Use of Biomass Energy in Portugal
The case study of Tratolixo

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Abstract

The Industrial Revolution played a major role in expanding the use of fossil fuels. However, environmental concerns have increased in line with the development of technology, in particular global greenhouse gases emissions resulting from processes that rely on this type of fuel. To overcome this issue, countries have been focusing on renewable energy as substitutes for fossil fuels. Of the available renewable energy sources, biomass has shown enormous potential due to existing stocks worldwide and for being nature's most flexible energy resource. Biomass can be converted directly into energy in the form of heat or electricity or biofuels. Thus, the main objective of this work is to analyze the potential of biomass at national level, characterizing the energy value chain of resources / waste, analyzing the different methods of collection and management of waste and the alternatives of energy conversion.

Keywords: Biomass, municipal solid waste, forest biomass, combustion, energetic valorization

1. Introduction

Fossil fuels represent, since the industrial revolution, a key role in the technological, social and economic development. However there are several negative factors associated, as the fact that it is in nature in limited quantities, they are distributed around the world unevenly, creating dependencies at the energy level in several countries, and contribute to the greenhouse effect.

In Europe it is also true that fossil fuels are the energy sources more used to meet the primary energy demand. In 2010 crude oil and its derivatives were the main energy source used to meet demand, securing 35,1% of the total energy consumed in that year, followed by natural gas and coal with 25,1% and 15,9%, respectively.

With regard to renewable energy sources, biomass was the most renewable resource consumed in the EU27 in 2010, representing 69% of total renewable consumption, followed by water and wind, with 18,3% and 7,4 % respectively (EC, 2012).

In Portugal, similar to Europe situation, oil has been the most used energy source over the years, though decreasing from 61,6 % of primary energy consumption in 2000 to 43,6 % in 2012. This year, the second most used energy source were the renewables with 20,9 % followed by natural gas with 18.6% and coal with 13,7% (DGEG 2014a).

Although biomass is less used than hydro and wind power to produce electricity in

Portugal, it may be stored and used only when demand justifies, allowing in some ways a constant supply, unlike other renewable energy sources that are dependent on the winds and the water level in the dams making the production of energy through these sources dependent and uncertain.

It is in this context that the present work has the following objectives:

i. Analyze synthetically the potential of biomass for energy recovery in Portugal, including the various possible scenarios for the management of forest and agricultural residues and the available technologies;
ii. Analyze in greater detail the energy potential of the biodegradable fraction of municipal solid waste, currently existing in the district of Lisbon, particularly in the municipalities of Mafra, Sintra , Cascais and Oeiras , in order to assess the implementation of integrated solutions for managing these wastes for energy recovery.

2. Biomass

In the EU biomass is defined as "the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste" (Directive 2008/98/EC). There are primary, secondary, and tertiary resources for biomass. Primary Biomass include those resources directly removed from nature, such as forest or agricultural waste, secondary biomass include residues obtained by physical, chemical or biological processing of primary and tertiary biomass is biodegradable waste generated by man and animals.

Biomass, as a renewable energy source, has the advantage of being able to be converted directly into energy, in the form of heat or electricity, or into biofuels (in liquid or gaseous form) through physical , chemical or biological processes (McKendry , 2002), reducing dependence on fossil fuels. The solid biofuels are the most widely used (REN21, 2014) such as, wood chips and pellet.

2.1. Electric generation methods using biomass

Biomass can be converted directly into energy, in the form of heat or electricity, or in biofuels, solid, liquid or gaseous. The biomass conversion technologies can be classified as thermochemical or biochemical conversion processes and are selected taking into account various factors such as the origin, type and availability of raw materials, the intended form of energy, demand , etc. (Fiorese et al., 2014 and Ferreira et al., 2009).

Biochemical conversion methods include fermentation and anaerobic digestion while thermochemical conversion methods include incineration, gasification and pyrolysis.

From these conversion methods, the most widely used in Portugal are anaerobic digestion and incineration.

Anaerobic digestion is the conversion of biomass into biogas by means of bacteria in a low oxygen environment. This process can be used for various types of biomass as raw material. Depending on the feedstock used it is possible to obtain two main products, biogas, produced by anaerobic digestion of sewage or animal waste, and landfill gas, produced by anaerobic digestion of MSW (Municipal Solid Waste) in landfill sites (Ferreira et al., 2009).

2.2. Portuguese Municipal Solid Waste Supply Chain

Currently, in continental Portugal, there are 23 management systems, 12 multi-municipal (SMM) and 11 inter-municipal (SM) that aim to ensure the management of municipal waste produced by municipal users in the respective geographical area. Each management system has its own characteristics, at strategic level and infrastructure, which are dependent on the number of municipalities covered, geographic dispersion, demographics, and other factors (Ordinance No. 187 - A / 2014).

At this time the most common waste treatment solutions are sanitary landfill, recycling, the valorization of organic waste and energy recovery.

2.3. Portuguese Forest Biomass Supply Chain

In Portugal the electricity from forest biomass is produced in thermoelectric plants or cogeneration. In 2006 a competition was launched for the implementation of 15 new thermoelectric plants, representing 100 MW of installed capacity. This competition aimed to achieve a target of at least 250 MW of installed capacity to the central forest biomass by 2014, however from these plants only two were completed by 2013, having been appointed several reasons for this failure as financial difficulties and poor location of some plants (RA, 2013). Currently there are twenty plants using forest biomass as raw material whose total installed capacity is approximately 453,2 MW. From these power plants ten are thermoelectric and the remaining cogeneration. All cogeneration plants are installed next to wood processing industries, including pulp and paper industries.

The thermoelectric plants, dedicated only to the production of electricity from forest biomass, have a total potential of 116 MW and an annual consumption of biomass of approximately 1,33 million tons. If we add to this value the electrical power from cogeneration plants using forest biomass, we come to a total electrical power of 453,2MW already currently existing in Portugal.

3. Case study

Tratolixo is an inter-municipal company of public capital, owned by AMTRES - Association of Municipalities of Cascais, Mafra, Oeiras and Sintra which is intended to provide services (treatment of MSW and similar) and the selling products derived from the activity, as recyclable materials (paper , cardboard, plastic, metals, glass and wood), waste (tires, batteries, accumulators, batteries, electrical and electronic equipment waste), products (compost , fuel derived from waste and woodchips) and electricity (Tratolixo , 2015).

In order to operate and manage the management system of municipal solid waste, which involves treatment, final disposal, recovery and recycling of solid waste, Tratolixo has several specialized infrastructure, as follows:

• Ecopark of Abrunheira - Located in the municipality of Mafra, has an area of 19 hectares and it has a Anaerobic Digestion Plant (CDA), an Industrial Wastewater Treatment Plant (WWTP), an sanitary landfill (in construction) and a Ecocentro (Tratolixo, 2015).

• Ecopark of Trajouce - Located in Cascais, has an area of 42,6 ha and it has a Solid Waste Treatment Plant (CITRS), a transfer of MSW and Packaging Waste Station at Ecocentro, a Landfill Gas Recovery (CVEBAT) and a Water Treatment Plant (ETAL) (Tratolixo, 2015).

• Ecocentro Ericeira - Located in Ericeira, Mafra Municipality. This infrastructure allows citizens drop off various types of waste, which by their type and size cannot be deposited in official collection point, like timber and pallets, furniture and other monsters, food and mineral oils, used clothes, paper and cardboard, batteries, tires, garden waste and parks, among others (Tratolixo, 2015).

As previously mentioned there are multiple infrastructure for the treatment of waste in Tratolixo. Today, however, the facilities are at full capacity, forcing the transport of the excess of municipal solid waste and refuse from the Ecopark transfer station Trajouce or Ecoparque of Abrunheira, to external destinations. The transport is mostly done by Tratolixo but also through external carriers. In 2013 were sent to external destinations 241 380 tons of mixed waste, of which 124 982 tons were sent directly (through the transfer station without having been subjected to any treatment in Tratolixo).

Analyzing the processes used in the treatment at Tratolixo it turns out that there are some limitations to be overcome and would contribute to reduce the amount of waste sent to external destinations and hence the respective costs.

With regard to CITRS, the process of Mechanical Treatment (TM) does not have enough capacity to receive all unsorted

MSW and also does not have the desired efficiency (in 2013 about 68% of undifferentiated MSW lodged were considered refuse and sent to an external MSW treatment facility, when there is still in its composition a lot of recyclable materials. Other limitations are in terms of equipment, the lack of an open bags limits the manual and mechanical sorting process, allowing plenty of material fit for multi-material recovery and organic is sent for incineration or landfill in another entity.
At CDA the major limitations are in terms of pre-treatment and capacity. Currently operating costs in CDA are very high, resulting in a negative operating balance of 13.95 €/ t, due mainly to personnel costs , maintenance and repair. Another limitation is the capacity, as mentioned before this center has capacity to treat 200 000 tonnes of MSW annually producing 75 000 t MSW / year to feed the digesters. However due to flaws in the pre-treatment, Tratolixo opted to use as raw material in this process only waste resulting from pre-treatment in Ecoparque of Trajouce (called by MSW pre -riddled), and waste from the Mafra municipality are routed for external destination without any pre - treatment. This option allows to achieve the same 75 000 tons of organic material with only 93 750 tons of pre-riddled MSW / year resulting from CITRS in Trajouce. Figure 1 shows a simplified diagram that contains the main material flows between the various processes and external destinations.

4. Material and methods

4.1. Forecasting of municipal solid waste generation

Correlation and regression analyses, as well as group comparisons, are the most beneficial modelling to forecast MSW generation (Beigl *et al*., 2008). For AMTRES system we will use multiple regression and was considered that production of MSW is dependent on the average per capita MSW and population.
Population data and MSW per capita were collected from INE (2015) and Tratolixo (2015).
Initially equations have been developed which result in production of MSW from the population and per capita MSW production rate for each municipality through the regression analysis tool of MS Excel 2013. These have been developed through the population registers and MSW production rate per capita were obtained in sites INE (2015) and Tratolixo (2015), respectively.
For the population forecast we used the growth rate verified between 2012 and 2013.

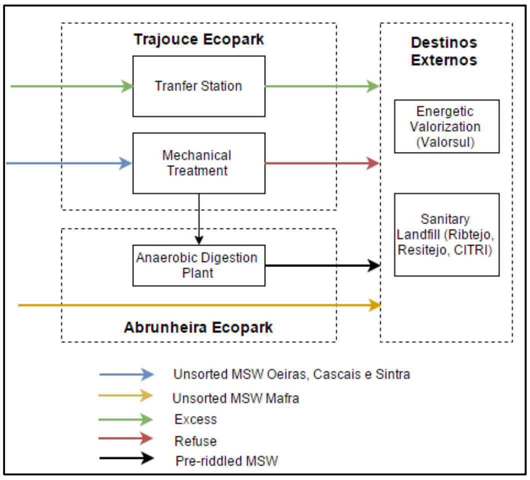

Figure 1 - Main material flows between internal and external MSW treatment processes

4.2. Investment analysis

The investment analysis is used to assess the viability of a project, considering the calculation of the associated investment, as well as the projection of cash flows that will occur during the time horizon considered. Consequently, the cash flow is the difference between inflows (yields) and output flows (expenses) occurring in each period (typically one year) life of the investment. From the company's perspective, the cash flows are expressed by the sum of the cash flows of investment with the operating cash flows generated in each period considered (Soares, 1999 and Menezes, 2003):

$$CF_k = ICF_k + OCF_k \quad (1)$$

$$ICF_k = IInv + VR_k \; com \; VR_k = VM_k - (VM_k - VC_k) \times r \quad (2)$$

$$OCF_k = EBIT_k \times (1 - IRC) + DC_k = (V_k - CV_k - CF_k - CD_k) \times (1 - IRC) + CD_k \quad (3)$$

where ICF_k is the cash flow of investment in the period k, OCF_k is the operating cash flow in the period k, $EBIT_k$ are the Earnings Before Interest and Taxes in the period k, IINV is the initial investment, RV_k the residual value in the last period, VM_k the market value at period k, VC_k the book value, V_k the income, CV_k the variable expenses, CF_k the fixed costs, IRC the Tax rate on Collective Income (IRC), CD_k the Depreciation expenses in the period k and k the period number .

The calculation of cash flows can be done through two methods: constant prices assumes that the expected inflation is zero; or by the current prices considering the effect of inflation on cash flows.

To be able to compare and add financial flows in different periods it is necessary to take into account the time value of money and therefore to update the values through a discount rate (Soares et al., 1999). In this study the current prices methodology is used.

There are several criteria for evaluating an investment that can be used individually or simultaneously, the most important being:

• Net Present Value (NPV) - is the sum of the current cash flows generated during the period of time corresponding to the project life. It is important to note that the refresh rate is adjusted to the risk of the project being the most widely used methodology for calculating the Weighted Average Cost of Capital (WACC). An isolated project is profitable when NPV> 0 (Soares et al., 1999). The NPV is expressed as (Eq. (4)):

$$VAL = \sum_{k=0}^{n} \frac{CF_k}{(1 + WACC)^k} \qquad (4)$$

CFK is the cash flow from investing or operating phases in the period k, WACC the weighted average cost of capital (WACC) and k the period number.

• Profitability Index (IR) - which indicates the number of net revenues of units (or profit) generated by a project by each invested capital unit (see Eq. (5)). The project is accepted if the IR value is less than zero (Sousa, 2005).

$$IR = \frac{VAL}{IInv} \qquad (5)$$

As mentioned previously to evaluate an investment project it is necessary to adjust the refresh rate risk associated with it, and the WACC expressed as follows:

$$WACC = r_E \times C_E + r_D \times C_D \times (1 - IRC) \qquad (6)$$

with r_E the cost of equity, r_D the cost of capital, C_D the participation of third-party financing in total liabilities, C_E the share of equity in total liabilities.

According to Brealey et al (2011) most companies use the CAPM (Capital Asset Pricing Model) to calculate the cost of equity, and its formulation is as follows (Eq. (7)):

$$r_E = r_f + \beta(r_m - r_f) \qquad (7)$$

where r_f is the risk free rate, β the beta of the company and r_m the expected market return. There are several ways of calculating the cost of equity. In this work will be used a methodology based on RTR (2014).

In RTR (2014) the cost of equity is defined as follows (Eq. (8)):

$$r_e = r_f + beta\ of\ the\ sector \times r_m \qquad (8)$$

where the risk free rate is the average annual values of the last 15 years in rates of return of Treasury Bonds of the Portuguese Republic to 10 years and the beta product sector equity at market risk premium has a maximum 3% (RTR, 2014). As for the cost of debt, this is defined by:

$$r_d = Reference\ interest\ rate + Spread \qquad (9)$$

It should be noted that, in Portugal, the municipal waste management services sector is regulated and supervised by the Regulatory Authority for Water and Waste Services (ERSAR) and there is a document, the Tariff Regulation of Urban Waste Management Services (RTR (2014)), which covers various activities related to waste management, including the treatment of waste resulting from undifferentiated collection.

According to paragraph 1 of Article 43 of the RTR (2014), the process of defining the allowed revenues of the multi-municipal systems, pursuant to RTR (2014), begins with the publication of a proposal by ERSAR parameters regulatory on 1st of January of the year preceding the respect the definition of income and tariffs, and ends, according to paragraph 10 of article 43 of the RTR (2014) with the publication by this entity, on the 30th of the following September, the allowed revenues and tariffs to be applied in the following year and therefore has a duration of 9 months. However, the Regulatory Authority for Water and Waste Services (ERSAR), published in Diário da Republica, Part E, Resolution No. 1152/2015, on June 9, 2015, the addition of Article 95a to Tariff regulation of the waste management service (RTR). This decision aims to readjust exceptionally timing of the regulatory process of the entire regulatory cycle setting rates for the first year referred to in RTR (2014th), through a transitional rule, even if this means that the final decision on the proposed regulatory parameters by ERSAR will occur in the course of 2016. However, the rates to be applied to users take effect from the first day of the financial year to which they relate, regardless of the date of the respective approval, the definition of tariffs that will occur during 2016 will take effect from the beginning of this year.

As an alternative to RTR (2014) and in the absence of tabulated data to calculate the NPV and IR more accurately, it was decided to make a comparison of different projects and scenarios based on an analysis of cash flows for the year 2020.

4.3. Calculation of MSW carbon emissions

The calculation of projects MSW carbon emissions is divided into three parts according to the three processing modes (sanitary landfill, anaerobic digestion and burning).

4.3.1. Sanitary Landfill

Sanitary landfill is the main disposal way of MSW in Portugal. Eq. (10) is the calculation process of CH_4 emission. Eq. (11) is the calculation process of CO_2 emission, and Eq. (12) is the global carbon emission. The meaning and value of each variable (sources) in Eq. (10) to Eq. (12) are shown in Table 1. $E_{CH4,\ landfill}$ is the CH_4 emission. $E_{CO2,\ landfill}$ is the CO_2 emission. $E_{CO2\ total,\ landfill}$ is the possible global carbon emission. MSW_{aterro} is the municipal solid waste going to sanitary landfill. DOC is the degradable organic carbon content. DOC_f is the actual decomposition of degradable organic carbon in the process of landfill. ρ_1 is the methane correction factor by sanitary landfill. ϒ is the percentage of CH_4 in the landfill gas volume. .$\frac{16}{12}$ is the molecular weight ratio of CH_4/C and $\frac{44}{12}$ is the molecular weight ratio of CO_2/C.

$$E_{CH4,landfill} = MSW_{landfill} \times DOC \times DOC_f \times \rho_1 \times \gamma \times \frac{16}{12} \quad (10)$$

$$E_{CO2,landfill} = MSW_{landfill} \times DOC \times DOC_f \times (1 - \rho_1 \times \gamma) \times \frac{44}{12} \quad (11)$$

$$E_{CO2\ total,landfill} = 25 \times C_1 + C_2 \quad (12)$$

Table 1 - Meaning and value of the variables

Variable	Meaning	Value
DOC	Degradable organic carbon content	12,5%
DOC_f	Actual decomposition of degradable organic carbon in the process of landfill	50%
ρ1	Sanitary landfill methane correction factors	100%
ϒ	The percentage of CH4 in the landfill gas volume	50%
φ	Combustible carbon content	16,5%
ω	Omega oxidation factor	85%
$EFd_{a,CH4}$	Emission factor for anaerobic digestion in CH_4/t MSW processed	2
$EF_{da,\ N2O}$	Emission factor for anaerobic digestion in N_2O/t MSW processed	negligible
PAG_{CH4}	Global Warming Potential for CH_4	25
PAG_{N2O}	Global Warming Potential for N_2O	298

4.3.2. Anaerobic Digestion

Eq. (13) is the calculation process of CH_4 emission. Eq. (14) is the calculation process of N_2O emission. And Eq. (15) is the max carbon emission. The meaning, and value of the variables (sources) in Eq. (13) to Eq. (15) are shown in Table 1. $E_{CH4,\ anaerobic\ digestion}$ is the CH_4 emission. $E_{CO2,\ anaerobic\ digestion}$ is the N_2O emission. $E_{CO2\ total,anaerobic\ digestion}$ is the possible max carbon emission. MSW_{da} is the municipal solid waste going to Anaerobic digestion, $E_{CH4,da}$ the emission factor for anaerobic digestion in kg CH_4/t MSW, $EF_{N2O,da}$, the emission factor for anaerobic digestion in kg N_2O/t MSW, R the CH_4 recovered in t CH_4, PAG the global warming potential for CH_4 in kg CO_2 equivalent/kg CH_4 and PAGN_2O the global warming potential for N_2O in kg CO_2 equivalent/kg N_2O.

$$E_{CH4,\text{ anaerobic digestion}} = \left(MSW_{da} \times EF_{da,CH4}\right) - R \quad (13)$$

$$E_{N2O\text{ anaerobic digestion}} = MSW_{da} \times EF_{da,N2O} \quad (14)$$

$$E_{CO2,\text{ anaerobic digestion}} = PAG_{CH4} \times E_{CH4,\text{ anaerobic digestio}} + PAG_{N2O} \times E_{N2O\text{ anaerobic digestio}} \quad (15)$$

4.3.3. Burning

The Eq. (16) is the calculation process of the carbon emission of burning MSW. The meaning, value, and value basis of the variables (sources) in Eq. (16) are shown in Table 1. C_5 is the CO_2 emission, MSW_{inc} is the municipal solid waste going to incinerator, φ is the combustible carbon content, ω is the omega oxidation factor and $\frac{44}{12}$ is the molecular weight ratio of CO_2/C

$$C_5 = MSW_{inc} \times \varphi \times \omega \times \frac{44}{12} \quad (16)$$

5. Results and analysis

5.1. Forecasting of municipal solid waste generation

The resulting equations are presented next with the numbers 17, 18, 19 and 20 and correspond to the municipalities of Oeiras, Cascais, Sintra and Mafra respectively.

For the population forecast we used the growth rate verified between 2012 and 2013 in the municipalities covered by Tratolixo (-0,06 %, 0,142 %, -0,0038 % and 1,28 % for Oeiras, Cascais, Sintra and Mafra, respectively). The projection was made for a time horizon of 20 (lifetime of the projects to study).

$$RSU_{Oeiras}(t) = -72526{,}2 + 0{,}409P(t) + 178374{,}9C(t)\ with\ \sigma = 109{,}9 \quad (17)$$

$$RSU_{Cascais}(t) = -144971{,}2 + 0{,}633P(t) + 240830{,}8C(t)\ with\ \sigma = 1465{,}9 \quad (18)$$

$$RSU_{Sintra}(t) = -155075{,}5 + 0{,}404P(t) + 385191{,}6C(t)\ with\ \sigma = 367{,}9 \quad (19)$$

$$RSU_{Mafra}(t) = -46694{,}9 + 0{,}538P(t) + 90867{,}3C(t)\ with\ \sigma = 474{,}0 \quad (20)$$

To forecast production of unsorted MSW is also necessary to determine the *per capita* waste generation rate. Since this parameter depends on several variables we chose to use the average between 2011 and 2013.

As in this work the future population was determined based on population growth rates of each municipality and *per capita* waste generation rate was consider constant, the unsorted MSW production will have a linear behavior.

5.2. Investment analysis

As mentioned earlier, in 2014 was approved the RTR (2014), expected to enter into force in 2016. Thus, this study can only be done in very rough and conservative manner, ie not considering to date unknown parameters, as the value of incentives, allowances, financial gains from interest rate subsidies, adjusting parameters, efficiency factors, among others. In this sense, it is not possible to draw realistic conclusions by using this method. Consequently, it was made, alternatively, a simplified investment analysis where the focus is on the additional costs, in avoided costs and additional revenue and compare with the present situation. We set 2020 as a year of analysis and calculated all the costs and all the revenue for each project/scenario with reference to operating costs, tariffs, among other parameters, recorded in 2015 and updated to 2020 (see Table 2).

In the first investment we will analyze the rehabilitation of the mechanical treatment in the Trajouce Ecopark, whose investment will be 15 million €. With regard to scenarios the difference focuses on the final destinations chosen for refuse and excess.

In the second investment project we will examine the construction of a new incineration plant in Trajouce Ecopak, whose investment will be 167 million €, where in the scenario 1 we consider that the new plant is a complement to existing operations (TM and CDA) and at scenario 2 the new power plant will replace the TM in Trajouce Ecopark.

In both scenarios we proceeded to the calculation of the revenue from sale of recyclable materials. To do this it was necessary to determine the role of fractions of cardboard, plastic and aluminum recovered in Trajouce and Abrunheira Mechanic Treatment and resorting to information on recyclable recovered in 2013 available in Tratolixo (2015). Thus it was considered that the plastic corresponded to 43% of recovered materials, paper and board 30% and metals 27% and that these fractions remain constant throughout the project life time.

In this analysis it was considered the most relevant costs the operating costs of each treatment operation, the transport costs between Tratolixo facilities and external destinations, the TGR and the tariffs payable. With regard to these revenues they are obtained by the rate charged by Tratolixo and the sale of recovered recyclables, compost and energy produced. In this analysis all costs and revenues have been updated to 2020 using a Harmonized Index of Consumer Prices (HICP) of 1.55%, a result of the average historical values between 2005 and 2015 (INE, 2015).

Table 3 shows the results obtained from the simplified analysis of investments in study. In addition to the cost and revenue was also calculated the benefit. This is the difference between the net income of each alternative under consideration and the current situation.

For this simplified analysis, and considering the level of costs avoided the best alternative is the scenario2/project 1, where the avoided costs are in the order of € 1,03 million, mainly due to the fact that if you stop sending waste to external destination, there is no purchasing of services.

Table 2 - Costs and revenues estimated (values of 2020)

	Value		Value
Operational Costs		**TGR**	
Mechanical Treatment – Trajouce (€/t)	10,80	Landfill (€/t)	11
Anaerobic Digestion plant – Abrunheira (€/t)	52,07	Energetic valorization (€/t)	2,75
Incineration plant – Trajouce (€/t)	29,16	Tariffs	
Sanitary landfill – Abrunheira (€/t)	5,94	Valorsul (€/t)	20,99
Custo de Transporte		CITRI (€/t)	44,53
Trajouce - Valorsul (€/t)	2,32	Ribtejo (€/t)	44,53
Trajouce - CITRI (€/t)	3,97	Resitejo (€/t)	44,53
Trajouce - Ribtejo (€/t)	10,12	**Revenues**	
Trajouce - Resitejo (€/t)	10,06	Electricity sale –biogas (€/MWh)	117,92
Trajouce – Abrunheira Ecopark (€/t)	1,88	Electricity sale – MSW (€/MWh)	93,94
Abrunheira - Valorsul (€/t)	2,14	Compound sale (€/t)	2,44
Abrunheira - CITRI (€/t)	4,58	Recyclable materials - plastic (€/t)	216,85
Abrunheira - Ribtejo (€/t)	9,88	Recyclable materials - paper (€/t)	81,97
Abrunheira - Resitejo (€/t)	9,56	Recyclable materials - aluminum (€/t)	156,27
		Tariff Tratolixo (€/t)	63,26

With regard to the additional revenue, project 2 is the one with a higher value and scenario 2 is the best alternative, with additional revenues of 10,7 million €, coming from electricity sales of the incineration plant.

With regard to benefits that brings each alternative over the current situation, we found that the three scenarios of the project 1 accrue greater benefits, between 1,49 and 5,1 million €.

5.3. Carbon emissions from MSW processing methods

In this section were calculated carbon emissions for each investment. The results represent the total CO_2 emissions obtained in the life of every design time. Table 1 shows the emission factors, correction factors, among other data values used to calculate the emissions for each operation.

Landfill emits more carbon per kg of MSW followed by incineration and anaerobic digestion. Per kg of MSW are produced 1,16

kg carbon in the landfill, 0,51 kg in the incineration, and 0,05 when subjected to anaerobic digestion. Emissions during mechanical treatment (recycling) are considered negligible (IPCC, 2006).
The scenarios that emit less carbon throughout the lifetime considered are those that deliver more waste for incineration, scenario 3/ project 1 and both scenarios of project 2. However, the design with lower carbon emissions is the scenario 3 of project 1 by issuing 2 326 530 tons of carbon in the time horizon considered.

Table 3 - Results of simplified investment analysis for 2020 (base year) in thousands of €

		Project 1			Project 2	
	Actual Situation	C1	C2	C3	C1	C2
Total Costs	15 153	17 741	14 121	15 717	28 201	32 305
Total Revenues	23 081	27 162	27 162	27 162	31 329	33 844
EBIT	7 928	9 421	13 041	11 445	3 128	1 539
EBT	7 928	8 541	12 162	10 566	-6 663	-8 252
Net income	6 144	6 620	9 425	8 188	-5 164	-6 395
Cash Flow	6 144	8 495	11 300	10 063	8 753	7 521
Additional Costs		2 588		563	13 048	17 151
Avoided costs			1 033			
Additional revenues	0	4 081	4 081	4 081	8 248	10 763
Benefit	0	1 493	5 113	3 517	-4 800	-6 389

6. Conclusions

With regard to the projects investment analysis it was concluded that the best solution will be the upgrading of the mechanical treatment in the Trajouce Ecopark where the waste is sent to landfill in the Abrunheira Ecopark. In this alternative all waste is treated in the Tratolixo facilities, with no need for external entities. However, from an environmental point of view and carbon emission analysis this option is the one with worse results. Carbon emissions from each MSW processing method can be calculated by Eqns. (10) to (16) where 1 kg of MSW may produce 1,16 kg carbon emissions under sanitary landfill, 0,05 kg under anaerobic digestion and 0,51 kg when burnt. Sanitary landfill's carbon emissions were more than twice those generated during burning.
It is also important to note that the methodology based on the Tariff Regulation of Urban Waste Management Services (RTR, 2014), which will come into force in the year 2016, does not allow including in the calculations many parameters that are not yet defined. So the results have a lot of associated uncertainty, as well as all parameters estimated as the production of unsorted MSW, compensation for sales of electricity, among others.

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