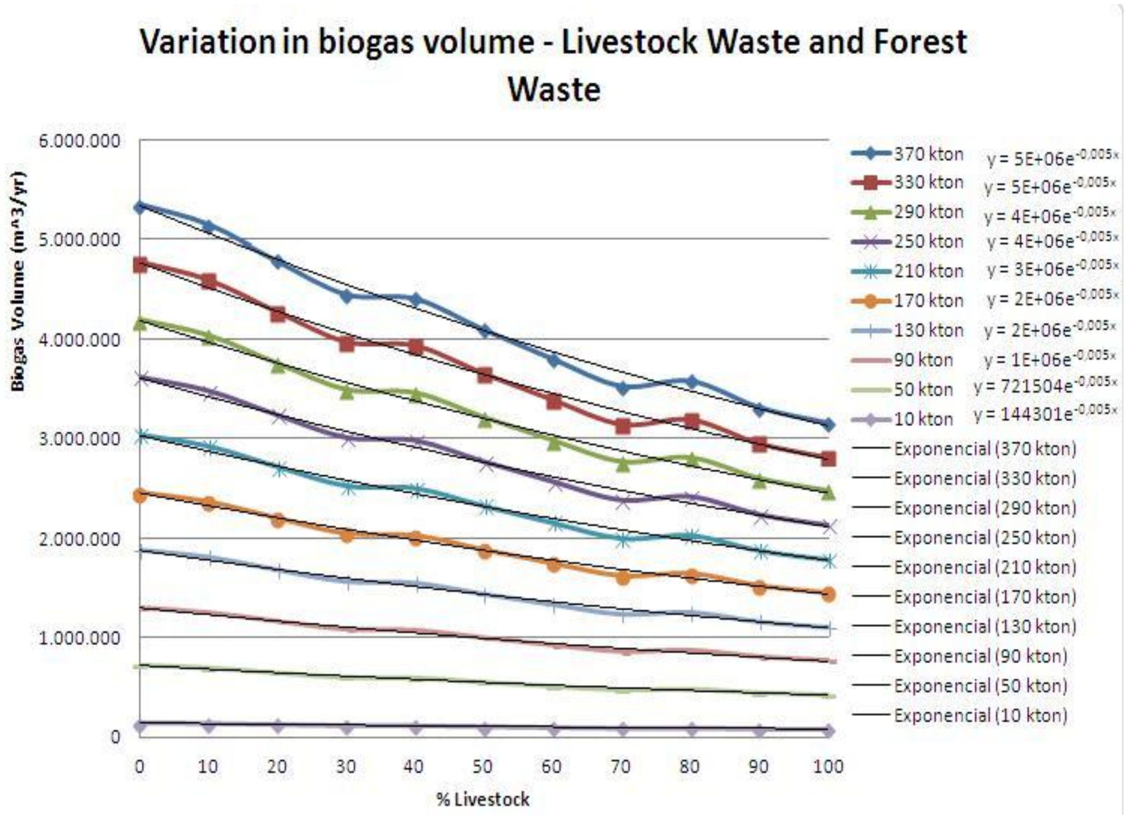

Figure Annexes 1 - Variation in biogas volume. Comparison between livestock waste and agricultural waste.

Analyzing the graph above [**Erro! A origem da referência não foi encontrada.**] it possible to conclude that the greater is the amount of livestock waste in the mixture, the lower is the amount of biogas produced.

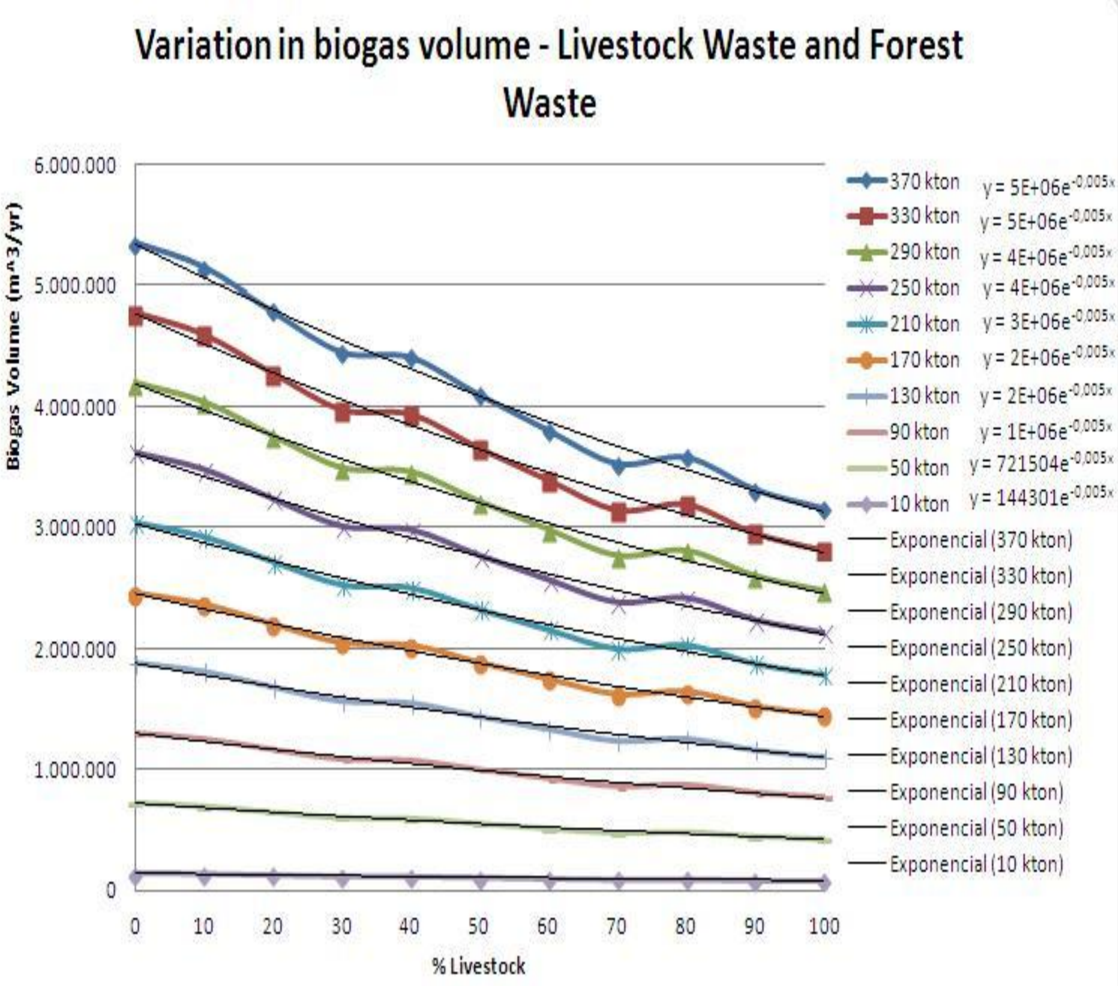

Figure Annexes 2 - Variation in biogas volume. Comparison between livestock waste and forest waste.

Looking at the chart above [**Erro! A origem da referência não foi encontrada.**] it is possible to conclude that livestock and forest waste has a similar behavior to the chart shown previously. A higher presence of livestock waste in the mixture represents a lower amount of biogas produced.

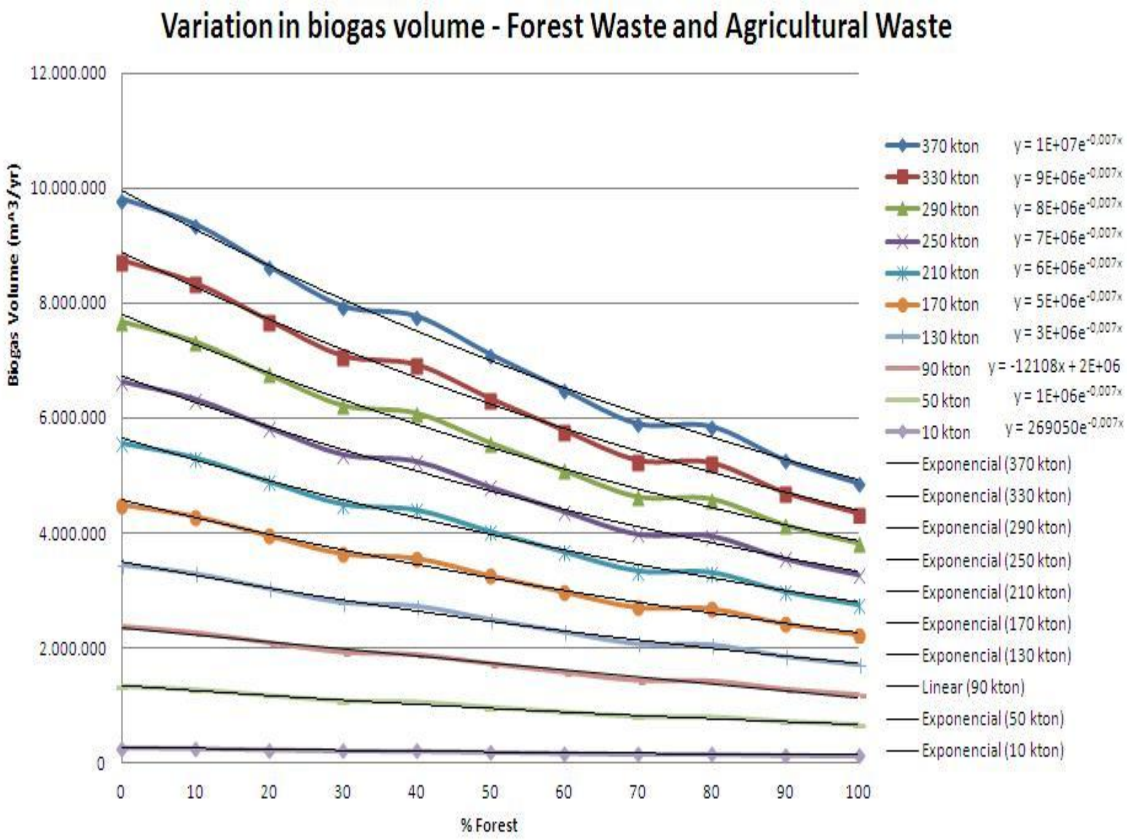

Figure Annexes 3 - Variation in biogas volume. Comparison between forest waste and agricultural waste.

To the forest waste and agricultural waste mixture it is possible to witness a similar behavior from previous curves. Thus, the higher is the amount of forestry waste in the mixture, smaller is the amount of biogas produced.

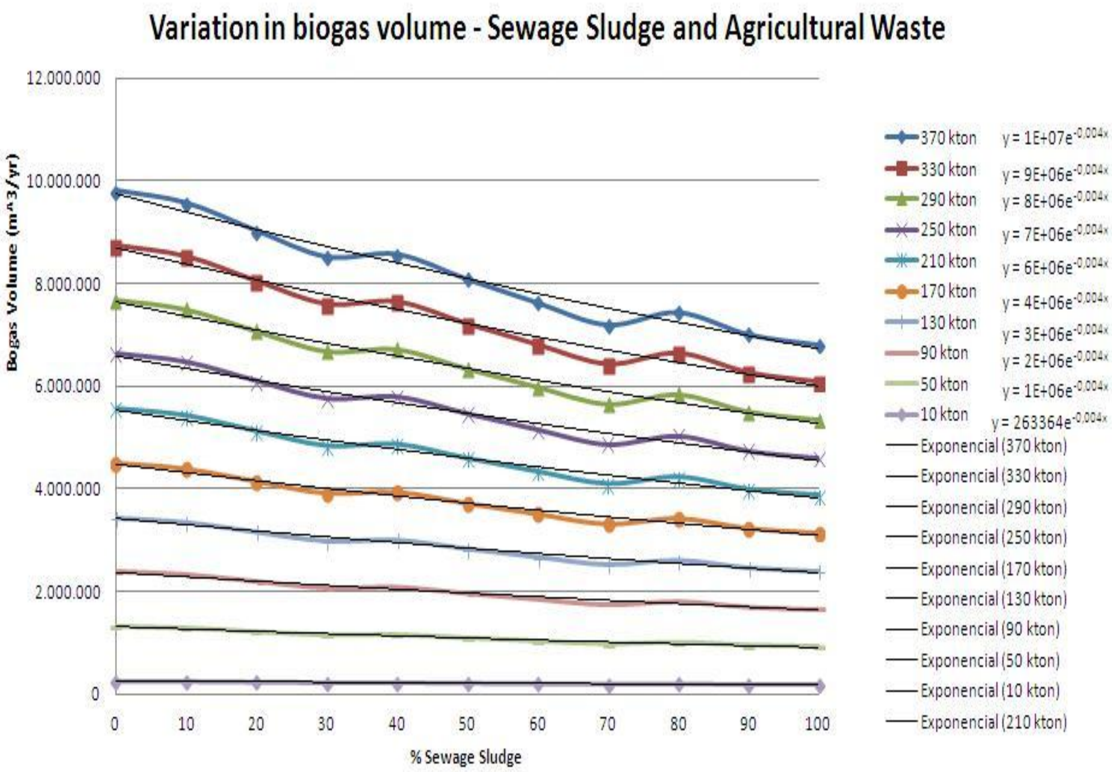

Figure Annexes 4 - Variation in biogas volume. Comparison between sewage sludge and agricultural waste.

By the analysis of the graph [**Erro! A origem da referência não foi encontrada.**] it can be concluded that the greater the amount of sewage sludge in the mixture, smaller the amount of biogas produced.

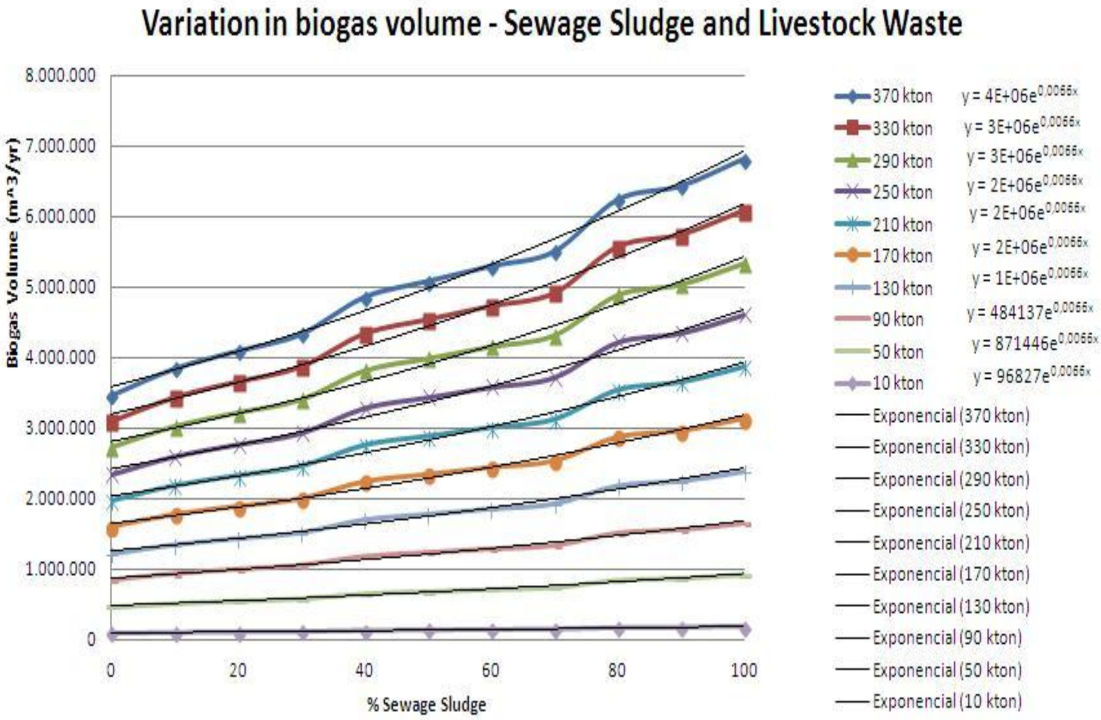

Figure Annexes 5 - Variation in biogas volume. Comparison between sewage sludge and livestock waste.

Comparing the amount of sewage sludge to the amount of livestock wastes it can be concluded that in the mixture the greater the amount of sewage sludge represents a greater amount of biogas produced.

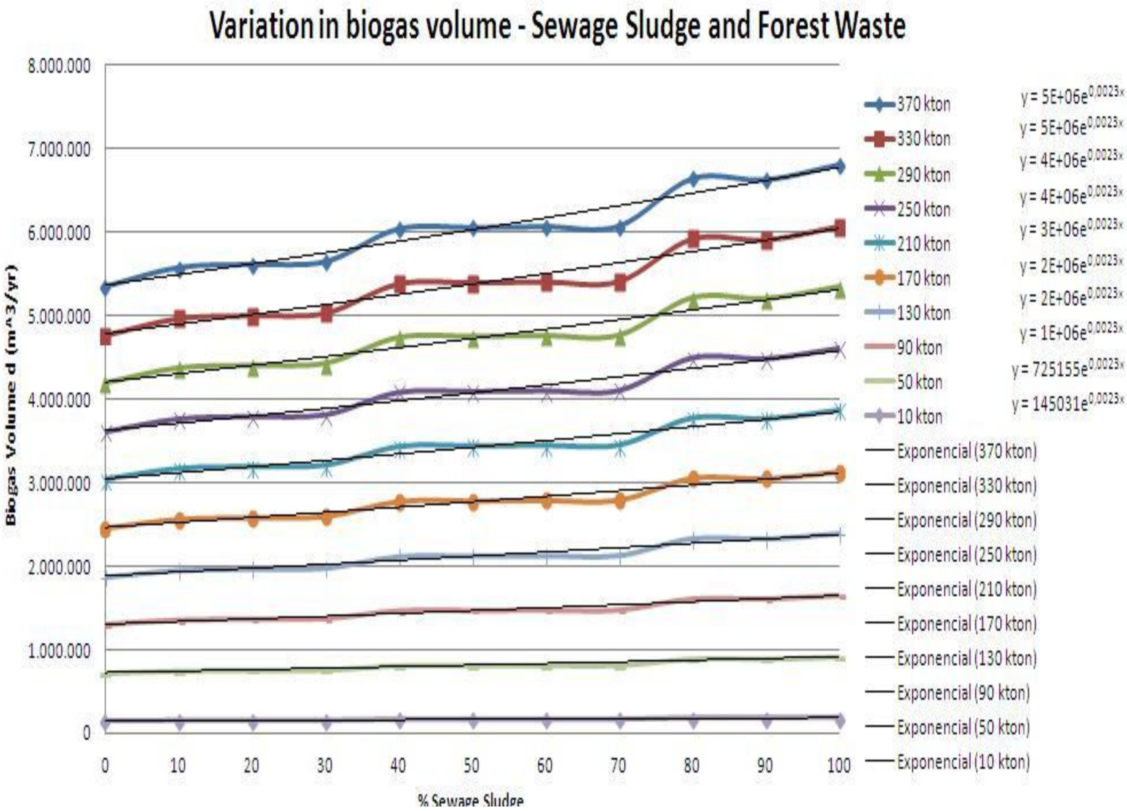

Figure Annexes 6 - Variation in biogas volume. Comparison between sewage sludge and forest waste.

By analysis of the graph [**Erro! A origem da referência não foi encontrada.**] is possible to note that there is a slight increase of biogas production as the amount of sludge increases. It follows that the greater amount of sewage sludge present in the mixture, increases the volume of biogas produced as well.

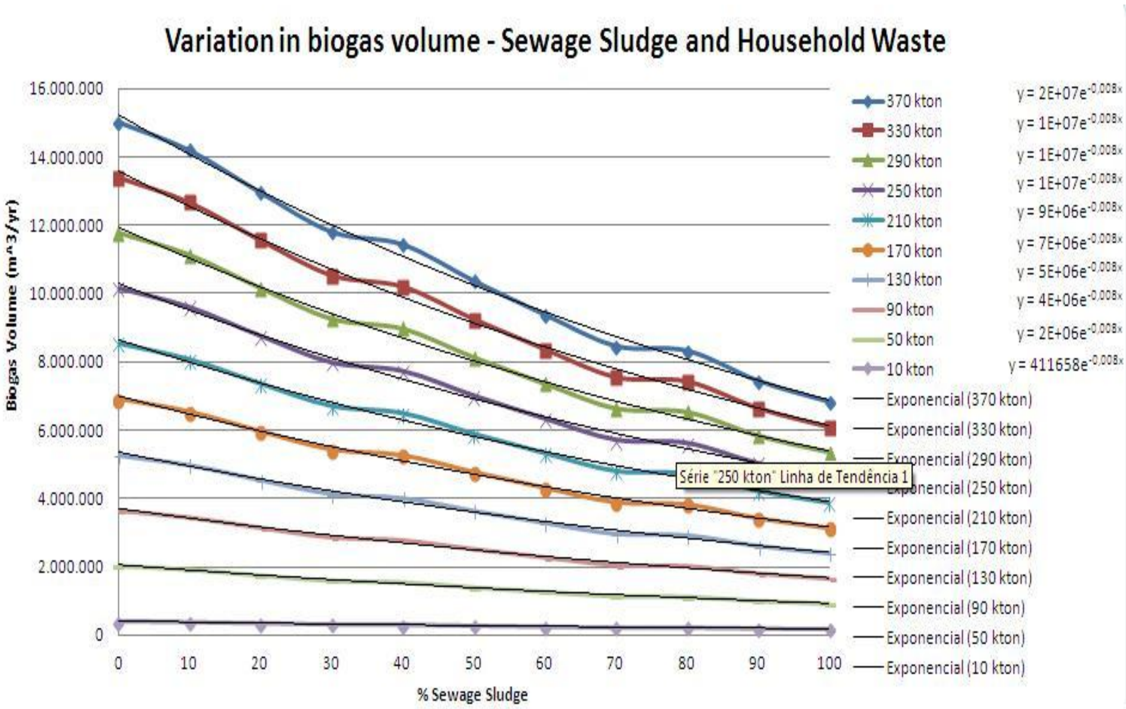

Figure Annexes 7 - Variation in biogas volume. Comparison between sewage sludge and household waste.

By analyzing the graph, the greater amount of sewage sludge, corresponds to a smaller amount of biogas produced.

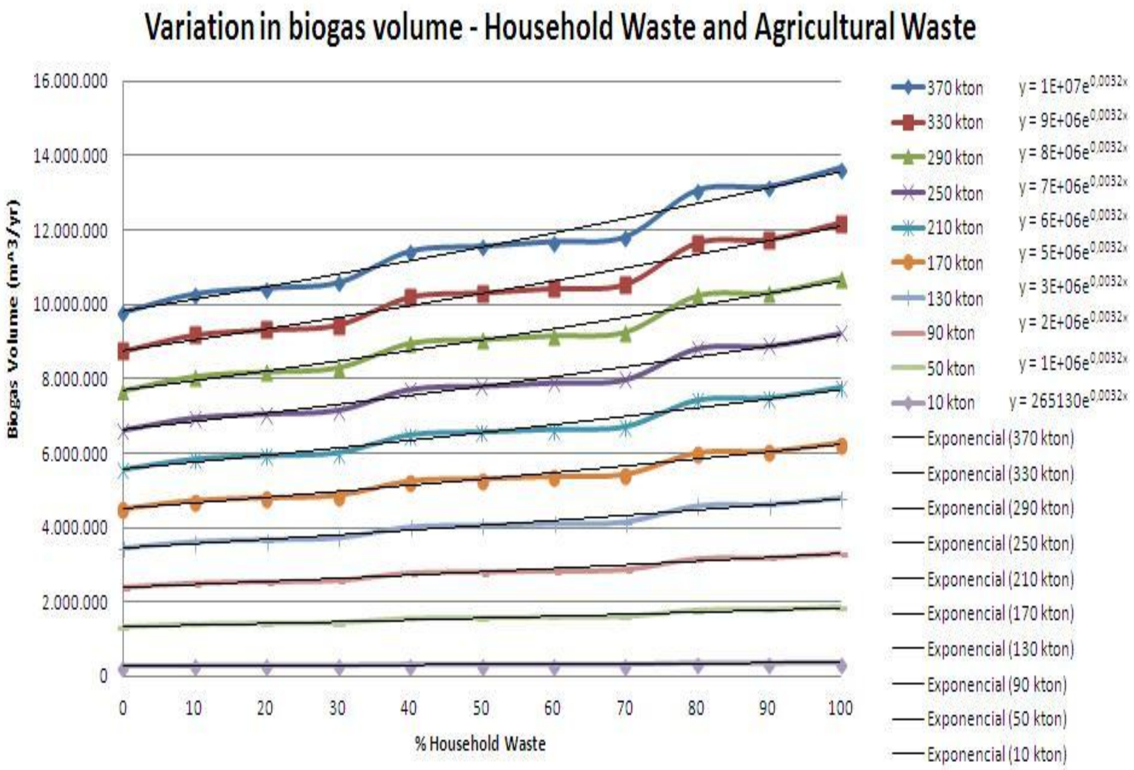

Figure Annexes 8 - Variation in biogas volume. Comparison between household waste and agricultural waste.

Comparing amounts of household waste with quantities of agriculture waste it’s possible to observe that the greater percentage of household waste in the mixture corresponds to an increasing on amount of biogas production.

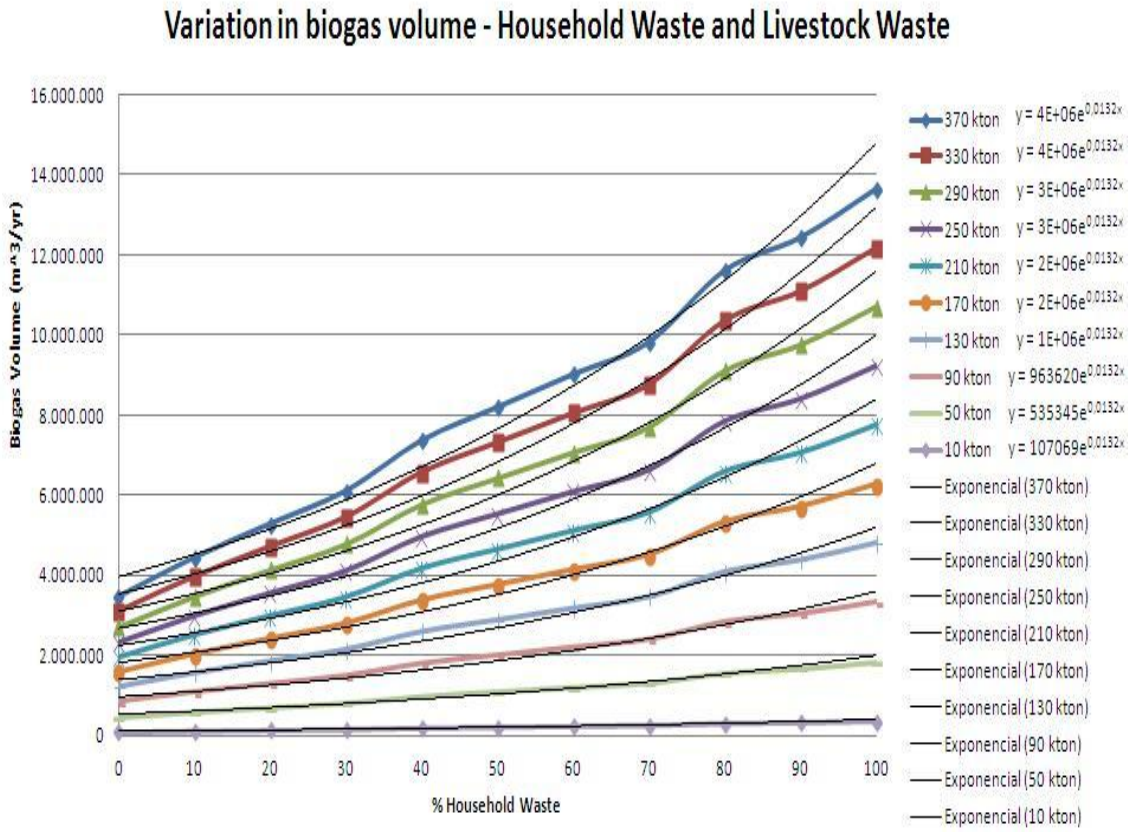

Figure Annexes 9 - Variation in biogas volume. Comparison between household waste and livestock waste.

By analyzing the graph shown above is possible to observe an increase of biogas production when the proportion of household waste is increased.

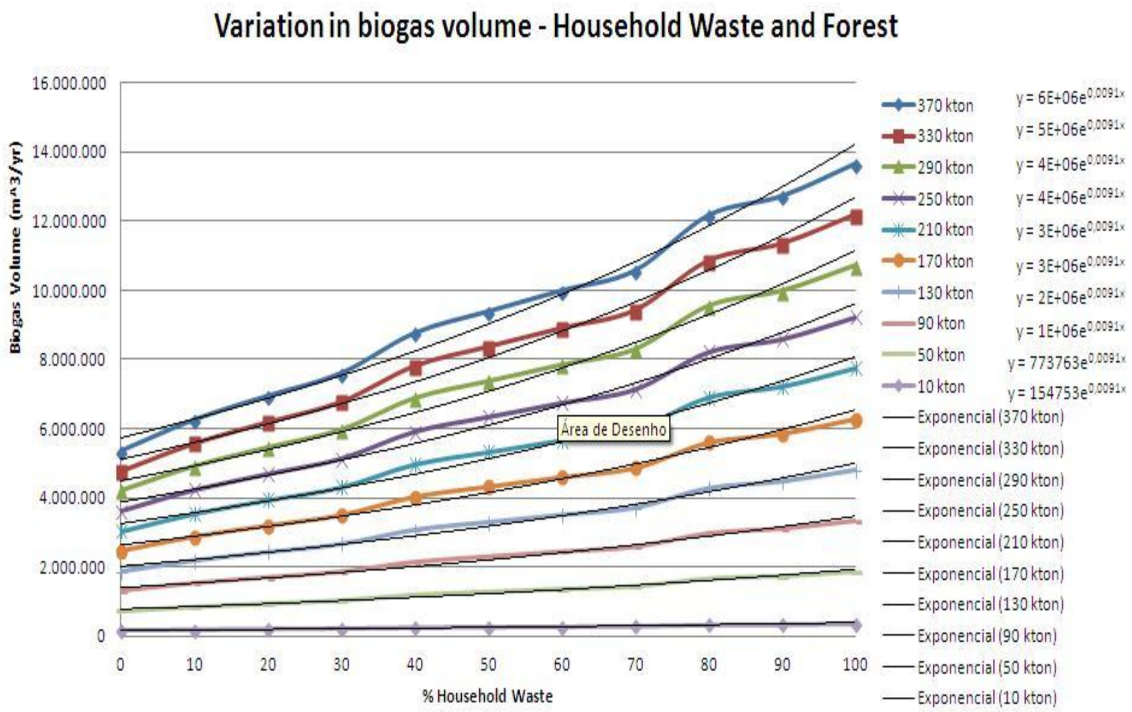

Figure Annexes 10 - Variation in biogas volume. Comparison between household waste and forest waste.

For this case taking into account only the amount of household waste and forest residues it is possible to see, as in previous cases that the amount of biogas increases when the fraction of household waste in the mix increases too.

Energy sustainability measures commitment with Covenant of Mayors

In Action Plan for Sustainable Energy, have been defined multiple sustainable energy measures whose implementation will enable the fulfilment of the commitment with Covenant of Mayors signing, including a reduction of at least 20% of emissions by 2020 . To ensure the implementing feasibility of proposed measures and the success of implementation of action plan, all presented measures were analyzed from potential reduction emissions viewpoint in the County, based on specific characteristics of County, energy characterization and identifying sources of CO_2 emissions resulting from implementation of reference inventory emissions.
Measures considered in this SEAP were selected taking into account the following options:

EFFICIENT LIGHTING

Elaboration of "Efficient Lighting Plan" that relies on the participation of energy managers in services and public facilities and/or private agents.

This plan should promote the replacement of inefficient lighting equipment by other energy efficient without compromising population needs in this area and light quality, reflecting a consumption reduction in fuel, consequently reduction of CO_2 emissions and energy invoice.

Illumination is one of energy uses that introduction of energy efficient solutions most offset in terms of energy bill and comfort level. Typically, in a dwelling it is possible to reduce electricity consumption just in lighting from 15 to 20%, without prejudice the light quality. This reduction potential still can reach 30 to 50% in offices, commercial buildings and leisure facilities.

In this context, we analyzed multiple possibilities of increasing efficiency indoor lighting, especially the replacement of incandescent light bulbs with compact fluorescent lamps (CFLs) or tubular, that can achieve savings of approximately 75%. This measure will reflect a reduction also in costs both for the reduction of energy invoice or durability of CFLs. Fluorescent lamps have a high shelf life, approximately 8000 hours, 15 times higher lifetime than incandescent lamp.

It was considered the possibility that, in particular cases, occurred replacing inefficient lamps by lamps with LED (Light Emitting Diode), obtaining an even greater reduction in consumption, which can achieve 90% reduction consumption in relation to incandescent lamps. Additionally, LED technology gives lamps a long-lived, made a lifetime about 50 times superior than a conventional incandescent lamp.

Besides directly reduction energy mentioned above, replacement of inefficient lamps also contributes to reduction in consumption of indirect cooling air, due to greater conversion ability of energy into light in more efficient lamps, thus minimizing the heat waste of it.

STREET LIGHTING OPTIMAL MANAGEMENT, (BALLAST REGULATING FLOW AND EFFICIENT)

Energy resources management improves with gradual replacement of inefficient ballasts with more efficient, including ballasts that allow better management of energy flow/light on PL.

Public lighting is one of the plots of major energy bill in cities, there is a high potential for energy savings associated with low expression of reducing current flow and twilight sensors to control the operating period, as well as low efficiency of ballasts used.

Luminous flux regulators are devices that automatically reduce public lighting luminous flux, resulting in the reduction of energy consumption during this period, without compromising the quality and safety of site to be lit. Thus, the flow regulators allow increasing the useful life of each light point and reduce energy consumption in hours of little movement on public roads, leading a energy consumption in street lighting a reduction of up to 40%. This equipment also has the advantage of being applicable on all circuits equipped with lighting discharge lamps such as fluorescent, mercury vapour, sodium vapour and metal halide.

Ballasts are devices that connect between the power supply of an electrical circuit and one or more discharge lamps. The main functions allow the start and limiting the lamp current to a normal range during operation.

The advantage of replacing conventional electromagnetic ballasts by electronic ballasts is that the latter allow better management of luminous flux and energy as a function of traffic density, weather conditions, adaptability to local parameters of lighting project and the compensation maintenance factor of luminous flux of lamps that depreciate over its lifetime. As electronic ballasts are electronic power converters used to control discharge lamp, allow substantially reduce energy losses compared to electromagnetic ballasts, the most common premises IP. This solution can be implemented in new equipment and equipment already in operation.

LEDS LAMPS AND EFFICIENT

Replacement of inefficient lighting fixtures by more efficient to improve quality/cost. LED technology is the most efficient solution within the Public Lighting (IP) and traffic light signalling.

High energy consumption in street lighting is often driven by a low efficiency of lighting system, a consequence of predominance of inefficient use of equipment such as mercury vapour lamps - highly inefficient lamps and traffic lights in low efficiency, including others. Currently there are already market solutions that enable an efficient IP with the same quality. One possibility is replacing inefficient lamps, such as lamps which emit light in different directions or areas which do not require illumination, for example emitted light towards the sky (light pollution).

Another solution consists in replacement of external fixtures to the lamps, for example. Mercury vapour lamps usage in street lighting is not advisable because these have a low light output as they age and their flow is reduced considerably. Use of lamps with a high luminous efficiency, as the case of sodium vapour lamps, for example, it is possible to reduce the power consumption and have a colour rendering suitable for urban roads lighting and pedestrian areas.

For public lighting lamps, market solutions also pass by LED technology, highlighting its use in traffic light signalling. The use of this technology allows a reduction in traffic lights consumption of about 80% to 90% when compared to the same intensity use of lamps. In addition, due to their low power consumption, LEDs may also be powered by solar panels.

Another advantage mentioned are related to the improvement of road safety, given that the index of reflection of sunlight is 50 percent lower than in the traditional system, allowing greater visibility and ending with illusion that the lights are connected, when actually they are not.

BUILDINGS CERTIFICATION

Conduct audits in buildings, utilities and industries to assess the degree of energy efficiency in it and identify the potential improvement.

Buildings sector is responsible for about 40% final energy consuming in Europe. Over 50% of this consumption can be reduced using energy efficiency measures.

Energy Certificate for a building should describe the actual energy performance of that building and including energy consumption calculation provided from their use, allowing proving the correct application of thermal regulation and indoor air quality in force for building and their energy systems. In existing buildings, the energy certificate provides information on measures to improve energy performance, economic viability that owner can implement to reduce their energy costs, risk-free to leverage, comfort and productivity. So with this classification it is known the level assigned to the building and what the next steps to achieve better efficiency for the building, service or industry certificate.

The certification process involves the action of a qualified expert, which will have to check through audits, regulatory compliance within the building(s) regulation(s) apply (RCCTE and/or RSECE) classifies it according to energy performance, based on a scale from A + (best performance) to G (poor performance) and eventually to propose measures for improvement. In legal context, the energy certification is compulsory from 1st January 2009 for all buildings that are in sale or rental process.

ACTIVE MONITORING

Available technologies that enable smart metering of energy consumption water data collection, electricity and gas, aiming to create a more efficient use of resources examined.

An appropriate introduction in energy management, consumption monitoring and adoption of good practice in equipment using allows the minimization of energy waste and a reduction in total energy consumption. Monitoring allows you to analyze and receive all data collected in real time, it checks the entire system and whenever there is something irregular, the system generates an alert that allows its real-time correction. The installation of measuring devices for energy consumption to provide immediate feedback helps reduce energy consumption in homes by 20%.

Beyond that, system maintenance procedures can be performed less frequently, since there is a parallel process which collects and processes the information in work areas, minimizing costs.

HOUSEHOLD EQUIPMENT RENEWAL

Promote a gradual of household renewal equipment consumers of energy inefficiently by other top-class energy, especially home appliances.

Appliances are common use equipment in a dwelling and use of more efficient equipment is preferred. Due to technological advances increasing consumers have at their disposal more efficient equipment and should therefore be promoted more or less regular replacement for more efficient models. For illustrate the potential in reducing consumption of this measure presents the scenario of replacement of all household equipment of a dwelling that could result in reduced annual electrical consumption in order of 30%.

In order to identify energy efficiency of home appliances, there is energy label. It’s used is common throughout Europe and it is an informational tool to the service consumer. According to current law the seller is required to display the energy label for each type of appliance. The Energy Star label and GEA are used in office equipment and electronics consumer.

OFFICE EQUIPMENT RENEWAL

Provide the gradual renewal of office equipment energy consumers with more efficient ones. The increasing introduction of electronic and electrical equipment in offices in recent years represents a considerable rise in energy consumption of buildings. Moreover, there is also a high energy potential savings associated with using such equipment.

Full exploitation of potential energy savings of some electrical and electronic equipment can be achieved through the selection and purchase of energy-efficient equipment.

For example, refers the possibility of achieving an energy saving up to 80% by substituting a desktop to portable computers. Similarly, the replacement of a conventional CRT monitor panel may lead to lower fuel consumption by about 50%, and the replacement by Mono-function devices that multifunction centralized devices allows also the order of 50% reduction in consumption.

In this context, we highlight the importance of promoting the energy efficiency criteria during selection of office equipment to purchase, including equipment that have opt-Energy Star label (equipment used in low power standby), showing a right-sizing, which have inhibitors of energy consumption in off mode, among others.

EQUIPMENT MODERNIZATION

Renew equipment gradually, substituting more efficient equipment in particular driving forces equipment.

All equipment has a lifetime. Over the years equipments begin to be less efficient, they begin to spend more energy for the same function.

In addition, technology evolves very quickly, always aiming to improve equipment performance and reduce power consumption per device/function.

Investment in efficient equipment can reduce energy consumption consequently reduction greenhouse gases emissions, highlighting the importance of efficient motive power equipment (electric motors), as they represent a major end uses electricity and that its application covers all activity sectors, from simple household appliances to industrial machinery.

SOLAR POWER

Installing solar thermal collectors in buildings for tourist accommodation, domestic activities of human health, sports and recreational activities and promote the production of electricity using photovoltaic systems.

Hot water production is a process which consumed a large amount of energy. Installation of solar thermal collectors, which harness the energy from the sun to heat water, thus presents a major impact on reducing energy consumption, saving as much as 70% of energy needed to heat water.

Energy provided by sun is transformed into heat/hot water by installing a screen placed on the roof or elsewhere in the building with plenty of sun exposure. Downstream of the panel there is a closed circuit of water to heat and maintain the hot water, even during the night.

All this system achieves the results with conventional systems of water heating gas, diesel or electricity, with however the advantage of power supplied by sun has no cost, enabling a huge reduction in the emission of greenhouse gases.

Photovoltaic systems allow the conversion of solar energy into electrical energy through photovoltaic cells that create an electric potential difference by light action. Photovoltaic cells are made of semiconductor materials, typically silicon and can convert 7-16% of solar energy captured into electrical energy, with a peak power from 60 to 140 W/m^2.

Evolution of technologies associated with photovoltaic systems and rising cost of fossil fuels has contributed to economic viability of photovoltaic power generation, which is further enhanced by reduced maintenance costs and high service life of these systems. The production of photovoltaic's can be aimed at home consumption or sale to public grid. The production for self allows the producer to replace the use of energy sources with greater environmental impacts of a renewable source, while still allowing a reduction in energy bills associated with acquisition of energy from these same sources. In turn, the production for sale to public allows the producer to obtain an attractive source of monthly income, especially by the application of subsidized rates, and simultaneously contribute to the increased rate of renewable in national energy mix.

HEAT PUMPS

Install heat pumps in buildings for tourist accommodation, domestic activities of human health, sport and recreational activities.

Heating systems play a crucial role in maintaining thermal comfort of the building, on cold days. However, these systems are responsible for a significant part of building energy bill and greenhouse gases emissions into atmosphere, so improving its energy efficiency is the key.

Heat pumps are thus sustainable as an option. Outside air temperature is the main energy source of heat pump regardless its temperature. When pulling and compressing the outside air through a compressor, this device allows, with the aid of a heat exchanger, warming the air within the building.

These systems allow hot water and ambient air in an efficient way, because this technology requires only 25% of electric energy in compressed air, obtaining of outside air the remaining 75% of the energy needed for heating.

ADVANCED BOILER

Install heat pumps in buildings for tourist accommodation, domestic activities of human health, sport and recreational activities.

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EFFICIENT VEHICLE ACCESSORIES AND EFFICIENT FLEET RENEWAL

Efficient vehicles incorporation through gradual renewal of vehicle fleet in land transport.

Road transport is responsible for most of mobility generated and the car in European Union in 2008 represented 72% of total motorized mobility. The growing dependence on private transport and the increase number of trips per passenger has caused serious social, economic and environmental impacts, including inefficient energy consumption in transport sector. Currently, over 20% of final energy consumed in European Union is the transport sector responsibility. Portugal, in 2008, was responsible for 28% of total final energy consumption in transport sector.

Efficiency and reducing emissions of greenhouse gases are increasingly present in auto industry: the automotive industry has been experiencing tremendous progress towards reducing CO_2 emissions and technological development has been evident in achievement this goal. At present, the replacement of older vehicles for new cars in the same range ensures alone an increase in energy efficiency and therefore energy reduction of fuel consumption per kilometre travelled.

However, it isn't necessary replace the full benefits of the vehicle for environmental and energy level, in many vehicles effective maintenance can be significant in terms of efficiency of vehicle.

ELECTRIC VEHICLES (EV)

Purchase of electric vehicles and creating a network to supply them.

As mentioned, transport is responsible for more than a third of final energy consumption in Portugal. To promote energy efficiency in this area, have already been launched several programs including the Mobi.E Program, an initiative of Portuguese electric mobility that put Portugal as a pioneer in the development and adoption of new energy models for sustainable mobility.

MOBI.E Program electric vehicles promotion will create a charging network nationwide, user-centred, accessible anywhere in the country and compatible with all brands of vehicles, open to all operators, enabling you to enter the electric vehicle as an alternative to road transportation using fossil fuels. By mid-2011 will be completed a pilot network of vehicle charging that incorporate 25 municipalities participation.

Electric vehicle purchase allows a great energy and financial savings because electric motors are more efficient than internal combustion engines. An electric vehicle spends, on average, between 0.1 to 0.23 kW/h per kilometre, while a vehicle with an internal combustion engine spends, on average about 0.98 kW/h per kilometre. With this performance electric vehicle allows a great reduction in cost per travel, besides not being subject to large fluctuations in the cost of traditional fuels in recent years.

SUPPLY IMPROVEMENT AND TRANSPORT NETWORK

Study and create new routes for transport network, with more and better linkages between them and study population displacement flow.

With an increasing in offer on public transportation which is responsible for serving population, there is a greater increase in moving people from starting point to destination also permitting gradual improvement of urban mobility system.

Analyzing and restructuring public transport system, creating new routes, adjusting schedules to people's daily lives and promoting synergies between different transport modes it is possible to put public transport network as a real alternative to private transport.

Reducing car using will promote a reduction in fuel consumption in a sector with high energy needs, which will bring many benefits to environmental, health, quality of life and even economics.

URBAN RENEWAL AND ROADS IMPROVEMENT

Develop a plan to better know the needs of collective transportation of new urbanizations in order to improving urban access through the rehabilitation and urban network improvement.

For the elaboration of the plan for urban renewal and accessibility improvement is crucial to identify areas with higher population flow, with more hits. Is necessary to understand where people go.

The majority of population movements is made between home and work, and should therefore be promoted the concentration of services sets that minimize travel distances and, simultaneously, allows you to create a good network of access to these sites and allow a wide range of collective public transport.

The plan should also structure urban primary road network for this to facilitate city crossing, as well as input and output of it to make it fully functional for different users and to liberate the secondary network for local easier access, focusing on pedestrian and cycling modes and using of public transport. Thus contributes significantly to increase the quality of life of citizens, as well as to promote sustainability of the city.

A city with good mobility urbanization policies, population quality of life increased because there is a reduction in travel times as well as necessary energy for the transport and greenhouse gases emissions.

INCREASED "PEDESTRIAN" AND USE OF BICYCLE

Create a network that allows making the city more pedestrian and cycling.

Currently, for environmental and public health issues it is increasingly recognized that soft modes (individual movement and locomotion on wheels without use of fuel energy) are may be an alternative in a short-distance travel or in a combination with other modes. The promotion of this type of travel would reduce the number of vehicles in circulation, so an asset for reducing energy dependence and of greenhouse gases emissions and also for human health.

In order to promote increased walking and cycling mobility, it is essential to ensure Ecopistas availability and qualification, providing better conditions for comfort and highest level of priority routes in higher flows or those who need for urgency improvement.

In this context it is argued that pedestrian and cycling networks are to serve areas with more intensive trade and services as well as poles of higher tourist concentration, surrounding areas with major travel generators and with interfaces, transport stops that serve residential areas.

The quality of network to create/maintain should be permanently guaranteed through an adequate monitoring of their condition and maintenance actions appropriate. Should be further promoted to increase the safety of its users by improve the urban design and correction situations that lead to risk of pedestrian accidents.

As an incentive to bicycle use, should be further promoted the existence of equipment and infrastructure to support the use and parking of bicycles.

To a greater successful in Ecopistas should proceed to population awareness and training for interaction and use these modes.

ENERGY OPTIMIZATION AND CLIMATE POLICY ASPECTS OF URBAN PLANNING AND MUNICIPAL

Municipality Master Plan (PDM) reviews considering energy sustainability as a core element in planning decision.

In a city where home to workplaces trips account for most of needs of population displacement, it is essential that PDM adapts to these needs in order to shorten distances.

A regional planning thought and weighted to maximize energy efficiency will contribute to a significant improvement in residents and employed quality of life in county, either by reducing costs and emissions associated with mobility or by reducing the travel length.

WATER MANAGEMENT

Improve the current model of demand management and water consumption, to search for better energy efficiency.

Water sector is a source of renewable energy and clean, as a consumer of energy, contributing to the greenhouse gases emissions when it is produced from fossil fuels. This sector is a major consumer of energy, particularly in areas of collecting, treatment, distribution of drinking water and drainage, treatment and discharge of wastewater.

Water management process should start in capturing maintained until the end customer and wastewater treatment. The prediction of water consumption per hour and the identification of peak hours allow management to better serve the customer and supplier, ensuring the maintenance of supply using the lowest energy consumption and therefore less CO_2 emissions.

Water heating for domestic use is also responsible for significant energy consumption, as collecting and pumping for agricultural use, another area where energy consumption can be significant. Awareness and implementation of measures to moderate the water consumption in these sectors may also be reflected in energy savings.

The possibility of treatment plants wastewater centres are energy producers using cogeneration and energy production in anaerobic digesters.

Water reduction consumption and increasing energy efficiency of operation systems and management of the resulting optimization model of water management thus contributes to a reduction in energy consumed.

WASTE MANAGEMENT

Designing or improving the model of waste management, achieving maximum efficiency in energy use.

In Portugal is produced daily on average 1.4 kg of household waste per inhabitant, it is important to raise awareness and education for prevention of waste production.

The energy impacts resulting from proper management of waste are enormous, in that preventing waste is allowed to consume a large amount of energy in processes of extraction, transport and raw materials transformation and then collecting and treating their own waste.

On the other hand, investment in education and awareness for equipment and materials reuse, separation and recycling materials such as glass, plastic, paper and metal allows to save resources, to combat pollutants emission and greenhouse gases and limit the occupation of land for disposal of waste, contributing to a sustainable development model and a better environment.

Organic recovery is also a strategic measure to reduce GHG emissions. Separation, collection and routing of organic material to a treatment station allow biogas production that can be used to produce energy and for producing a high quality "compound" for agriculture.

Used cooking oil can also be reused for biodiesel production, as previously mentioned.

Waste sector is responsible for direct and indirect emissions that can be reduced with an appropriate model for waste management. Direct emissions result primarily in support activities, such as fossil fuels consumption, incineration and composting operation, collection fleets and mobile machinery in existing landfills. Indirect emissions are related to electricity consumed on facilities.

FLEET MANAGEMENT DISTRIBUTION

Conceive a plan for improving transport network in distribution and urban support services and better manage their fleets.

Many companies have fleets of vehicles that affect the activity and/or assigned to company's staff, typically with management functions (county administration, staff directors). Thus, fleet management, particularly in logistics terms, assumes a central role in improving business efficiency, since it integrates the management of supply chain that plans, implements and controls goods flow, services and information between origin point and consumption point, in order to meet customer needs.

Measures typology to be implemented within fleet management includes routes optimization – it is especially important in cases of distribution companies or whose activity involves regular visits to customers - the purchase less polluting vehicles fleets (e.g. hybrid vehicles, electric vehicles, use of bicycles for local distribution or others that allow the reduction of environmental externalities) and allocation policy review of company cars in order to promote the rationalization of vehicles allocation. A good fleet management leads to a competitive advantage and cost savings, as well as reduction of energy consumption and respective CO_2 emissions.

OCCUPATIONAL AND COMMUTING MOBILITY OPTIMIZATION

Realization and implementation of integrated plans for mobility in public transportation level should be adaptive for workers and customers of business establishments in county.

Workers movement, visitors and service providers constitute a significant share of trips made daily in county and therefore the poles generators/attractors of travel, have an important role in mobility and sustainability system management. As such the adoption of good practices of mobility should establish itself as a reality within labour activity, especially in large companies and generators/attractors poles of trips.

In this context, conception and implementation of integrated mobility plan that encourages the use of public transport especially for commuting becomes relevant and it is a valuable tool to promote energy sustainability.

There will always be a group of individuals who for professional or personal life will continue to use the car to do their movements, should also be advocated measures to optimize/streamline car use. In this case it should be done a feasibility study for implementation of measures to promote Carpooling (sharing a car between employees performing the same route by allocating the travel cost), Carsharing (vehicle use available/rented at certain points to local displacement) or Vanpooling (shared minibuses available for traveling to specific points, such as companies, business services, among others), for example, would reduce both the number of vehicles on road daily.

The creation management models of parking can also be used as a management instrument and demand control for individual transportation. In city central areas, including the use of long-term parking on public roads associated with commuting (employees in commerce and services) will ensure the existence of rotational parking for visitors, including customers and suppliers. In addition, availability of parking areas free or reduced cost on outskirts of the city served by an adequate network of public transport provides a private transport alternative in inner cities.

AWARENESS, EDUCATION AND PREMIUMS FOR ENERGY EFFICIENCY

Planning a set of actions to raise awareness and educate the population to environmental and energy practices.
Some social, cultural and psychological prevent users from making energy savings. These barriers are associated to energy-efficient behaviour, especially the lack of awareness and information and bad habits.

Sustainability path involves permanently affect the behaviour and then acquire new habits. Information and education are the keys elements to transform knowledge into action.

This includes population awareness/education, highlight adapted campaigns to various age groups of population, especially in energy efficiency, labelling machines, equipment warnings about energy efficiency or performance education in schools, use information technologies such as consumption meters. Counselling experts during audits may be necessary to help people become aware of possible energy savings and to measure the impact of their behaviour. Well-informed consumers choose actions to save energy with minimal impact on their comfort. The perception of comfort is important, there must be a balance between energy saving and perception of any comfort loss.

CONDOMINIUS SUPPORT AND RESIDENTS ASSOCIATIONS FOR ENERGY EFFICIENCY MANAGEMENT

Promote and create a technical framework for counselling in energy efficiency area for domestic sector with a strong focus on condominiums and/or neighbourhood organizations.

The network creation of experts to conduct audits in domestic sector will allow the identification and presentation of measures with technical and economic feasibility, which allow the effective reduction of consumption in buildings audited.

After the audit will facilitate awareness, collective or individual small changes residents that lead to more efficient habits and possible promotion rules to implement efficiency in buildings audited.

OPTIMIZATION OF PROFESSIONAL PERFORMANCE

Implement training, awareness and education for municipal workers and private companies that operate vehicles or equipment-intensive energy consumers.

Good practices awareness against waste allows for workers to increase environmental consciousness. Although there are its countless applications of control in order to consume as little as possible by performing the same task, there are factors that are totally controlled by worker.

Promote awareness of a worker through formation can create a contagion effect, according as learner can teach colleagues, friends and family to have a more sustainable attitude in their actions.

In this context, and presents itself as an example the fact that few drivers know how to exploit optimally the potential of vehicles with increasingly lower average consumption and CO_2 emissions per kilometre. Implement training-formations, awareness and education allow instil changes in driving habits that can translate into significant gains.

NATURAL GAS CONVERSION

Convert gradually heat consumer equipment to natural gas.

Natural gas has significantly increased its participation in national energy balance bringing a number of advantages in terms of environmental impacts, safety and convenience of use.

This fuel has a broad spectrum of applications in domestic and industrial use. In domestic sector, natural gas consumption allows replacement of petroleum gas (LPG), reducing the amount of CO_2, according as natural gas combustion results in an amount of CO_2 lower than any product petroleum origin. In industrial sector natural gas can be used in boilers substituting less sustainable fuel to produce steam for heating. Heat transfer fluids used in various industries or for use in industrial furnaces.

Natural gas can also be used as automotive fuel, reducing pollutants emission and greenhouse gases in transport sector. It is considerably more expensive than diesel and petrol, its use as fuel increases the lifetime of engine, reducing maintenance costs and consumption of lubricating oils.

CARBON EMISSIONS VOLUNTARY REDUCTION

Promote and create a technical framework for counselling in energy efficiency area for industry and services sector.

Voluntary Carbon Market appears in parallel with Regulated Carbon Market and aims to offset individuals or companies emissions that have no legal obligation in accordance with European Emissions Trading Scheme (ETS) in order to mitigate their environmental effects on units of CO_2 equivalent.

Scientific principle is based on fact that greenhouse gases are mixed rapidly in dispersing air throughout the world. As such, it is irrelevant where GHG reductions occur; only that matter is emitted less carbon into atmosphere.

Voluntary Carbon Market has grown strongly in recent years given companies growing concern with their emissions increasing the number of related projects, for example, renewable energy and planting forests.

The main advantage of this market is the possibility of being accepted small projects, unlike what happens in arranged market today.

Currently, there are still many industries without limitation in greenhouse gases emissions, but through these markets, may help to reduce those. For this a technique structure should be established to promote the potential of Voluntary Carbon Markets and promotes the inclusion of projects in this market. This team should also have the technical capability to undertake the implementation of emission inventories fit to specifics of each client and adaptable to a specific period, enabling accounting any specific production (any product or service), event, or other unanticipated, based on international guidelines calculation.

Implementation of this measure in many companies will voluntarily change their history in energy and increase their sustainability and it is vital awareness of business sector.

GREEN PUBLIC PURCHASE (GPP)

Designing a tool to measure all purchases as environmentally, energy-using equipment, vehicles and contracts

Procurement accounts for over 16% of European Union Gross Domestic Product. Thus, there is a great potential that GPP have for sustainable development and reducing GHG.

At the same time, buying green products or services by public bodies conveys gives a positive image to market, providing an example to other identities, and encourages companies to innovate their products and show that these are true sustainable products.

Recognizing the contribution that GPP will have for sustainable development, it was presented a Resolution of the Cabinet of Ministers n.º 65/2007, approving the National Strategy for Green Public Purchase 2008-2010. This Strategy sets out the priority products and services which public authorities should start their green purchasing policy. In relation to these products and services, it was also developed ecological criteria to be implemented by various agencies in their procurement policy.

Thus, arises the need of design a tool that takes into account ecological criteria to apply under the new public procurement policy and to measure all eco products and services to be contracted stamps municipal services.

SUPORT URBAN INVESTMENT AND SUSTAINABLE BUSINESS

Sustainable technical support and positive discrimination to new sustainable real estate investments and certificates.

Support for new investments is extremely important to region's economic development and should therefore be offered support and information that would allow attracting investment and encouraging entrepreneurship. It is essential in this step providing the necessary support to promotion of sustainable projects, aiming at economic growth that contributes to sustainability goals of region and does not compromise the quality of life of surrounding where it belongs.

With the positive discrimination becomes easier for companies that don't have yet a sustainable activity to focus on environmental issues when developing their business plan. Positive discrimination should focus on investments that take into account sustainable growth and encouraging the development of projects/activities sustainable and energy efficient.

MOBILITY FOR EVENTS OPTIMIZATION

Designing and planning a network of transport and parking for events with presence of broad public.

The shift from public to major events always brings with it several factors that are hardly controlled as traffic jams, difficulties associated with vehicles parking, among others, often compromising sustainability of these initiatives.

As such, one of fundamental measure in planning events is the availability of parking for public who travels by car. Parking areas should provide multiple areas and information about being full.

It should also be planned availability public transportation between the event and the local focus of all public transport and car parks. Thus, it should minimize the movement of visitors in private transport and corresponding CO_2 emissions.

Reference Cases that helped in the construction of the scenarios

	Amsterdam	**Bern**	**Birmingham**
Separation			The feedstock would be separately collected food waste from households and commercial and industrial customers
Collection		Citizens have to pay a supervisor	The majority of waste is going through a waste transfer station
Incineration	To generate energy from Municipal Solid Waste	Local energy supplier for the City of Bern supplies energy	As a help for the production of energy
Anaerobic Digestion			Link the AD facility to a further CHP system. A better approach to save energy
Biogas	Biogas is used as a fuel from the municipal waste water plant	Local Waste Water Treatment Plant produces biogas and up-grades it to biomethane	Can be used to generate electricity for export or used on site. Used in some instances as a bio-fuel.
CO_2 Emission	Development of smart ICT solutions to decrease CO_2-emissions		Create a vibrant low carbon low waste economy

	Brussels	Göteborg	Helsinki
Separation	The introduction of selective collection of waste.	Bulk household waste, electrical and electronic waste, and hazardous waste is often taken to municipal recycling stations or left in a bulk waste room.	The waste treatment centre receives unsorted waste and separately collected organic waste from over a million inhabitants
Collection	Activities for the '-100 kg' campaign	Household waste that is not subject to producer responsibility is collected by municipalities themselves or by their contractors	The average inhabitant in the Helsinki metropolitan area produces annually about 300 kilos of household waste. About 55% of household waste is recycled or reused.
Incineration	Undertake a study to consider an incineration tax		Helsinki has decided to introduce a new incineration plant in 2014.
Anaerobic Digestion		The waste water treatment plant at Gryaab has been digesting waste water sludge anaerobically since 1990.	Helsinki is planning to increase the efficiency of organic waste management by constructing a biogas digester to extract biogas from the collected organic waste before the composting process
Biogas		The biogas was originally used to generate electricity and heat. Later, the biogas was distributed through the Göteburg gas grid	Biogas is also collected from old landfills and waste treatment plants.
CO_2 Emission			

	Jomala	**Lidköping**	**Münster**
Separation			Brochures covering all topics related to the avoidance and separation of waste are vitally important for the information of Münster citizens
Collection			At the end of each year, all citizens will receive a waste disposal calendar that includes the collection schedules for the bio-waste container, yellow bag, residual waste container and paper container but also other important information.
Incineration			
Anaerobic Digestion			
Biogas	The main byproduct utilized in the gasification is whey. The gas is fed to the district heating boiler and also used for heating in the dairy process	It is one of the first of its kind in the world producing both compressed and liquid biomethane for vehicles.	Sewage gas, landfill gas and biogas gained from fermentation run a combined heat and power plant
CO_2 Emission		Reduction of 16,000 toe of CO_2 emissions per year	Reduction of CO_2 Emissions 1995 – 2005 • Target: - 25% • Achievement: - 21%

	Münster	**Riga**	**Rogerste**
Separation	Brochures covering all topics related to the avoidance and separation of waste are vitally important for the information of Münster citizens	The recycling process of waste has been implemented and today 25% of the total amount of waste is recycled.	
Collection	At the end of each year, all citizens will receive a waste disposal calendar that includes the collection schedules for the bio-waste container, yellow bag, residual waste container and paper container but also other important information.	Waste collection in Riga is centralized. Waste producers sign agreements with waste collection and transportation organizations.	
Incineration			
Anaerobic Digestion			
Biogas	Sewage gas, landfill gas and biogas gained from fermentation run a combined heat and power plant	Old landfill area has been covered and land-fill gas production system (13 million Nm3/year – 26000 MWh) has been built	By-products from a food factory are converted into methane, which is burned to generate electricity that feeds back into the factory
CO_2 Emission	Reduction of CO_2 Emissions 1995 – 2005 • Target: - 25% • Achievement: - 21%	In 2004, total amount of CO2 and CH4 emissions per capita was 4.04 toe in Riga, which is quite low in comparison with other European cities	The new facility will not only reduce the amount of waste sent to landfill, but reduce carbon emissions by around 8,500 toe each year.

	Stavanger	Stockholm	Tallinn
Separation	Stavanger has come far in the area of waste management. About 65% of all household waste is sorted.	All of the City's operations will sort their food waste for biological treatment aimed at biogas production and nutrient recycling	City-wide network of 23 waste stations accept recyclable, electronic and hazardous waste free of charge from residents
Collection	In 2002 every inhabitant of Stavanger generated 372 kg of household waste, while in 2008 this figure had grown to 427 kg	Differentiated waste fees, weight-based fees and similar actions can inspire and motivate to changed behaviour aimed at minimizing waste quantities and directing towards increased sorting	Tallinn has organized municipal waste transport system to avoid illegal waste disposal and harm to the environment
Incineration	25% of household waste consists of residual waste for incineration		
Anaerobic Digestion			
Biogas	Bio-waste collected from the households to be used for production of bio-gas	The City will strive to increase biogas production in the region.	In 2010, heat and electricity co-production started in new landfill from gas gathered from landfill deposits
CO_2 Emission	Stavanger will endeavour to ensure that all stages of the chain are optimized with a view to minimizing greenhouse gas emissions.		