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Ex post evaluation of cohesion policy interventions 2000-2006 financed by the Cohesion Fund (including former ISPA)

Work Package C - Cost benefit analysis of environment projects

Case study - Project no. 50: LIPOR - Municipal Solid Waste Integrated Management (2002PT16CPE002)

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Foreword

This document presents one of ten case study that has been elaborated as part of the study ‘Ex post evaluation of cohesion policy interventions 2000-2006 financed by the Cohesion Fund (including former ISPA) - Work Package C - Cost benefit analysis of environment projects. The study was commissioned by the European Commission, DG Regio. During the project ten case studies were elaborated that can be used as guidance or good practice for future Cost Benefit Assessments in relation to Cohesion Fund/ISPA applications.

The overall approach to the case studies is as follows:

The projects have been analysed in the period July to October 2010 and contains the simple and most important story concerning:

- Why the project was formulated?
- Who the relevant stakeholders were in the decision making process?
- How the project was analysed and decided upon?
- What the outcome of the project was in the ex-post perspective?

The project analyses include to the largest possible extent the ex-ante and ex-post figures in order to assess the project’s performance. Due to the great variety in the data quality, data access and possibility to reconstruct data, the analyses vary in quality and extent. However, in every case there is a significant learning that can contribute to the fundamental questions of the study[1]:

- What were the impacts of the examined projects?
- How can ex post cost-benefit analyses contribute to the practice of ex ante cost-benefit analyses?
- What are the potentials and limits to carry out an ex post cost-benefit analysis to identify and/or analyse the impact of the projects? Is it an appropriate tool for impact analysis?

The CBA guidelines have been used to analyse the projects. In all cases the project teams have visited the project sites and the teams have interviewed technical, financial and managerial staff concerning the project development, implementation and the results of the project. Furthermore, the project teams have been in dialogue with the project beneficiaries on the data used in the ex-post analysis.

[1] Terms of reference page 6 in chapter 3. Subject of the contract.

List of Abbreviations

B/C	Benefit-Cost ratio
CBA	Cost Benefit Analysis
CF	Cohesion Fund
CO_2	Carbon Dioxide
EC	European Commission
ENPV	Economic Net Present Value
ERR	Economic Net Present Value
EUR	Euro
FNPV	Financial Net Present Value
FRR	Financial Rate of Return
GDP	Gross Domestic Product
GDP	Gross Domestic Product
GHG	Green House Gases
H_2S	Hydrogen Sulphide
Ha	Hectare
IRR	Internal Rate of Return
ISPA	Instrument for Structural Policies for Pre-Accession
kW	Kilo Watt
LFG	Landfill gas
Nm3	Normal Cubic Metres
NPV	Net Present Value
NPV	Net Present Value
PV	Present Value
PV	Present Value
SDR	Social Discount Rate

1 Project no. 50: LIPOR - Municipal Solid Waste Integrated Management

1.1 Project Description

1.1.1 Project context

LIPOR is an association of city councils of the Porto metropolitan area, in the North of mainland Portugal. Since it was created in 1982, this association has been implementing an integrated solid waste management system encompassing 8 municipalities of the Greater Porto sub-region (NUTS III)[2].

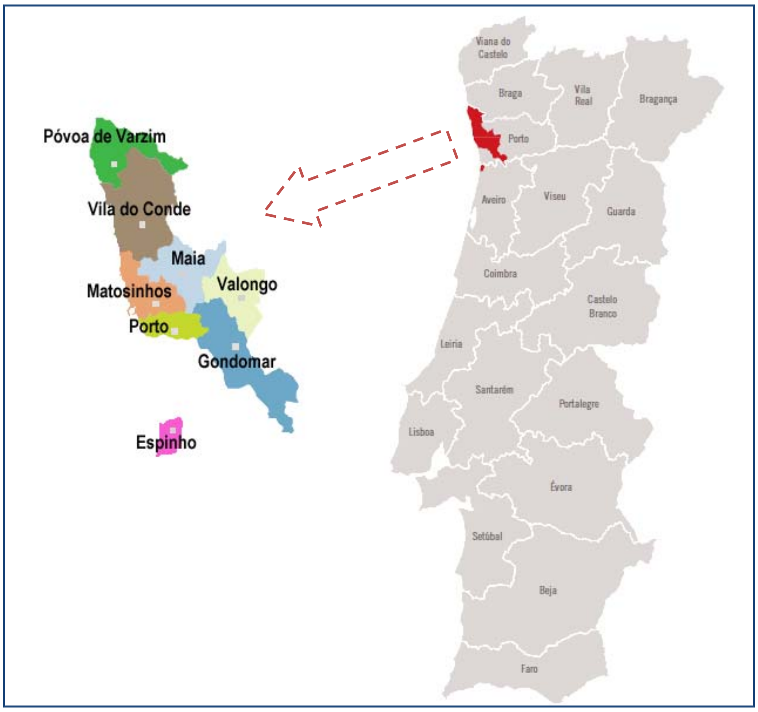

Figure 1-1 LIPOR territory in Mainland Portugal

[2] LIPOR membership is made up of the following city councils: Espinho, Gondomar, Maia, Matosinhos, Porto, Póvoa de Varzim, Valongo and Vila do Conde. From the 11 municipalities of the Greater Porto region, only 3 are not included in the inter-municipal association: one since long belonging to the Greater Porto (Gaia) and 2 that only recently were incorporated in the sub-region (Trofa and Santo Tirso).

The Greater Porto sub region has a population of 1.4 million (2007) and a surface of 817 km². It is a highly industrialised area that, together with the neighbouring sub regions, is the main source of the Portuguese exports and home to one of the busiest Portuguese harbours, located in Leixões. Grande Porto serves as the commercial, educational, political and economical centre of northern Portugal.

1.1.2 Project history and timeline

LIPOR inherited some environmental facilities of their members, which included, besides a number of landfills and waste collection facilities, a composting plant created in 1966 by a private investor[3].

Since its inception LIPOR, continued to develop its environmental assets through a number of investment projects, which included the construction of an urban waste incinerator, the improvement of the landfill operations and the development of a source separated waste collection system in its area of influence. In 2000/2001 LIPOR prepared a new strategic plan covering the period 2000-2014, which entailed an investment programme of around EUR100 million (exclusive of taxes), comprising all operational areas of the company[4].

The main investment projects foreseen in this plan were organised as an investment programme and submitted to the Cohesion Fund for financial assistance. Approved by the Commission in 19/12/2002 [2002/PT/16/C/PE/002], the assistance involved a co-funding package of around EUR 26.6 million (50% of the eligible and 26% of the overall investment).

The programme was also co-funded by a loan of EUR 53 millions from the European Investment Bank, signed in 11/12/2001. The balance was provided by own funds.

1.1.3 Technical overview

The objective of the project was to complement or to extend some of the existing activities LIPOR and its city councils shareholders and to remedy some environmental liabilities, aiming at the consolidation of the integrated management system in the region. Five components were included:

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3 Since the beginning, this composting plant was operated as a profitable private enterprise. In the early seventies this operation became unprofitable due to increasing labour costs and was acquired by some of the municipalities that later incorporated LIPOR.

4 The interventions foreseen in the programme under appreciation were complementary to previous projects approved for financing under the Cohesion Fund (Ref 1993/10/61/016, Ref. 1995/10/61/023, Ref. 1994/10/61/026 and 2000/PT/16/C/PE003).

Table 1-1 Overview of the components of the project

Main investment Units	Recycling	Composting	Landfill Sealing-off and Use	Energy Recovery Plants	Communication
lipor Serviço Intermunicipalizado de Gestão de Resíduos do Grande Porto www.lipor.pt					
Component	**A**	**B**	**C**	**D**	**E**
Description	Collection, sorting and preparation for recycling of paper, glass, plastic and metal waste	Selective collection and controlled aerobic composting of food and green waste	Sealling-off, LFG collection and burning, leachate/water processing, landscape recovery of 4 landfills	Using LFG of the 2 largest landfills to generate electricity	Awareness campaigns in various media to promote source separation practices by the public at large
Benefits	NOT QUANTIFIED Decreased air pollution and greenhouse gases (incineration), hazardous waste leaching (landfills), energy consumption, and resource consumption.	NOT QUANTIFIED Decreased air pollution and greenhouse gases (incineration), waste leaching (landfills), energy consumption, and resource consumption (fertilizers).	NOT QUANTIFIED Decreased air pollution and greenhouse gases, waste leaching and resource consumption. Use value	NOT QUANTIFIED Decreased greenhouse gases and resource consumption (natural gas)	Set of activities geared to support the execution of 2 other components (recycling and composting).

The last component, the awareness and information campaign to help motivating the population in taking up the source separation programme for the recycling and composting projects, does not stand as an investment component *per se*, as its specific objective is to provide support to the execution of other components.

The programme was carried out at 4 locations in 4 different municipalities: Valongo, at Ermesinde where the headquarters and "LIPOR I" facilities are located (sorting plant, composting plant, 1 landfill and 1 energy generating plant), Matosinhos (1 landfill and 1 energy generating plant), Póvoa de Varzim (1 landfill) and Vila do Conde (1 landfill).

The main segments of each component of the programme are depicted in Table 2 – 2.

Table 1-2 Main investment items

Programme Components	Main investment items
Recycling	• Domestic and multiple dwelling containers • Collection vehicles • Igloo containers for drop-off/collection centres • Pre-sorting platform to handle large pieces (furniture, appliances, etc.)
Composting	• New composting plant • Organic waste containers • Organic waste collection vehicles
Landfill Recovery (4 landfills)	• Confinement of the waste mass • LFG, leachate and rainwater collection and control systems
Energy Generation (2 landfills)	• Gas cleanup and compression station • Energy conversion unit (combustion engines) • Interconnection (transforming, switching, protection, metering, etc.) • Emergency flare

Recycling

This component consists in the expansion of the municipal recycling system, including the acquisition of containers and vehicles for the collection of source-separated waste and the construction of pre-sorting facilities for large pieces of waste.

Recycling activities existed before the project started, based on a sorting plant built in the eighties, which is operated by LIPOR, and various collection systems of source separated waste (both door-to-door and drop-off centres with ‘igloo’ containers) operated by 8 different city councils (the shareholders of LIPOR).

The investment aimed at expanding the capacity of the collection system. The additional containers and vehicles included in the collection system increased its operational capacity. The pre-sorting platform, as it improves the productivity of the sorting plant, allows the additional tonnage collected by the system to be handled by the existing sorting plant without further investment. Between 2003 and 2009 the tonnage of materials prepared for recycling (‘recyclates’) increased by 58% (Fig. 2 - 2). The capacity utilisation is over 70% with the current exploitation model, capacity of which can be easily expanded by increasing the number of working shifts.

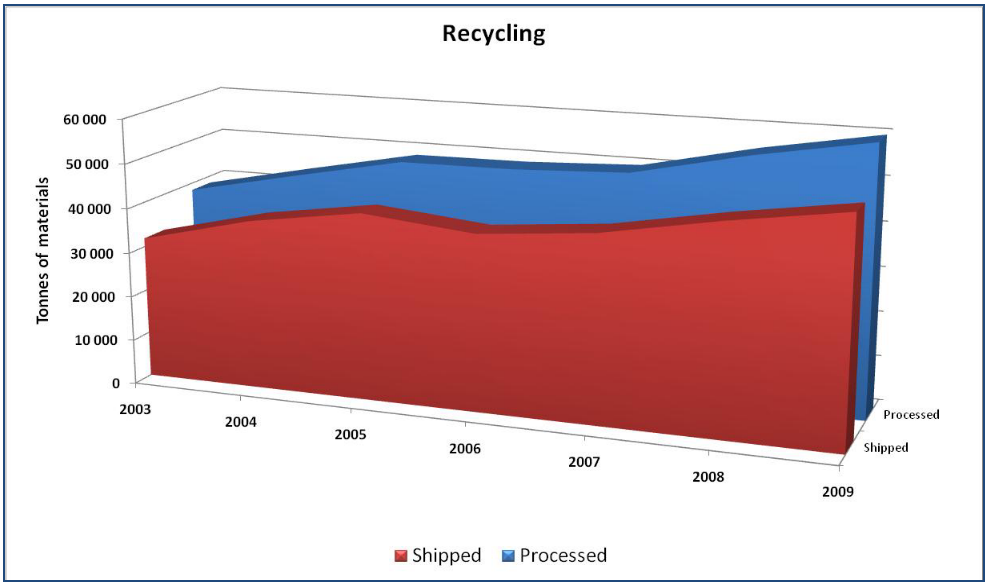


Figure 1-2 Multi-material recycling

Sorted and prepared recyclable materials are marketed directly by LIPOR. The sales are mostly made at administrative prices, under a government regulated "warranty system"[5].

The investment entailed by this component amounted to 13.3% of total.

Composting

This was the main component of the programme (46.8%). It involved the erection of a new composting plant to replace the existing one (quite old and outdated facility, continuously in operation since 1966) and the acquisition of organic waste collection containers and vehicles. It is a replacement investment of a completely depreciated facility.

The new plant is located at the Ermesinde site of LIPOR in an area of 40 thousand m^2. Its capacity allows to process 60 thousand tonnes of food and green waste per year. At full capacity the plant will generate about 20 thousand tonnes of compost. In 2009 the utilisation of this capacity was slightly over 50%.

Collection of food waste and green/park waste is done using specific networks directly operated by LIPOR.

5 In the last 5 years the fraction of *recyclates* that were sold at "warranty" prices increased from 62 to 75%.

The operation of the plant includes four basic processes:

- Mechanical preparation of waste;
- Biological process: aerobic, in-vessel technology (tunnels)
- Correction/rectification of compost
- Storing and bagging

The plant occupies 2 adjacent buildings, one for administrative, supporting and quality control functions and a second one where the composting process takes place. To eliminate the emission of odours, the latter is completely closed, maintained under negative air pressure and the inside air is run through bio filters to scrub off odours.

The plant is operated by a concessionaire (the same that built the plant), since 2005, for an initial period of 5 years. The concession can be renewed by 3-year periods, at discretion of LIPOR, with a 180-days notice.

The compost is marketed directly by LIPOR, under the "Nutrimais" brand name, in bulk and retail brown paper bags. The compost complies with the stability degree test Rottegrad V and its sale is made at market prices. The production of compost since the new plant was launched in 2006 increased by 150% (Fig. 2-3). However, the sales of the product are developing more slowly and even decreased in 2009 (12.6%). This was attributed to difficulties of the agricultural sector in the region and bad weather conditions in the 2008/2009 season.

The so called "information asymmetry" (buyers are not completely aware of the quality of the compost) may play a role in slowing the penetration of compost in the regional agriculture, as most consumers may not be aware of the intrinsic quality of the product. LIPOR is fighting this barrier by certifying the quality of its compost products and diversifying its range: recently LIPOR introduced a new compost specifically designed for the organic agricultural sector.

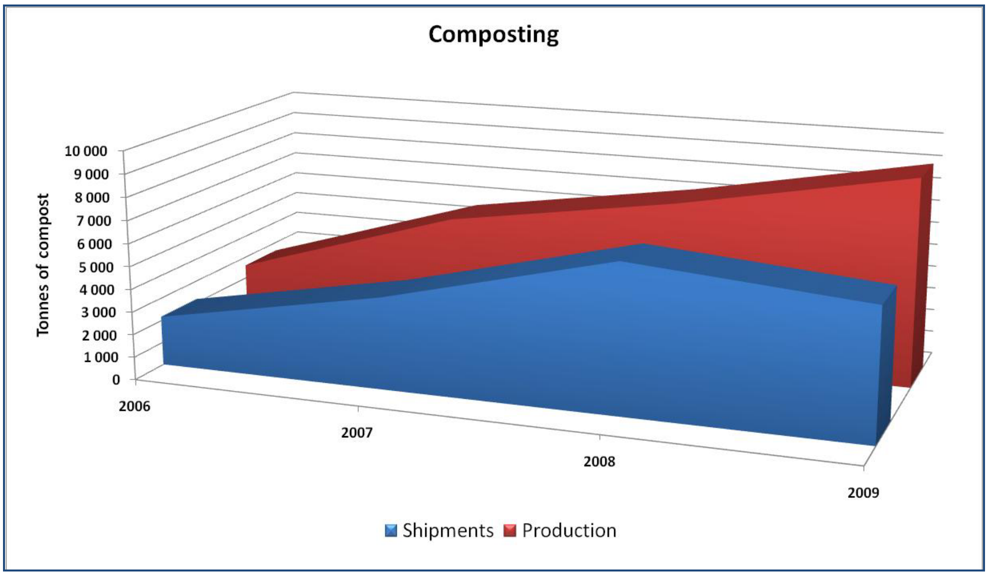


Figure 1-3 Composting

Landfill sealing and use (4 landfills)

Four old landfills were technically confined as part of the investment programme. These projects correspond to about 22.3 percent of the overall investment.

The sealing-off procedures were conducted in agreement with Directive 1999/31/EC and involved the following main investment items for each of the 4 landfills:

- Cleaning-up the top of the landfill;
- Modelling the surface of the landfill by applying a foundation layer;
- Applying additional layers:
    - o Drain for LFG (geodrains for biogas);
    - o Plateau and slope sealing layers (geomembrane);
    - o Drain layer for rain water;
    - o Reinforced geonet;
    - o Top soil;
- Construction of drain lines for leachate;
- Construction of drain lines for rain water;

- Construction of wells and piping for LFG drainage;
- Landscaping, vegetative cover;
- Monitoring systems (gas, leachate, water)

The following table shows the main attributes of the 4 landfills.

Table 1-3 Main features of the landfills

Landfill	Area (ha)	Landfill Gas			Leachates (m^3/h)	End of closure
		No. of wells	No. of control stations	Burning installation		
Valongo	19.0	81	4	C. Engine (3.2kVA)	20.6	2008
Matosinhos	8.0	38	2	C. Engine (0.5kVA)	1.25	2009
Póvoa de Varzim	6.9	33	4	Flare (250m^3/h)	0.14	2004
Vila do Conde	2.5	10	-	None	0.14	2004

Source: Monitoring reports, 2009, except for leachates at Matosinhos, flow of which corresponds to design data

The areas on the top of the confined waste of all landfills were recovered for various uses, mainly as recreational parks (Valongo, Matosinhos and Vila do Conde). In the Póvoa de Varzim landfill it was built an airfield for ultra-light aircrafts which is currently used by the municipal aero club. The construction of the runway and taxiways was funded by LIPOR (but not included in the investment programme) and the rest of the facilities by the city council of Póvoa de Varzim.

Except for the smallest landfill (Vila do Conde), facilities were built to burn the LFG generated after the closure of the landfills. In the Póvoa de Varzim, though, the flaring of the biogas was discontinued in 2007 due to low quantity of gas generated[6]. The larger landfills (Valongo and Matosinhos) the biogas is extracted, compressed and burned to generate energy.

The leachates generated in the 4 sealed landfills are collected and stored locally in appropriate tanks. Subsequently, they are carried by truck to nearby waste water treatment plants operated by the city councils. These are fully licensed to process this kind of waste water.

Sealed landfills are managed directly by the project owner, LIPOR.

Energy recovery plants (2 plants)

In the Valongo and Matosinhos landfills the amount of biogas to be generated after the closure was sufficient to justify the setting up of energy generating facilities. The capital cost of these facilities amounted to EUR 3.4 million or 4.2% of the overall investment.

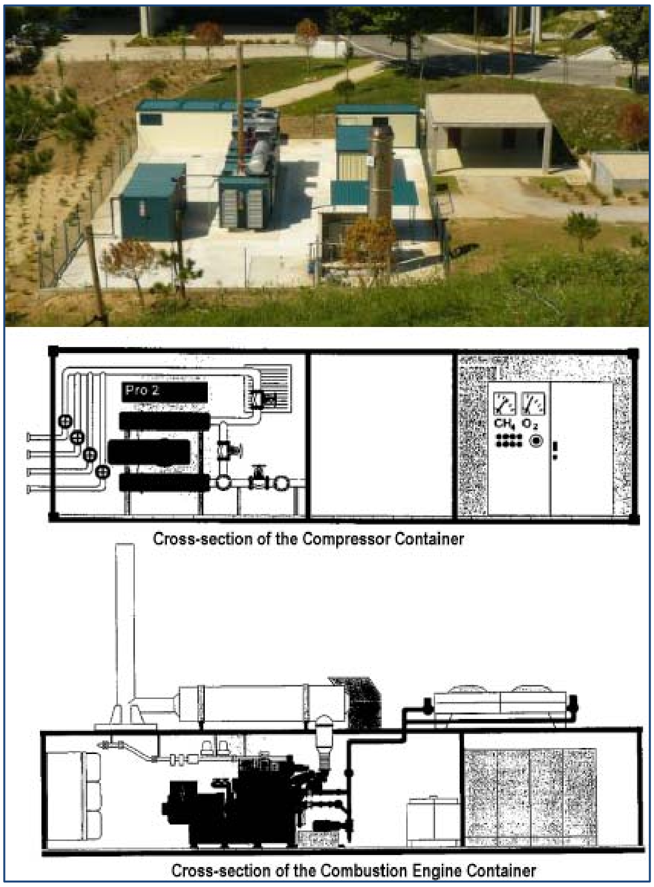
[6] Between 2004 and 2007, the flare station operated only for 181, 9, 4 and 2 hours.

These small-scale power plants consist of the following major components:

- Compressor unit packed into a movable steel container, including, besides the compressor, gas analysis, cleaning and control systems, electrical/mechanical instrumentation and other ancillary equipment;

- Internal combustion engine group packed into a second movable steel container, including, besides the engine (Otto cycle), ignition, starter and batteries, synchronous electricity generator, cooling and ventilation systems, interconnection (transforming, switching, protection, metering, etc.), instrumentation and control systems;

- Emergency flare station.



The 2 electricity generating plants, which have different electric power capacity (Valongo: 3,225 kVA and Matosinhos: 537 kVA), are managed by 2 concessionaires. Both contracts are valid for an initial period of 10 years that can be renewed by 5-year periods. Both contemplate the voluntary resolution of the contract when the volume of extracted gas falls under the threshold of technical feasibility for energy generation.

The operations of these plants started only recently: Valongo in 2008 and Matosinhos in May 2009 (Fig. 2 - 4). The electricity is marketed directly by LIPOR at government subsidised prices ("green" energy). The capacity utilisation is low, which is not uncommon in the first years of operation of these energy plants that have difficulties in controlling the variables affecting the generation of gas.

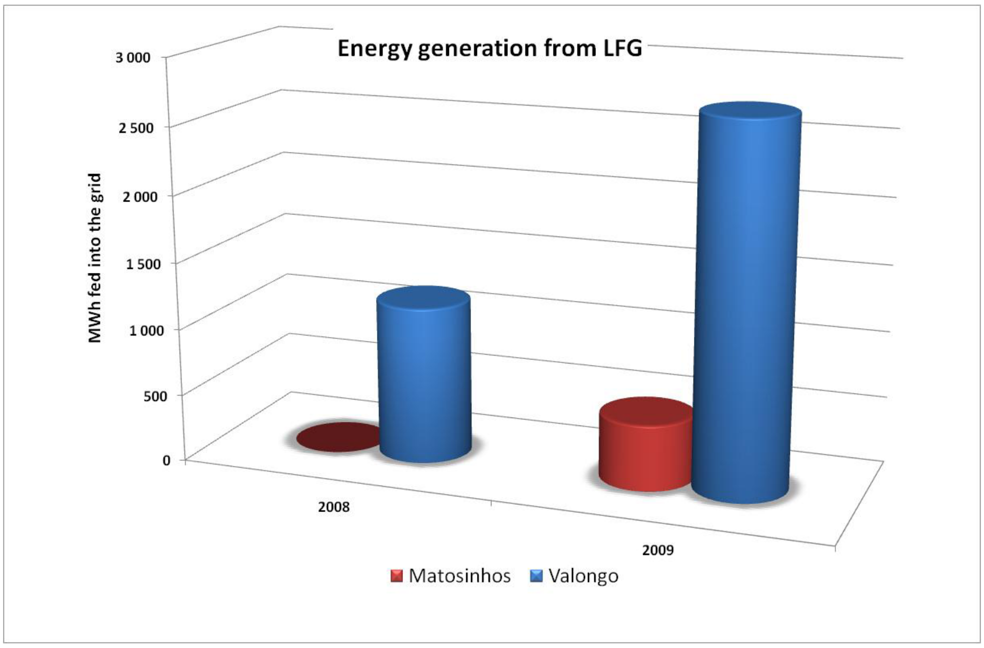


Figure 1-4 Electricity from LFG

1.1.4 Summary of project outcomes

The programme was officially closed in the 31st of March 2009. Nevertheless, there are investments underway and LIPOR expects that the overall investments (eligible and non-eligible) will be finished by 2013, with a total capital outlay of EUR 80.3 million (Table 2 - 4), about 86.3% of the amount that was planned in 2001.

Table 1-4 Overall investment (actual amounts and projections as of 2010)

Component	2000/2010	2011/2013	Total	%
A. Recycling	9.4	2.4	11.8	13.3
B. Composting	37.6		37.6	46.8
C. Landfill Sealing-off & Use	17.0	0.9	17.9	22.3
D. Energy Recovery Plants	3.4		3.4	4.2
E. Communication Campaigns	4.3	5.4	9.6	11.0
Non-allocated to the above	-	1.9	1.9	2.4
Total	**71.6**	**8.7**	**80.3**	**100.0**

Unit: EUR millions

The following table, based on the CF closing report, shows the outcomes of the programme in relation to the components considered initially.

Table 1-5 Main technical outcomes of the programme

Programme Components	Physical Indicators	No.
Recycling	Door-to-door containers and bags	1,399,563
	Collection vehicles	20
	Drop-off/collection centres	2,672
	Pre -sorting platform	1
Composting	Composting plant	1
	Organic waste containers	78,605
	Organic waste collection vehicles	11
Landfill Recovery	Landfills sealed-off	4
Energy Generation	Electricity generating plants	2
(Communication)	(Awareness campaigns)	3

1.2 Revision of ex ante cost benefit analysis

1.2.1 Use of ex ante cost benefit analysis for decision-making

The ex-ante CBA was conducted in an aggregate fashion for the whole of the programme, comprising the 5 components defined in the application (Table 2 -1, section 2.1.3). Hence, the economic benefits were not tied to any particular project component. The exception is the financial income, calculated separately for each component, which was added to the quantified economic and social benefits without any adjustment.

Three social and economic benefits were calculated:

- "Improvement of Public Health", measured by the reduction of the number of working days lost due to illness (the *cost of illness method*). The annual figures (avoided costs of illness) were obtained by multiplying the unit cost of illness (EUR 3,990.4 for 5 days of absence[7]) by 1% (reduction of illness due to the investment programme) by the active population (assumed to be 40% of the total population of the sub region over the projection period). This benefit accounted for 38% of the total benefits.

- "Improvement of the regional value added", measured by the increase of unspecified economic activities. This economic benefit was about 5% of total benefits. The increase in regional value added was calcu-

[7] The social cost directly attached to an absence of 5 days was gauged at EUR 2,992.8 per person per 5 days (assumed as the average lost days due to illness). This amount increased by EUR 997.6 (1/3 of the former) assumed to be the social costs induced in the non-active population by illness of the active members.

lated by using a multiplier of 5 times the direct and indirect wages (these assumed to be 40% of direct wages).

- “Additional improvement of the regional value added”, measured by the increase of tourism activities. The tourism related annual income of the regional population, gauged at EUR 15 *per capita*, would have an increase of 15% due to the enhanced amenities of the region brought about by the investment. Of this income about 2/3 would represent an increase of the regional value added. To this increase 5% was subtracted to allow for the costs of unspecified mitigation measures. This benefit accounted for 3% of overall benefits.

In addition to the above, non-pegged benefits, the financial turnover of each component (except for component C and D, for which no financial income was calculated) was added as an economic benefit. It amounted to about 52% of total benefits accounted for.

1.2.2 Review of ex ante assumptions

The approach used for the CBA calculations were troubled by a number of flaws[8]:

- the investment value was submitted as a single figure, comprising all individual components, broken-down only by the nature of expenses (pre-investment expenses, construction, machinery, vehicles), thus not allowing the determination of ex ante investment unit costs, neither to compare, component by component, ex ante with ex post investment costs; overall investment comparison is included in section 2.3.2 below;

- the operational costs were broken-down by the nature of expenses (staff, energy, maintenance, insurance, transportation, indirect costs, factory overheads, etc.) and appearing to include costs not related to the activities relevant for the investments under consideration, thus not allowing the determination of ex ante operational unit costs, neither to compare, component by component by component, ex ante and ex post operational costs;

- annual turnover included income that are not related to the activities of the components under consideration (e.g.: energy from the existing incinerator, which is not part of the investment programme) or were not adjusted to the operational increment due to the incremental nature of the investment in the case of recycling, thus not allowing a comparison of ex ante and ex post revenues;

8 It should be stressed that, at the time the application of the investment programme was prepared, the existing EC guidelines for carrying out CBAs were very limited and sketchy. There was a brief text, published in 1999, which was a new version of the first one published in 1997. The first edition of the CBA guide was only published in 2002.

- there are unadjusted costs and non-market and/or unadjusted prices embedded in the financial turnover (e.g.: the income from sales of recyclable materials is mostly based on government regulated "warranty" prices, electricity is marketed at "green prices", municipal tariffs are based in political/administrative considerations);

- there was no justification and/or explanation for most of the ratios and unit values used for calculating the social and economic benefits of "improvement of public health", "improvement of regional value added" and "additional improvement of regional value added";

- there is the risk of double counting some benefits (e.g.: the value added in tourism activities might already been considered in the value added in unspecified activities);

- the incremental net benefits technique[9] was not followed in the case of the recycling component: the turnover considered when calculating the income was derived from the sales of all collected recyclables, while it should be only the fraction of sales attached to the capacity increase;

The reference period adopted in the CBA was of 15 years (2000/2014); the cash-flows were calculated at current prices and discounted at an acceptable 8.65% rate[10].

The performance indicators calculated from the above assumptions were as follows:

- ENPV: EUR 243.3 thousand
- EIRR: Not calculated[11]
- B/C: 1.73

[9] "The calculation of the financial and economic performance indicators must be made with the incremental net benefits technique, which considers the differences in the costs and benefits between the do something alternative(s) and a single counterfactual without the project, that is, in principle, the BAU [*Business As Usual*] scenario." Guide to Cost Benefit Analysis of Investment Projects", European Commission, Directorate General Regional Policy, July 2008, p. 34

[10] The calculation of the ENPV was conducted in PT Escudos, assuming a uniform annual inflation rate of 2.5%. The calculated value was then converted into Euros by applying the standard exchange rate of PTE 200.482 to EUR 1.0. Under these circumstances, the implicit real discount rate (at constant prices) was 6%, slightly above Guide benchmark for Cohesion countries (5.5%). Thus, ex-ante discount rate is acceptable and does not present an issue of the ex ante analysis.

[11] The EIRR was not calculated because all economic cash-flows over the projection period were positive. In the cases such as this there are no positive roots (neither negative actually, there are no real roots) to the n^{th} degree polynomial equation EIRR (r) = 0. In this case all14 roots of the equation are imaginary numbers.

1.2.3 Project identification and alternative options

As noted before (section 2.1.2) the programme submitted to the CF assistance was selected from a continuing flow of capital investment projects (including expansion, replacement and greenfield operations), which was taking place in the various businesses of LIPOR. These investments were part of a long range strategic plan for the period 2000/2014.

A document with the main guidelines, strategic thrusts and capital improvement programmes of this plan was submitted with the application. Even though there is not any mention to alternative technical options (which is understandable due to the nature of the document), it turned up that several technical alternatives were considered during its preparation (e.g.: aerobic vs. anaerobic digestion for the composting component, internal combustion engines vs. gas turbines for the electricity generation). The selection of the preferred options were based on technical risks and cost criteria.

1.3 Ex post cost benefit analysis

1.3.1 Project identification

The project involved a programme of investments amounting to EUR 80 millions, including the construction of various facilities, the acquisition of equipment and machinery and the remediation of historical liabilities in the environmental sector. The project was carried out by LIPOR, in several locations of the Greater Porto area.

LIPOR invested directly in all assets, having transferred the property of some (multi-material collection equipment and vehicles) to its city council members. 3 of the facilities (the composting plant and the 2 power plants) are operated by concessionaires, which are only responsible for running and maintaining the plants, LIPOR keeping its ownership and being responsible for providing the production factors (the “raw materials”: organic waste and LFG) to the concessionaires and by marketing the results of the production.

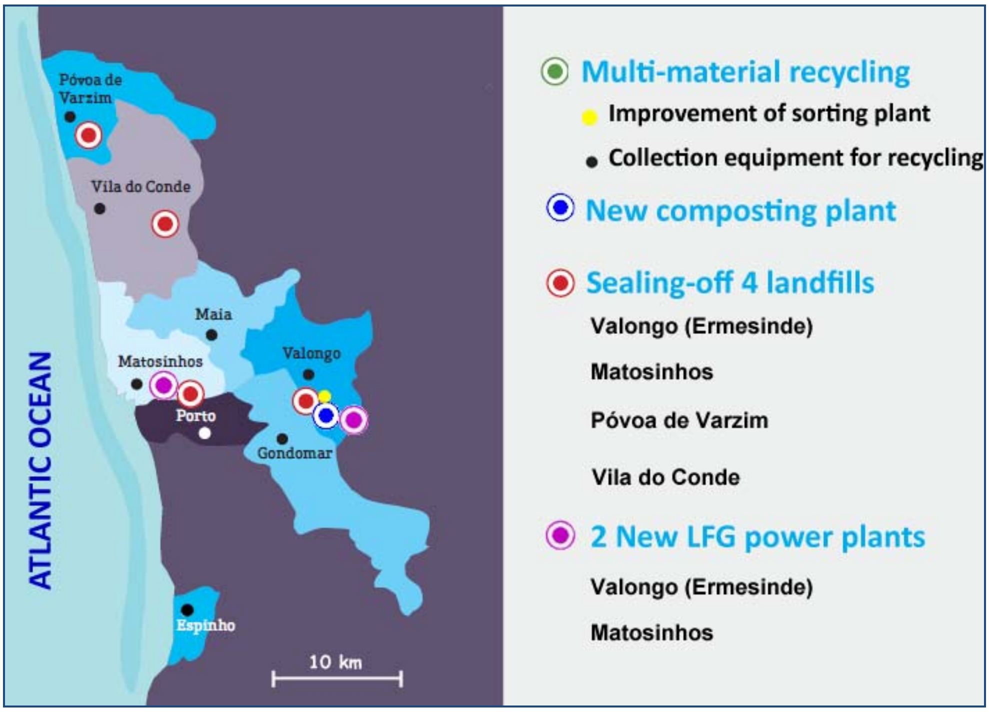


Figure 2- 5 The Programme

1.3.2 Ex post financial analysis

Investment

While the actual amount of the eligible investment coincide with the planned, the only difference being the time scale, the total investment costs are now estimated at EUR 80.3 million, or 28% less than the budgeted 112 millions. Part of this difference is due to the annual inflation rate embedded in the projections (2.5%), which was higher than the actual figures in the first years of the projection period.

According to the CF closing report filed by LIPOR there were 2 alterations to the investment project: (a) a new small unit to process slag from the incinerator plant was not built, because it was not possible to find any operator willing to bid for the concession of its exploitation, in spite of the international tender procedure carried out by LIPOR, (b) resources allocated to the recycling activities of the municipalities were increased. The non-used financial resources for the slag unit (about EUR 1.4 million) were applied to the composting plant (whose execution costs were higher than expected) and to strengthening the recycling components. Thus, these alterations did not have any implications in terms of differences in overall investment costs.

Thus, the reduction of planned investment costs of more than 20% can only be attributable to an overestimation of the initial projections, which is likely bearing in mind the manner the programme was prepared[12].

[12] As mentioned in section 2.2.2, the investment programme was not based on specifically planned and designed investment projects, but extracted from a continuing flow of pro-

The time scale was altered due to some delays in the execution of the project in the first years of the investment (Figure 2 - 6), mostly due to tendering and contracting difficulties. This was one of the bases for re-programming the time scale of the CF funding that was approved in 2008.

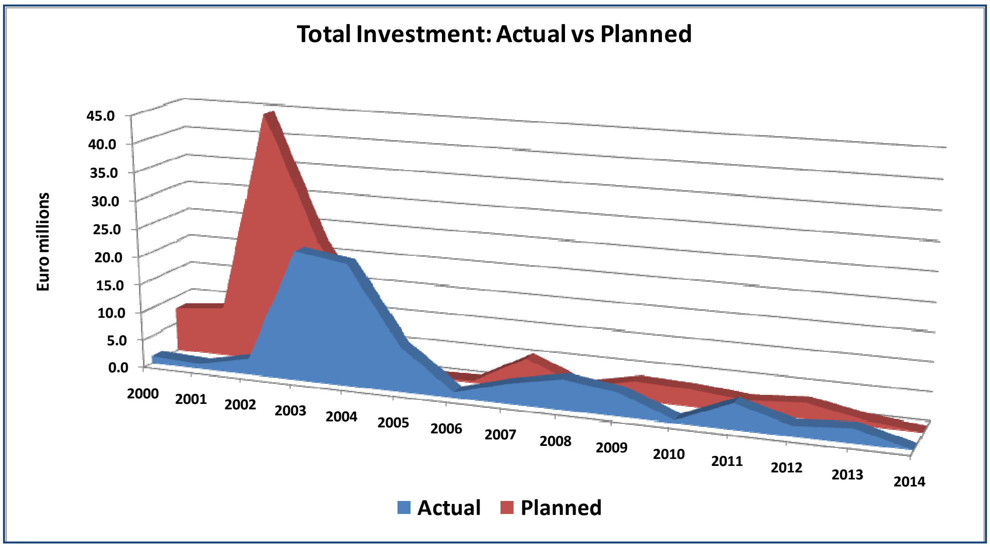


Figure 1-5 Investments

Operational costs and revenues

In this case, the contrast between planned and actual flows is not significant because the ex-post analysis was conducted on component-by-component basis and following strictly the incremental net benefits technique, while the ex-ante was conducted in an aggregate manner and including the flaws and mistakes already described in section 2.2.2. Consequently, the flows concerning costs and revenues available from the ex ante analysis, which cannot be corrected *a posterior*, are not comparable with the relevant flows that were calculated from the historical data in the ex post analysis. The latter are described in the next paragraphs.

In the ex-post analysis, the flows of all operational costs and revenues accrued before the new capacities entered into operation (recycling: 2003, composting: 2006, closed landfills: from 2004 to 2009 and energy generation: 2008 and 2009) were excluded. In addition, in the case of the recycling component, the flows occurring after the date the new capacity was considered to start operating (2003) were apportioned between the “old” and the “new” capacity, and only the later were taken into account.

All costs and revenues not directly attached to any of the components were excluded. For instance, revenues from tariffs were disregarded as these tariffs apply only to waste sent to landfills or the incinerators, and these infrastructures,

jected capital investment costs (including expansion, replacement and greenfield operations), which were foreseen in a strategic plan for the 200-2014 period. The investment values were not individualized in terms of specific projects thus making it impossible to establish which investment components were responsible for the differences between planned and executed investment costs.

although owned by LIPOR, were not part of the investment programme under evaluation. This also applied to revenues from the electricity generated by the incinerator.

Financial result

The following table summarises the performance indicators for the components and the overall programme.

Table 1-6 Financial performance indicators

Component	Ex post		Ex ante	
	NPV*	IRR	NPV*	IRR
A. Recycling	– 0.4	+ 7.7%		
B. Composting	– 30.6	N.A.		
C. Landfill Sealing-off & Use	– 11.1	N.A.		
D. Energy Recovery Plants	+ 0.1	+ 9.8%		
E. Communication Campaigns	Allocated to A and B			
Overall	– 42.0	**< 0**	**+ 9.6**	**7.3%**

** EUR millions.*

The differences in the overall indicators are due to the adjustments to revenue and operating costs that were introduced in the ex-post analysis, as already mentioned above.

Only one of the 4 components shows a small positive NPV, the component concerning the energy generation from LFG. In the first 2 operation years, when adjustments are needed to increase the efficiency of the extraction and generating systems (avoiding leakages, keeping a good balance between extraction flows and proper environmental conditions for the biological processes, etc.), while the results for the concessionaires are reportedly negative[13], the project shows a positive contribution for the project owner. This is due to the contractual arrangements that allocate to concessionaire most of the technical risks.

The marginal unprofitability of the recycling component (NPV: – 0.4 millions; IRR: + 7.7%) is very low when compared with the allocation of a substantial part of the investment cost of communication/awareness activities. These costs, which are instrumental to 2 components (recycling and composting), were allocated to these components *pro rata* of respective investments costs. Thus it is not correct to conclude precipitously that recycling component is financially unprofitable because the negative value of its NPV falls within the unavoidable margin of error brought about by any allocation exercise. The activity is financially rewarding before the allocation of indirect “marketing expenses” (the

13 “Relatório de Exploração 2009” (*Exploitation Report 2009*), RESIDEL, January 2010, pp. 7-8.

cost of communication/awareness activities), which is equivalent to say that its gross margin[14] is financially.

1.3.3 Economic analysis

The LIPOR investment programme comprised 4 investment projects which can and should be analysed individually under an “effect-by-effect” CBA. The following paragraphs report the results of the individual ex-post economic analysis, which were carried out for 3 of the 4 components. For one of them, recycling, it was not possible to find the specific data that would permit a meaningful exercise. All cash-flow were discounted at the same discount rate (8.65%, current prices), the same used in the ex ante analysis, which is deemed to fall within acceptable limits.

Component A – Recycling

In general, recycling is viewed as virtuous activity as it allows, besides the reduction of waste and its externalities, the reduction of consumption of natural resources and contributes to greater energy efficiency. The official policy of the Commission is to promote recycling because “if waste cannot be prevented, as many of the materials as possible should be recovered, preferably by recycling”[15]. The *Thematic Strategy*[16] on the prevention and recycling of waste is one of the seven thematic strategies programmed in the 6th Environmental Action Plan. The Commission has defined several *waste streams* for priority attention, including packaging waste, end-of-life vehicles, batteries, electrical and electronic waste. There are EU directives requiring member states to introduce legislation on waste collection, reuse, recycling and disposal of these waste streams. This view is quite widespread; for instance a relatively recent OECD book asserts “A policy to recycle more waste materials, for example, would need to take account of the upstream savings in virgin materials. Using less virgin material – timber, say – would mean that various environmental impacts from forestry could be reduced. Those reduced environmental impacts are a benefit that can legitimately be credited to the recycling policy.”[17]

However, there are many research studies that cast doubts about whether waste recycling is a socially desirable and worthy option. In a recent article[18] that

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14 Gross margin, or gross profit, is the excess of sales over the inventory cost of goods sold, including fixed indirect manufacturing (Horngreen, Charles T., “Cost Accounting”, 4th edition, Prentice-Hall 1977, p.58.

15 “Environment – Waste”, European Commission Web site (http://ec.europa.eu/environment/waste/index.htm, assessed 24/09/2010).

16 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and The Committee of the Regions - Taking sustainable use of resources forward - A Thematic Strategy on the prevention and recycling of waste {SEC(2005) 1681} {SEC(2005) 1682}/* COM/2005/0666 final */.

17 David Pearce, and all., “Cost-Benefit Analysis and the Environment – Recent Developments”, OECD, 2006, p. 56

18 Joe Pickin, “Representations of environmental concerns in cost–benefit analyses of solid waste recycling”, in Resources, Conservation and Recycling, 53 (2008), Elsevier B.V., pp. 79–85

scrutinised 37 'effect-by-effect' English language studies of waste policy options, five critical areas where CBAs are often inconsistent with each other were identified: the types of environmental impact and their valuation; the relevance of upstream externalities; whether there is a scarcity externality; the economic significance of householder efforts; and the need to drive towards long-term sustainability through eco-restructuring. The main conclusion is that, in addition to biases that arise more often than not in research studies (e.g.: methods of valuation, excluded or unvalued components), the balance between benefits and costs depends on the specific situation under consideration and the use of valuations selected from specific cases in different contexts does not lead to sound, well grounded results.

In the case of the recycling component of the LIPOR programme, it was not possible to obtain and validate any data upstream the operation of sorting the recyclable materials[19]. It is well know the importance of this upstream direct costs and externalities as the «price of a good carries the costs of the entire economic life cycle»[20] thus environmental effects should also be included. Thus any attempt to conduct a C/B analysis in the absence of local specific data would be speculative and unreliable.

The alternative of approaching the analysis of the recycling component using the contingent valuation method was not a feasible option due to time and scope restrictions[21]. To this respect it is also interesting to be aware of that, at least in some EU member states, the public does not place a high value in packaging and organic material recycling programmes as opposed to the values that the contingent valuation method arrives for the more perceptible and obvious landfill improvement programmes[22].

Component B - Composting

Aerobic composting is one of several methods of turning biodegradable organic waste (food, green, etc.) into a usable material, a fertiliser that can be applied in agriculture. Composting is preferred to other methods of organic waste disposal, landfill and incineration, because the first one can cause environmental

19 The collection at source separated recyclable materials in Greater Porto area is carried out by 8 different city councils, the shareholders of LIPOR. It is not a practice of these councils to gather and assemble cost and other data (such as the average distance travelled by collection trucks per tonne of recyclable materials) on a systematic and reliable way.

20 Joe Pickin, "Representations of environmental concerns in cost–benefit analyses of solid waste recycling", in Resources, Conservation and Recycling, 53 (2008), Elsevier B.V., pp. 79–85

21 The contingent valuation method involves conducting surveys to collect stated preferences from the population to estimate a value function that 'explains' their willingness to pay for a positive change in their environment. These surveys should be done before or at the time the environmental change takes place.

22 See, for instance, R. Bluffstone and J.R. DeShazo, "Upgrading Municipal Environmental Services to European Union Levels: A Case Study of Household Willingness to Pay in Lithuania" in Environment and Development Economics 8: 637–654, Cambridge University Press, 2003

and social externalities through leachate discharges, gaseous emissions, loss of landscape amenities, unpleasant odours and the sheltering of pests that may carry diseases, and the second (incineration) can generate toxic emissions, if not properly controlled.

Thus, by reducing the amount of biodegradable waste to landfill, composting can decrease its potential for polluting. A European Landfill Directive (1999/31/EC of 26 April 1999) introduced significant changes in the treatment of waste in Europe. This Directive, which was mainly concerned with ensuring that landfill standards and waste acceptance standards are uniform across the EU to avoid dumping of hazardous waste into low standard sites, also sets up targets for the reduction of biodegradable municipal waste in the European Union[23].

The composting component of the LIPOR investment programme follows the objectives of Landfill Directive as well as the Portuguese legislation[24] that transposed and extended this Directive.

C/B analysis used the cost and revenue flows of the financial analysis, after being corrected, in the absence of standard conversion factors of the Portuguese "planning authority"[25], by determining specific parameters from public datasets[26] to adjust investment and operative costs (as advised by the Guide[27]). Financial income was not corrected as it is based on market driven prices formed under competitive conditions with internationally traded commodities.

An additional benefit, encompassing economical, social and environmental components, was added to the adjusted financial flows: the avoided external net costs of the next-best alternative (incineration). Incineration was adopted as the next-best alternative, because (a) it is so considered by the Commission: "Where possible, waste that cannot be recycled or reused should be safely incinerated, with landfill only used as a last resort."[28] and (b) this view is fol-

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23 All EU countries must, pursuant to the Landfill Directive, reduce the amount of biodegradable waste disposed to landfill by 50% by 2010.

24 The most important legislation to this respect is PNGR, the National Plan for Managing Waste (Decree-Law no. 310/95 and 239/97) and PERSU, the Strategic Plan for Municipal Solid Waste (published in July 1997 by the Waste Institute.

25 According to the CBA Guide, the "authority" (or the "Member State") is supposed, in principle, to "develop its CBA guidelines focusing on the estimation of a set of national parameters, including some key shadow prices or conversion factors, in the context of the EU Cohesion Policy priorities". Guide to Cost Benefit Analysis of Investment Projects", European Commission, Directorate General Regional Policy, July 2008, pp. 47-48.

26 BP Stat (on line statistics of the Bank of Portugal). http://www.bportugal.pt/EstatisticasWeb/(S(5wwyn245upbfn355owjekt55))/DEFAULT.ASPX?Lang=en-GB, accessed November 2010.

27 Guide to Cost Benefit Analysis of Investment Projects", European Commission, Directorate General Regional Policy, July 2008, pp. 91-92.

28 "Waste", European Commission, Environment, http://ec.europa.eu/environment/waste/index.htm, accessed October 2010.

lowed by the Portuguese authorities "(. . .) elimination by deposition in landfill as the last option to be considered"[29].

To calculate the net costs of the next best alternative, it is necessary to compute the unit value of the benefits (direct income derived from generating electricity at its opportunity cost in Portugal, minus the negative externalities of Portuguese electricity system when generating the same amount of electricity) to which it should be deducted the costs incurred by incinerating 1 tonne of organic waste (only the external costs are relevant, as the collection costs are also incurred when the same tonne is composted, and there are no other direct costs).

The table below summarises the calculations and shows the sources of the data.

Table 1-7 Calculation of the Net External Cost of Incineration

Sign	Variable	Value type and source
Externalities of incinerating 1 tonne of organic waste		
+	Health	Avoided externality, Benefit transfer[30]
+	Materials and agricultural crops	Avoided externality, Benefit transfer[29]
+	Disamenity	Avoided externality, Benefit transfer[29]
+	Climate change	Avoided externality, Benefit transfer[29]
+	Transport-related	Excluded. Same for incinerating or composting
+	Solid and chemical waste residues	Avoided externality, Benefit transfer[26]
=	**External costs of the next-best alternative**	
–	Opportunity cost of electricity in Portugal	Forgone benefit. Direct calculation[31]
+	External cost of electricity in Portugal	Avoided externality. Direct calculation[32]
=	**Net forgone benefits of the next-best alternative**	
Σ	**Net external costs of the next-best alternative = EUR – 1,528,048**	

The following table summarises the calculation of the net present value of the composting component.

29 "PERSU II – Plano Estratégico para os Resíduos Sólidos Urbanos 2007-2016" (*Strategic Plan for Urban Solid Waste 2007-2016*), Ministério do Ambiente, do Ordenamento do Território e Desenvolvimento Regional, 2007, p. 44.

30 Heleen Bartelings et Al., "Effectiveness of landfill taxation", Institute for Environmental Studies, Vrije Universiteit, Amsterdam, November 2005, pp. 69-113.

31 Specific unit energy production assumed an average lower heating value (LHV) for the organic waste processed in the composting plant of 5.42 MJ/kg (50% of water content) and adjusting to 80% water content, lead to a technical coefficient of 169.75 kWh per tonne of organic waste. Source for prices: "MIBEL: The Iberian Electricity Market. Prices for 2007-2010", http://www.erse.pt/pt/electricidade/mibel/Paginas/default.aspx, accessed October 2010

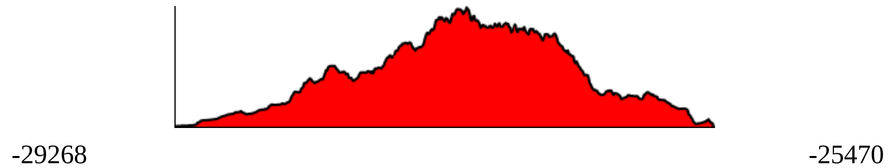
32 "External costs of electricity production", European Environment Agency, http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production, accessed on October 2010

Table 1-8 Net present value of Composting

Flow	Present value EUR	Remarks
Investment costs	– 20,987,317	From financial analysis, adjusted
Operating costs	– 7,757,560	From financial analysis, adjusted
Sales revenue	+ 2,050,904	From financial analysis, unadjusted
Net external avoided cost	+ 1,528,048	Benefit transfer and direct calculations
Residual value	+ 3,214,629	From financial analysis, adjusted
Total	– 21,951,296	Net Present Value of Component B

A Monte Carlo simulation was used to explore probabilistically the significant uncertainties of several input variables: Total investment, operating costs and avoided costs of the next-best alternative. The results are shown in the figure below.

NET PRES VAL	
Expected value	-27227
10%	-28226
50%	-27207
90%	-26292



NPV / PV INV	
Expected value	-1.2017
10%	-1.2464
50%	-1.2005
90%	-1.1605

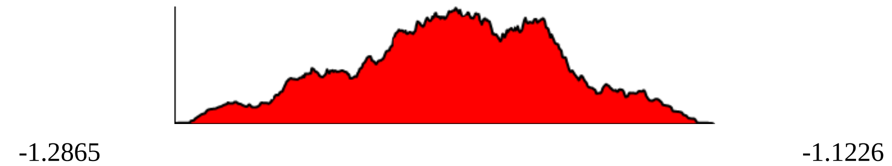


Figure 1-6 Composting: Probability distribution of the results

The expected value was reduced from the deterministic EUR – 21.95 million to EUR – 27.23 million. On the basis of the uncertainties that were made explicit in this exercise, the probability of this component being economically feasible is zero.

Component C - Landfill sealing-off and use

This component of the LIPOR investment programme has many similarities with component A (dubbed "the environmental minimum") of the "Solid Waste Management in Madrid", pilot case ES13. In both cases the intervention consisted in the technical confinement of landfills in agreement with Directive 1999/31/EC. Main differences were basically the size of the landfills (LIPOR with a total area of 36.4 ha vs. 110 ha in Madrid) and the number of landfills (LIPOR closed 4 landfills against only 1 in Madrid).

Thus, it is little wonder that the approach used in the calculating benefits and costs were the same as in the Madrid's. Two benefits were considered and quantified:

- The willingness to pay by the affected population for the improved amenity of the sites where the landfills are placed.

- The reduction of GHG emissions that was made possible by the capture of LFG.

As in the Madrid case, it was used the method of benefit transfer to calculate the first category of benefits, based on the same study of the Hiriya landfill in Israel[33]. Similar adjustments were also carried out to the specific conditions of Portugal and the areas where sites are located.

The second benefit (avoidance of GHG emissions) was calculated also the same way, bearing in mind the actual developments in the area. As already mentioned the 2 smaller landfills were closed in 2004. For the smallest (Vila do Conde 2.5 ha), it was never intended to extract and burn the expected small volume LFG that would be generated in the remaining life of the landfill. In the next one (Póvoa de Varzim 6.9 ha) a drainage piping and a flare were installed since the inception. Though, after a couple of years of operation, the LFG flaring was discontinued due to the low volume of gas generated in the landfill. In the larger landfills (Valongo 19.0 ha and Matosinhos 8.0 ha), the efficiency of gas extraction has been also impaired by technical difficulties since the starting of operation in 2008 and 2009. Thus, the design calculations were reviewed to adopt more conservative rates of efficiency.

Next table summarises deterministic calculations for the component under appreciation.

Table 1-9 Performance indicators of Landfill sealing-off

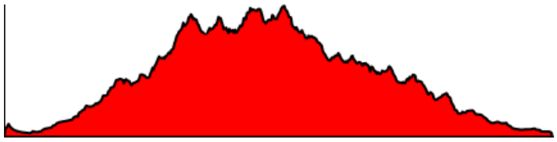
Flow	Present value EUR	Remarks
Investment costs	– 8,609,274	From financial analysis, adjusted
Operating costs	– 44,036	From financial analysis, adjusted
Willingness-to-pay (BT)	+ 6,250,313	Transfer from Hiriya study
Avoided GHG emissions	+ 3,114,134	Direct calculations[34]
Residual value	0	From financial analysis, adjusted
Total	+ 711 137	Net Present Value of Component C
EIRR	9.93%	Economic Internal Rate of Return
B/C Ratio	1.08	Benefits/Costs Ratio

The risk analysis used a Monte Carlo simulation that conducted to the results shown in Figure 2 – 8.

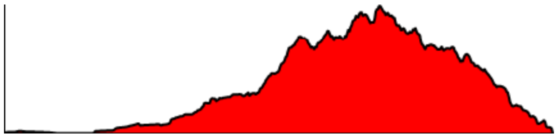
33 O. Aylon, N. Becker and E. Shani, “Economic aspects of the rehabilitation of the Hiriya landfill”, in Waste Management 26 (2006), pp. 1313-1323

34 “MIBEL: The Iberian Electricity Market. Prices for 2007-2010”, http://www.erse.pt/pt/electricidade/mibel/Paginas/default.aspx, accessed October 2010 and “External costs of electricity production”, European Environment Agency, http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production, accessed on October 2010

NET PRES VAL	
Expected value	708
10%	-2882
50%	594
90%	4529



INT R OF RET	
Expected value	9.2271
10%	2.8141
50%	9.6440
90%	15.17



NPV / PV INV	
Expected value	0.0760
10%	-0.3112
50%	0.0639
90%	0.4847

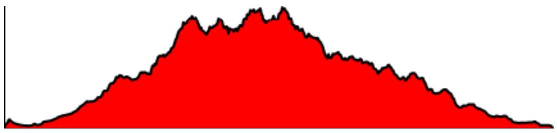


Figure 1-7 Sealing-off landfills: Probability distribution of the results

The expected values were similar to the deterministic ones. On the basis of the uncertainties associated to the randomised variables (investment costs, operating costs, price of CO_2 and avoided volume of GHG captured), the likelihood of having a positive net present value is over 50%.

Component D – Energy generation from LFG

Just like the previous (Landfill sealing-off) this component is similar to Madrid's pilot project B component. In both cases, the project concerned setting up electricity generating facilities close to sealed-off landfills to use LFG to generate electricity. Main differences concerned the scale: the size of landfills (around 27 ha in the LIPOR case versus 110 ha in Madrid's) and the number (2 plants with 3 combustion engines vs. one plant with 8 in Madrid) and generating capacity of the plants.

Calculation of benefits was conducted the same way, basically consisting of adjusting financial analysis to the social and economic standpoint. Besides the adjusted investment and operating costs derived from the financial analysis, it was computed a benefit corresponding to the value of the energy generated during the economic life of the 2 projects (2009 to 2016/2017).

The energy generated was valued at its opportunity cost (market price of electricity in the Iberian Peninsula), added of the external cost of energy generation in Portugal. Following table summarises the calculations

Table 1-10 Performance indicators of energy generation from LFG

Flow	Present value EUR	Remarks
Investment costs	– 1,707,571	From financial analysis, adjusted
Operating costs	– 997,292	From financial analysis, adjusted

Direct opportunity costs	+ 1,258,160	Direct calculation[35]
Avoided GHG emissions	+ 1,478,910	Direct calculations[36]
Residual value	0	From financial analysis, adjusted
Total	+ 32,207	Net Present Value of Component D
EIRR	+ 8.89%	Economic Internal Rate of Return
B/C Ratio	1.01	Benefits/Costs Ratio

The risk analysis used a Monte Carlo simulation that conducted to the results shown in Figure 2 – 9.

NET PRES VAL	
Expected value	634
10%	-464
50%	518
90%	1949
INT R OF RET	
Expected value	12.45
10%	4.9573
50%	12.27
90%	20.46
NPV / PV INV	
Expected value	0.2284
10%	-0.1672
50%	0.1864
90%	0.7020

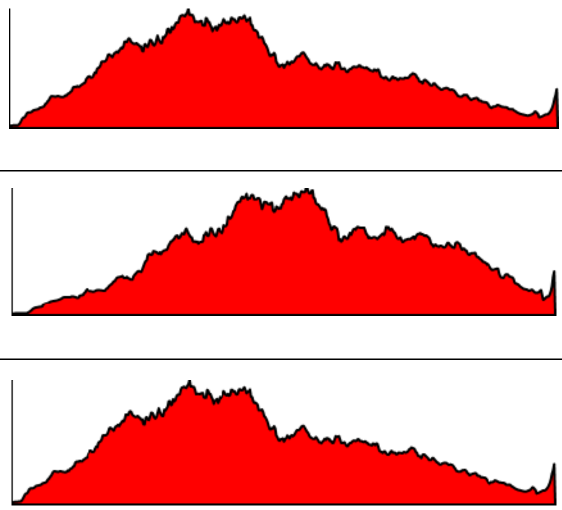


Figure 1-8 Energy generation: Probability distribution of the results

Expected values and probability distributions from the risk assessment show a feasible, though rather timid project.

1.4 Comparing the ex ante and ex post cost benefit analyses

Because component A was not appraised under the CBA approach, it is not possible to perform a full comparison between the ex-ante and ex-post analyses. On the other hand, as the ex-ante analysis was conducted on an aggregated way, a component-by-component assessment it is not possible either.

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[35] “MIBEL: The Iberian Electricity Market. Prices for 2007-2010”, http://www.erse.pt/pt/electricidade/mibel/Paginas/default.aspx, accessed October 2010.

[36] “External costs of electricity production”, European Environment Agency, http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production, accessed on October 2010

Though, bearing in mind that component A only represents only 13.3% of total investment, the following conclusions stand:

- As to the quality of the ex-ante analysis and its usefulness to decision making, the main finding is that it is highly probable that the overall investment would have a negative social and economic present value (EIRR) if a proper ex-ante CBA was carried out.
- The global unfeasibility is due to one component only (composting, the major one contributing with 46.8% to total investment), as the other 2 assessed (landfills sealing and energy generating) proved both feasible and it is quite likely that the recycling component would be economically feasible or only marginally negative. This signifies that investments carried out are useful, with the exception of the composting plant.
- The unfeasibility of the composting is quite acute as shown by the risk analysis (the probability of having a positive economic net present value is nil). Notwithstanding, the quality of the plant and of its current operational features conform perfectly to relevant international standards.
- The ex ante analysis did not incorporate any quantified risk assessment;
- It should be stressed that there is in general[37] a high level of uncertainty, mostly due to the lack of specific analysis aiming at monetising direct benefits and externalities of most of the components of the programme. A single example shows how wide could be the range of variability of the chain-composed uncertainties (compound probabilities) of the variates: the global climate change potential of methane is usually taken by the specialised literature to be close to 21 (one tonne of methane has the same damaging effect than 21 tonnes of carbon dioxide), but there are many recent studies placing this conversion rate in range from 11 to 30[38].
- Should the ex-ante CBA be performed on an effect-by-effect basis in the LIPOR case, maybe the composting component would have been looked into more closely and would encourage carrying out a more specific to the local situation and detailed feasibility analysis.
- The discount rate used for the financial and economic analysis (8.65% at current prices) fall within acceptable limits39, for which they were kept in the ex post analysis and its adjustment to the currently recommended (but not prescribed) by the Guide would not have any material effect in the conclusions. So, discount rate is not an issue in financial and CBA analyses.
- As far as it could be grasped in the documentation or in the interviewing programme there was no unintended effect worth mentioning.

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37 The possible exception is the electricity generation. Though, as this component started recently, the operational experience is not sufficient to remove the technical uncertainties.

38 Heleen Bartelings et Al., “Effectiveness of landfill taxation”, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, November 2005, p. 86.

39 The equivalent real rate (at constant prices ex post and ex ante) would be 5.9 and 6%. These are slightly above the Guide benchmark for Cohesion countries (5.5%).

1.5 Unit costs

Due to the shortfalls of ex-ante analysis (see section 1.2.2) it is not possible to derive any significant unit values, either in terms of costs and of market prices. From the ex-post financial analysis some unit investment and operational costs and market prices concerning the composting operations were collected and are depicted in the following table:

Table 1-11 Unit values

Name	Low	Average	High	Remarks
Investment costs				
Composting plant		€ 38.7 mn.		60,000 tpy
Energy plant (LFG)		€ 1.649 mn.		3.2 kVA
nergy plant (LFG)		€ 0.880 mn		0.5 kVA
Operational costs				
Composting	€ 52	€ 54	€ 74	Per tonne of organic waste
Composting	€ 226	€ 242	€ 460	Per tonne of compost
Market prices				
Compost	€ 66	€ 74	€ 80	Per tonne of compost, ex works

In the Technical annex many other unit values (notably, external costs) are included. These unit values correspond to secondary data as they were retrieved in bibliographic sources and not derived directly from the field work of this case.

1.6 Project specific lessons

Key issues	LIPOR - Municipal Solid Waste Integrated Management
Identification of project	The Applicant extracted from a continuing flow of capital investment projects (including expansion, replacement and greenfield operations), which were foreseen in its strategic plan, a selection of projects that were put together and submitted to the Cohesion Fund and prepared a slim economic study to barely comply with the existing requirements at the time. Frequently CBA is viewed mainly as an unavoidable requirement, which does not add any value to the standard financial analysis.
Technical analysis including rate of utilisation	The rate of utilisation of the recycling facility is over 70%, for the composting facility it is around 50% and for the energy generation is still relatively low, which however is not uncommon during the first years of operation.
Options	The LIPOR Strategic Plan covering the period 2000-20014 did suggest that several technical options were considered during the preparation of the overall strategy. A separate evaluation of all project components could have resulted in a more economically efficient project.

Other aspects justifying the decision process?	As in many similar situations the strategy behind the investment programme meets the policy orientations of both the Commission and the Portuguese government. Project components are instrumental to fulfil regional and national goals, which are grounded in overall mandatory or quasi-mandatory directives.
Wider observations	• The **Benefits Transfer** method consists in taking a unit value for a non-market good estimated in an "original study" and using this estimate, after some adjustments, to value the benefits (or costs) that arise when a policy or project is implemented "elsewhere". As the time goes by the probability of finding more than one "original study" on which such transfer can be based increases and with it increases the variety of different estimates for the benefits that are being transferred to the "elsewhere" project, possibly leading to contradictory outcomes. This raises the issue of what criteria for selecting the "original study" should be applied and the possible introduction of a novel concept (inspired on the opportunity cost concept) of *next-best original study* to be used. This is an issue that needs to be seriously addressed, so the idea that the benefits transfer method is a scientifically unfounded expediency can be faded away. • As mentioned in the Guide, the member states of the EU were supposed to provide estimates "of a set of national parameters, including some key **shadow prices or conversion factors**, in the context of the EU Cohesion Policy priorities". In the cases reviewed in this research study no sign of the existence of such parameters was found. Little wonder that no conversion or shadow prices are being used in CBAs, with the possible exception of shadow wages calculated by the simplified method prescribed by the Guide. Thus, for CBA to become a reliable way of improving public interest decisions something should be done to persuade EU member states to develop their set of national parameters to be used in CBAs. • Contrary to what happens in the transportation sector, for which it is possible to resort to a number of European well grounded calculations of externality parameters, in the environmental area the absence of consistent resources in externality calculations is notorious. There is a proliferation of studies offering quite different ratios, coefficients, unit values, for every type of variable needed to perform the **monetisation of environmental externalities**. This is clearly calling for an EU effort to scientifically standardise these variables, which are of paramount importance for conducting meaningful CBAs.

Annex PT-50

Ex post evaluation of cohesion interventions 2000-2006, LIPOR - Municipal Solid Waste Integrated Management

Technical Annex

A.Introduction

The CBA of this project comprises the following separate analyses:

- Component B: Composting. This is described in **Section B** of this Annex.
- Component C: Landfill sealing-off and use. This is described in **Section C** of this Annex.
- Component D: Energy generation from LFG. This is described in **Section D** of this Annex.

The final calculations presented were made using a project evaluation software called PROPLAN.[40] A full explanation on how to interpret the results presented is provided in Annex X.

A CBA consists of comparing flows of costs and benefits that can be incrementally attributed to a project, or by explicit comparison of such flows in the with and without project situation. For this reason this technical annex focuses on the definition of flows, and is organized as follows:

- For each project component, the flows used in the analysis will be listed.
- The way in which each flow was defined is described, and an explanation is provided for the data and assumptions used. The margins of error of data that were probabilistically defined are described.
- The results of running 500 Monte Carlo simulations of the CBA calculations are presented. Please see Annex X for a detailed description of the interpretation of the results of the stochastic analysis performed.
- Detailed tables are provided showing the net flow obtained from the flows defined, as well as the values of those flows, as computed when using the expected values of the variables defined. The flows of investments, operating costs and benefits are so labeled. Occasionally intermediate flows are needed to be able to define the cash flow components. These are also shown, but are unlabeled as to kind. Thus the reader interesting in tracing the calculation is able to do so.

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B. Component B: Composting

1. Descriptions of flows employed and the assumptions underlying them

SUMMARY OF FLOWS USED:

Number	Name	Kind	Comment
1	Adjust INV		Adjustment of flow 2 by a triangular distribution:
2	Investment	inv	Investment of the project
3	Adjust COST		Adjustment of flow 4 by a triangular distribution:
4	Operating Cost	op cost	Aggregated operating costs of the project
5	Unit Benefit	benefit	Environmental benefit per tonne of processed organic waste measured by a triangular distribution.
6	Volume		Avoided tonnage of organic waste sent to incinerator
7	Income	benefit	Income from sales

In what follows the definitions of the above 7 flows is presented in detail. Following the specification, relevant assumptions and explanations are provided.

```
 BASIC VARIABLES USED
                    ====================

VAR.             DISTRIB.              VALUES                 CORRELATION
NO.   NAME         TYPE       LOW         MID        HIGH     TO VAR. COEF.
---------------------------------------------------------------------------
1  SH PR F FEXCH DETERM.        0.000       0.000       0.000
2  SH PR F LABOR DETERM.        0.000       0.000       0.000
3  DISCOUNT RATE DETERM.        8.650       8.650       8.650
4  % WORKING CAP DETERM.        0.000       0.000       0.000
5  DOMES RES VAL DETERM.        0.000       0.000       0.000
6  FEXCH RES VAL DETERM.        0.000       0.000       0.000
```

No shadow prices are used in this analysis, but for certain inputs (investment and operating costs) were used sectoral adjustment factors based on estimates of long run marginal costs ("best", "high" and "low" estimates). Working capital adjustment is not made. The projection period is of 15 years and a residual value of about 39% of total investment was considered.

```
                   DESCRIPTION OF THE FLOWS USED
                   =============================
```

```
FLOW  NO.:   1          NAME:  Adjust INV
================================================

Type of flow:  Intermediate flow.
This flow extends from period 1 to period 14 and is defined by the method
of constant values.


The variables used in its definition are the following:

VAR. DISTRIB.               VALUES                CORRELATION:
NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
--------------------------------------------------------------------------------
  7 TRIANG.        0.791       0.806       0.806               CONSTANT VALUE
```

This is a flow that serves the purpose of establishing the joint sensitivity of the variables defining the investment flow, based on the estimates of the adjustment factors ("low", "best", "high"). As this flow multiplies the investment flow, changes to the variable that defines it result effectively in simultaneous changes in all of those defining the investments.

```
FLOW  NO.:   2          NAME:  Investment
================================================

Type of flow:  Investment             (Situation with the project)
This flow is multiplied by flow No.  1.
This flow extends from period  1 to period 14 and is defined by the method
of varied flow.


The variables used in its definition are the following:

VAR. DISTRIB.               VALUES                CORRELATION:
NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
--------------------------------------------------------------------------------
  8 DETERM.      155.000     155.000     155.000               VALUE PERIOD   1
  9 DETERM.       59.000      59.000      59.000               VALUE PERIOD   2
 10 DETERM.      604.000     604.000     604.000               VALUE PERIOD   3
 11 DETERM.    17347.000   17347.000   17347.000               VALUE PERIOD   4
 12 DETERM.    13801.000   13801.000   13801.000               VALUE PERIOD   5
 13 DETERM.     5073.000    5073.000    5073.000               VALUE PERIOD   6
 14 DETERM.      291.000     291.000     291.000               VALUE PERIOD   7
 15 DETERM.      154.000     154.000     154.000               VALUE PERIOD   8
 16 DETERM.      449.000     449.000     449.000               VALUE PERIOD   9
 17 DETERM.      172.000     172.000     172.000               VALUE PERIOD  10
 18 DETERM.        3.000       3.000       3.000               VALUE PERIOD  11
 19 DETERM.      281.000     281.000     281.000               VALUE PERIOD  12
 20 DETERM.        0.000       0.000       0.000               VALUE PERIOD  13
```

```
 21 DETERM.      271.000     271.000     271.000               VALUE PERIOD  14
```

The investments have been completed, so no uncertainty has been associated with them in nominal terms. We have taken the figures from the reports received. The values shown are in EUR million.

```
FLOW  NO.:   3           NAME:  Adjust COST
================================================


Type of flow:  Intermediate flow.
This flow extends from period  6 to period 15 and is defined by the method
of constant values.



The variables used in its definition are the following:

VAR. DISTRIB.               VALUES                CORRELATION:
NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
--------------------------------------------------------------------------------
 22 TRIANG.        0.632       0.728       0.758               CONSTANT VALUE
```

This is a flow that serves the purpose of establishing the joint sensitivity of the variables defining the operating costs flow, based on the estimates of the adjustment factors (“low”, “best”, “high”).. As this flow multiplies the operating costs flow, changes to the variable that defines it result effectively in simultaneous changes in all of those defining the operating costs.

```
FLOW  NO.:   4           NAME:  Costs
 ================================================


 Type of flow:  Operating cost         (Situation with the project)
 This flow is multiplied by flow No.  3.
 This flow extends from period  6 to period 15 and is defined by the method
 of varied flow.



 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  23 DETERM.     1296.000    1296.000    1296.000               VALUE PERIOD   6
  24 DETERM.     1919.000    1919.000    1919.000               VALUE PERIOD   7
  25 DETERM.     2162.000    2162.000    2162.000               VALUE PERIOD   8
  26 DETERM.     2492.000    2492.000    2492.000               VALUE PERIOD   9
  27 DETERM.     2820.000    2820.000    2820.000               VALUE PERIOD  10
  28 DETERM.     2964.000    2964.000    2964.000               VALUE PERIOD  11
  29 DETERM.     3023.000    3023.000    3023.000               VALUE PERIOD  12
  30 DETERM.     3083.000    3083.000    3083.000               VALUE PERIOD  13
  31 DETERM.     3145.000    3145.000    3145.000               VALUE PERIOD  14
  32 DETERM.     3228.000    3228.000    3228.000               VALUE PERIOD  15
THRU PERIOD  33
```

The units of this flow are EUR million. They have been taken from updated budget figures.

```
FLOW  NO.:   5           NAME:  Unit Benefit
 ================================================
Type of flow:  Intermediate flow.
 This flow extends from period  6 to period 15 and is defined by the method
 of constant values.


 The variables used in its definition are the following:
VAR. DISTRIB.               VALUES               CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 ---------------------------------------------------------------------------------
  33 TRIANG.       -2.240      11.110      18.790              CONSTANT VALUE
```

The units of this flow are Eur/tonne of processed organic waste. The basis for the quantification of this unit value was based on the avoided balance of cost – benefits of the next-best alternative for disposing the organic waste used in the composting process. Next-best alternative was assumed to be incineration, in accordance with the policies of the European Union ("Where possible, waste that cannot be recycled or reused should be safely incinerated, with landfill only used as a last resort."[41]) and Portugal (". . . elimination by deposition in landfill as the last option to be considered"[42].

There is no source providing values of the costs and benefits of disposing waste in landfills in Portugal. Thus, the following approach was used:

a) To breakdown the various components of such cost and benefits in economic and social terms and including environmental externalities;

b) To calculate directly the value of the components for which there are regional or national values.

c) To use the "benefits transfer method"[43] for the remaining components.

d) Subtracting to the above costs the benefits from the energy fed into the grid by the incinerating plant.

The basis for splitting incineration costs and benefits is the most recent and comprehensive study on the external costs of land filling and incineration, conducted by a team of the Vrije University of Amsterdam[44].

The following costs (per tonne of waste processed in the plant) were considered to be transferred:

Costs	Estimates (€/t)	Method of calculation
Health	1.37 - 7.09 – 7.09	Benefit transfer

41 "Waste", European Commission, Environment, http://ec.europa.eu/environment/waste/index.htm, accessed October 2010.

42 "PERSU II – Plano Estratégico para os Resíduos Sólidos Urbanos 2007-2016" (Strategic Plan for Urban Solid Waste 2007-2016), Ministério do Ambiente, do Ordenamento do Território e Desenvolvimento Regional, 2007, p. 44

43 "Guide to Cost Benefit Analysis of Investment Projects", European Commission, Directorate General Regional Policy, July 2008, pp. 228-230

44 Heleen Bartelings et Al., "Effectiveness of landfill taxation", Institute for Environmental Studies, Vrije Universiteit, Amsterdam, November 2005, pp. 69-113.

Materials and agricultural crops	0.13	Benefit transfer
Disamenity[45]	9.09 – 9.09 -9.87	Benefit transfer
Climate change	0.06 – 0.11 – 0.88	Benefit transfer
Transport-related		Excluded[46]
Solid and chemical waste residues	0.09 – 0.11 – 5.62	Benefit Transfer

Leading to the following aggregated values:

	Best estimate	High estimate	Low estimate
Cost of land filling (€/tonne)	+ 9.99	+ 13.50	+ 6.34

Benefits from not burning organic waste in the LIPOR incinerator (per kWh).

Benefits per kWh	Best estimate	High estimate	Low estimate
Lost energy sales[47]	- 0.03688	- 0.037432295	- 0.070591329
Avoided Externalities from energy generation	+ .02	+ .02	+ .02

Assuming an average lower heating value (LHV) for the organic waste processed in the composting plant of 5.42 MJ/kg (50% of water content) and adjusting to 80% water content, leads to a technical coefficient of 169.75 kWh per tonne of organic waste. Thus:
The benefits from avoiding to burn organic waste in the LIPOR incinerator (per tonne of waste) are:

Benefits per tonne of waste	Best estimate	High estimate	Low estimate
Lost energy sales	- 6.260340348	- 6.354091855	- 11.98280225
Avoided Externalities from energy generation	3.394978497	3.394978497	3.394978497

```
FLOW  NO.:   6           NAME:  Tonnage avoided
 ================================================

 Type of flow:  Benefit                (Situation with the project)
 This flow is multiplied by flow No.  5.
 This flow extends from period  6 to period 15 and is defined by the method
 of varied flow.

 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  34 DETERM.       10.500      10.500      10.500               VALUE PERIOD   6
  35 DETERM.       19.000      19.000      19.000               VALUE PERIOD   7
  36 DETERM.       28.200      28.200      28.200               VALUE PERIOD   8
  37 DETERM.       33.800      33.800      33.800               VALUE PERIOD   9
```

45 Including noise, vibrations, odours, visual/aesthetics, psychological (e.g.: fear for health risks). This externality was calculated indirectly, by benefits transfer from an US hedonic research study, which, according to the authors was the only one available.

46 This cost is pegged to the transportation of the waste, which was assumed to be the same for both incineration and composting.

47 Source: “MIBEL: The Iberian Electricity Market. Prices for 2007-2010”, http://www.erse.pt/pt/electricidade/mibel/Paginas/default.aspx, accessed October 2010

```
 38 DETERM.       39.400      39.400      39.400              VALUE PERIOD  10
 39 DETERM.       41.300      41.300      41.300              VALUE PERIOD  11
 40 DETERM.       41.900      41.900      41.900              VALUE PERIOD  12
 41 DETERM.       42.500      42.500      42.500              VALUE PERIOD  13
 42 DETERM.       43.200      43.200      43.200              VALUE PERIOD  14
 43 DETERM.       44.100      44.100      44.100              VALUE PERIOD  15
```

As this flow is multiplied by Flow 5, it effectively becomes the environmental benefit of composting, and is expressed in million EUR.

```
FLOW  NO.:   7           NAME:  Income
 ================================================

 Type of flow:  Benefit                (Situation with the project)
 This flow extends from period  7 to period 15 and is defined by the method
 of varied flow.


 The variables used in its definition are the following:

 VAR. DISTRIB.              VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  44 DETERM.        6.200       6.200       6.200              VALUE PERIOD   7
  45 DETERM.      266.900     266.900     266.900              VALUE PERIOD   8
  46 DETERM.      473.600     473.600     473.600              VALUE PERIOD   9
  47 DETERM.      458.200     458.200     458.200              VALUE PERIOD  10
  48 DETERM.      599.100     599.100     599.100              VALUE PERIOD  11
  49 DETERM.      742.700     742.700     742.700              VALUE PERIOD  12
  50 DETERM.      889.200     889.200     889.200              VALUE PERIOD  13
  51 DETERM.     1039.000    1039.000    1039.000              VALUE PERIOD  14
  52 DETERM.     1191.000    1191.000    1191.000              VALUE PERIOD  15
```

This flow is the financial income from the sales of compost at market prices and is added to the environmental benefit.

2. Results of the calculations

SENSITIVITY ANALYSIS OF

LIPOR Municipal waste, compost

(REF. = -27232.27)

VARIABLE		% OF CHANGE				ELASTICITIES			
		CHANGES				CHANGES			
NO.	NAME	-25	-10	+10	+25	-25	-10	+10	+25
7	Adjust INV	20.8	8.3	-8.3	-20.8	-0.832	-0.832	-0.832	-0.832
11	Investment	9.9	4.0	-4.0	-9.9	-0.398	-0.398	-0.398	-0.398
3	DISCOUNT RATE	-9.7	-3.7	3.5	8.5	0.387	0.371	0.352	0.338
22	Adjust COST	7.5	3.0	-3.0	-7.5	-0.300	-0.300	-0.300	-0.300
12	Investment	7.3	2.9	-2.9	-7.3	-0.291	-0.291	-0.291	-0.291
13	Investment	2.5	1.0	-1.0	-2.5	-0.099	-0.099	-0.099	-0.099
33	Unit Benefit	-1.3	-0.5	0.5	1.3	0.051	0.051	0.051	0.051
27	Costs	0.9	0.3	-0.3	-0.9	-0.035	-0.035	-0.035	-0.035
28	Costs	0.8	0.3	-0.3	-0.8	-0.034	-0.034	-0.034	-0.034
26	Costs	0.8	0.3	-0.3	-0.8	-0.033	-0.033	-0.033	-0.033
29	Costs	0.8	0.3	-0.3	-0.8	-0.031	-0.031	-0.031	-0.031
25	Costs	0.8	0.3	-0.3	-0.8	-0.031	-0.031	-0.031	-0.031
24	Costs	0.8	0.3	-0.3	-0.8	-0.030	-0.030	-0.030	-0.030
30	Costs	0.7	0.3	-0.3	-0.7	-0.030	-0.030	-0.030	-0.030
31	Costs	0.7	0.3	-0.3	-0.7	-0.028	-0.028	-0.028	-0.028
32	Costs	0.7	0.3	-0.3	-0.7	-0.026	-0.026	-0.026	-0.026
23	Costs	0.6	0.2	-0.2	-0.6	-0.022	-0.022	-0.022	-0.022
10	Investment	0.4	0.2	-0.2	-0.4	-0.015	-0.015	-0.015	-0.015
52	Income	-0.3	-0.1	0.1	0.3	0.014	0.014	0.014	0.014
51	Income	-0.3	-0.1	0.1	0.3	0.013	0.013	0.013	0.013
50	Income	-0.3	-0.1	0.1	0.3	0.012	0.012	0.012	0.012
49	Income	-0.3	-0.1	0.1	0.3	0.011	0.011	0.011	0.011
48	Income	-0.2	-0.1	0.1	0.2	0.010	0.010	0.010	0.010
46	Income	-0.2	-0.1	0.1	0.2	0.009	0.009	0.009	0.009
47	Income	-0.2	-0.1	0.1	0.2	0.008	0.008	0.008	0.008
16	Investment	0.2	0.1	-0.1	-0.2	-0.007	-0.007	-0.007	-0.007
38	Tonnage avoided	-0.2	-0.1	0.1	0.2	0.006	0.006	0.006	0.006
39	Tonnage avoided	-0.2	-0.1	0.1	0.2	0.006	0.006	0.006	0.006
37	Tonnage avoided	-0.1	-0.1	0.1	0.1	0.006	0.006	0.006	0.006
40	Tonnage avoided	-0.1	-0.1	0.1	0.1	0.006	0.006	0.006	0.006
45	Income	-0.1	-0.1	0.1	0.1	0.005	0.005	0.005	0.005
36	Tonnage avoided	-0.1	-0.1	0.1	0.1	0.005	0.005	0.005	0.005

41	Tonnage avoided	-0.1	-0.1	0.1	0.1	0.005	0.005	0.005	0.005
14	Investment	0.1	0.1	-0.1	-0.1	-0.005	-0.005	-0.005	-0.005
42	Tonnage avoided	-0.1	0.0	0.0	0.1	0.005	0.005	0.005	0.005
43	Tonnage avoided	-0.1	0.0	0.0	0.1	0.005	0.005	0.005	0.005
8	Investment	0.1	0.0	0.0	-0.1	-0.005	-0.005	-0.005	-0.005
35	Tonnage avoided	-0.1	0.0	0.0	0.1	0.004	0.004	0.004	0.004
19	Investment	0.1	0.0	0.0	-0.1	-0.003	-0.003	-0.003	-0.003
21	Investment	0.1	0.0	0.0	-0.1	-0.003	-0.003	-0.003	-0.003
15	Investment	0.1	0.0	0.0	-0.1	-0.003	-0.003	-0.003	-0.003
17	Investment	0.1	0.0	0.0	-0.1	-0.002	-0.002	-0.002	-0.002
34	Tonnage avoided	-0.1	0.0	0.0	0.1	0.002	0.002	0.002	0.002
9	Investment	0.0	0.0	0.0	0.0	-0.002	-0.002	-0.002	-0.002
44	Income	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
18	Investment	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
1	SH PR FCTR FEXCH	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
2	SH PR FCTR LABOR	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
4	%WORKING CAPITAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
5	DOMEST RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
6	FOR EX RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
20	Investment	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000

1PT-50b: LIPOR Municipal waste, composting Component

RISK ANALYSIS

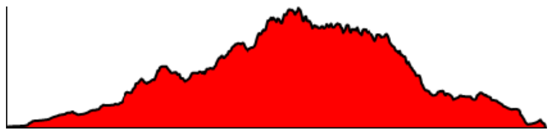
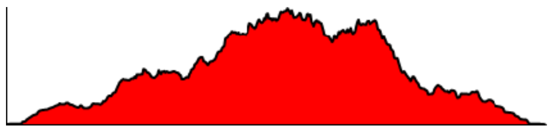
RESULT NO.	NAME	MEAN VALUE	CUMULATIVE PROBABILITY DISTRIBUTION 10%	50%	90%
1	NET PRES VAL	-27227.	-28226.	-27207.	-26292.
2	INT R OF RET	-50.00	-50.00	-50.00	-50.00
3	NPV / PV INV	-1.20	-1.25	-1.20	-1.16
4	TOTAL FX INV	0.0000	0.0000	0.0000	0.0000
5	FX INV YEAR 1	0.0000	0.0000	0.0000	0.0000
6	FX INV YEAR 2	0.0000	0.0000	0.0000	0.0000
7	FX INV YEAR 3	0.0000	0.0000	0.0000	0.0000
8	FX INV YEAR 4	0.0000	0.0000	0.0000	0.0000
9	FX INV YEAR 5	0.0000	0.0000	0.0000	0.0000
10	FX INV YEAR 6	0.0000	0.0000	0.0000	0.0000
11	FX INV REST	0.0000	0.0000	0.0000	0.0000
12	TOTAL DOM INV	30971.	30780.	30991.	31135.
13	DOM INV YR 1	124.	123.	124.	125.
14	DOM INV YR 2	47.26	46.97	47.30	47.52

15 DOM INV YR 3	484.	481.	484.	486.
16 DOM INV YR 4	13897.	13811.	13906.	13971.
17 DOM INV YR 5	11056.	10988.	11063.	11115.
18 DOM INV YR 6	4064.	4039.	4067.	4086.
19 DOM INV REST	1299.	1291.	1299.	1305.
20 FX NET FLOW 1	0.0000	0.0000	0.0000	0.0000
21 FX NET FLOW 2	0.0000	0.0000	0.0000	0.0000
22 FX NET FLOW 3	0.0000	0.0000	0.0000	0.0000
23 FX NET FLOW 4	0.0000	0.0000	0.0000	0.0000
24 FX NET FLOW 5	0.0000	0.0000	0.0000	0.0000
25 FX NET FLOW 6	0.0000	0.0000	0.0000	0.0000
26 FX NET FLOW 7	0.0000	0.0000	0.0000	0.0000
27 FX NET FLOW 8	0.0000	0.0000	0.0000	0.0000
28 FX NET FLOW 9	0.0000	0.0000	0.0000	0.0000
29 FX NET FLOW 10	0.0000	0.0000	0.0000	0.0000
30 DOM NET FLOW 1	-124.	-125.	-124.	-123.
31 DOM NET FLOW 2	-47.26	-47.51	-47.30	-46.97
32 DOM NET FLOW 3	-484.	-486.	-484.	-481.
33 DOM NET FLOW 4	-13897.	-13970.	-13906.	-13811.
34 DOM NET FLOW 5	-11056.	-11114.	-11063.	-10988.
35 DOM NET FLOW 6	-4882.	-4961.	-4883.	-4802.
36 DOM NET FLOW 7	-1407.	-1542.	-1405.	-1285.
37 DOM NET FLOW 8	-1123.	-1315.	-1116.	-948.
38 DOM NET FLOW 9	-1334.	-1563.	-1326.	-1127.
39 DOM NET FLOW 10	-1308.	-1573.	-1301.	-1068.

1PT-50b: LIPOR Municipal waste, composting Component

HISTOGRAMS

Probability distributions of the results

NET PRES VAL		
Expected value	-27227	
10%	-28226	
50%	-27207	
90%	-26292	-29268 … -25470
INT R OF RET		
Expected value	-50.00	Deterministic variable, value: -50.00
10%	-50.00	
50%	-50.00	
90%	-50.00	
NPV / PV INV		
Expected value	-1.2017	
10%	-1.2464	
50%	-1.2005	
90%	-1.1605	-1.2865 … -1.1226

ANALYTICAL TABLE

ANALYSIS OF COURSES OF ACTION

ACTION	EXP. OPTY. LOSS
ACCEPTANCE	27227.
REJECTION	0.0000

THIS PROJECT SHOULD BE REJECTED ASSUMING RISK NEUTRALITY

THE COST OF UNCERTAINTY IS 0.0000

THE COST OF IRRATIONALITY IS 27227.

DETAILED RISK ANALYSIS

POSSIBLE LOSSES

FROM	TO	PROBABILITY
25469.65	26229.34	9.00 %
26229.34	26989.02	30.00 %
26989.02	27748.70	37.40 %
27748.70	28508.38	19.00 %
28508.38	29268.06	4.60 %

TOTAL PROBABILITY OF LOSSES 100.00 %

3. Detailed flow values using the expected values of the data employed

NET PRESENT VALUE: -27342.74

INTERNAL RATE OF RETURN -50.00

NET FLOWS

=========

	FOREIGN EXCHANGE	LOCAL CURRENCY	TOTAL
0	0.0	0.0	0.0
1	0.0	-125.0	-125.0
2	0.0	-47.6	-47.6
3	0.0	-487.0	-487.0
4	0.0	-13985.7	-13985.7
5	0.0	-11126.8	-11126.8
6	0.0	-4916.9	-4916.9
7	0.0	-1414.4	-1414.4
8	0.0	-1117.9	-1117.9
9	0.0	-1327.1	-1327.1
10	0.0	-1295.8	-1295.8
11	0.0	-1102.3	-1102.3
12	0.0	-1219.1	-1219.1
13	0.0	-883.1	-883.1
14	0.0	-989.2	-989.2
15	0.0	-669.1	-669.1

Values in EUR million. As the shadow price of foreign exchange was not used, the net flow appears in the local currency column.

FLOWS, in EUR million:

	Adjust INV	Investment inv	Adjust COST	Costs op cost	Unit Benefit	Volume avoided benefit	Income benefit
1	0.80623	124.97	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.80623	47.568	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.80623	486.96	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.80623	13986.	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.80623	11127.	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.80623	4090.0	0.72802	943.51	11.110	116.65	0.0000
7	0.80623	234.61	0.72802	1397.1	11.110	211.09	6.2000
8	0.80623	124.16	0.72802	1574.0	11.110	313.30	266.90
9	0.80623	362.00	0.72802	1814.2	11.110	375.52	473.60
10	0.80623	138.67	0.72802	2053.0	11.110	437.73	458.20
11	0.80623	2.4187	0.72802	2157.9	11.110	458.84	599.10
12	0.80623	226.55	0.72802	2200.8	11.110	465.51	742.70
13	0.80623	0.0000	0.72802	2244.5	11.110	472.17	889.20
14	0.80623	218.49	0.72802	2289.6	11.110	479.95	1039.0
15	0.0000	0.0000	0.72802	2350.0	11.110	489.95	1191.0

C. Component C: Landfill sealing-off and use

1. Descriptions of flows employed and the assumptions underlying them

SUMMARY OF FLOWS USED:

Number	Name	Kind	Comment
1	Adjust INV		Adjustment of flow 2 by a triangular distribution
2	Investment	inv	Investment of the project
3	Adjust COST		Adjustment of flow 4 by a triangular distribution
4	Costs	op cost	Aggregated operating costs of the project
5	Price of Carbon		By multiplying flow 6 by the price of carbon the GHG abatement benefit is obtained
6	Vol Emiss avoid	benefit	Volume of CO2 emission avoided due to the flaring of landfill gas
7	Willingness to P		Per household willingness to pay value in the comparable project, adjusted by income distribution factor
8	Families	benefit	Willingness to pay for the project by affected households

In what follows the definitions of the above 8 flows is presented in detail. Following the specification, relevant assumptions and explanations are provided.

```
PROJECT NO.: PT-50S           (ECONOMIC ANALYSIS)
 PROJECT NAME: LIPOR Sealing Component



                     BASIC VARIABLES USED
                     ====================

 VAR.             DISTRIB.              VALUES                 CORRELATION
 NO.   NAME         TYPE       LOW         MID         HIGH     TO VAR. COEF.
 ---------------------------------------------------------------------------
 1  SH PR F FEXCH DETERM.        0.000       0.000       0.000
 2  SH PR F LABOR DETERM.        0.000       0.000       0.000
 3  DISCOUNT RATE DETERM.        8.650       8.650       8.650
 4  % WORKING CAP DETERM.        0.000       0.000       0.000
```

```
 5  DOMES RES VAL DETERM.        0.000       0.000       0.000
 6  FEXCH RES VAL DETERM.        0.000       0.000       0.000
```

No shadow prices are used in this analysis, but for certain inputs (investment and operating costs) were used sectoral adjustment factors based on estimates of long run marginal costs (“best”, “high” and “low” estimates). Working capital adjustment is not made. The projection period is of 15 years and a residual value of zero was assumed.

```
                   DESCRIPTION OF THE FLOWS USED
                   =============================

FLOW  NO.:   1           NAME:  Adjust INV
 ================================================

 Type of flow:  Intermediate flow.
 This flow extends from period  1 to period 13 and is defined by the method
 of constant values.

 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
   7 TRIANG.        0.763       0.780       0.789              CONSTANT VALUE
```

This is a flow that serves the purpose of establishing the joint sensitivity of the variables defining the investment flow, based on the estimates of the adjustment factors (“low”, “best”, “high”). As this flow multiplies the investment flow, changes to the variable that defines it result effectively in simultaneous changes in all of those defining the investments.

```
FLOW  NO.:   2           NAME:  Investment
 ================================================

 Type of flow:  Investment             (Situation with the project)
 This flow is multiplied by flow No.  1.
 This flow extends from period  1 to period 13 and is defined by the method
 of varied flow.

 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
   8 DETERM.      110.000     110.000     110.000              VALUE PERIOD   1
```

```
  9 DETERM.       96.000      96.000      96.000               VALUE PERIOD   2
 10 DETERM.     1346.000    1346.000    1346.000               VALUE PERIOD   3
 11 DETERM.     2245.000    2245.000    2245.000               VALUE PERIOD   4
 12 DETERM.     7482.000    7482.000    7482.000               VALUE PERIOD   5
 13 DETERM.     1486.000    1486.000    1486.000               VALUE PERIOD   6
 14 DETERM.      169.000     169.000     169.000               VALUE PERIOD   7
 15 DETERM.      866.000     866.000     866.000               VALUE PERIOD   8
 16 DETERM.     2652.000    2652.000    2652.000               VALUE PERIOD   9
 17 DETERM.      536.000     536.000     536.000               VALUE PERIOD  10
 18 DETERM.        0.550       0.550       0.550               VALUE PERIOD  11
 19 DETERM.      257.000     257.000     257.000               VALUE PERIOD  12
 20 DETERM.      649.000     649.000     649.000               VALUE PERIOD  13
```

The investments have been completed, so no uncertainty has been associated with them in nominal terms. We have taken the figures from the reports received. The values shown are in EUR million.

```
FLOW  NO.:   3           NAME:  Adjust COST
================================================

Type of flow:  Intermediate flow.
This flow extends from period  9 to period 15 and is defined by the method
of constant values.


The variables used in its definition are the following:

VAR. DISTRIB.               VALUES               CORRELATION:
NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
--------------------------------------------------------------------------------
 21 TRIANG.        0.589       0.650       0.693               CONSTANT VALUE
```

This is a flow that serves the purpose of establishing the joint sensitivity of the variables defining the operating costs flow, based on the estimates of the adjustment factors (“low”, “best”, “high”).. As this flow multiplies the operating costs flow, changes to the variable that defines it result effectively in simultaneous changes in all of those defining the operating costs.

```
FLOW  NO.:   4           NAME:  Costs
================================================

Type of flow:  Operating cost         (Situation with the project)
This flow is multiplied by flow No.  3.
This flow extends from period  9 to period 15 and is defined by the method
of varied flow.


The variables used in its definition are the following:
```

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR. COEF.	USE
22	DETERM.	1.190	1.190	1.190		VALUE PERIOD 9
23	DETERM.	29.400	29.400	29.400		VALUE PERIOD 10
24	DETERM.	30.600	30.600	30.600		VALUE PERIOD 11
25	DETERM.	31.200	31.200	31.200		VALUE PERIOD 12
26	DETERM.	31.800	31.800	31.800		VALUE PERIOD 13
27	DETERM.	32.500	32.500	32.500		VALUE PERIOD 14
28	DETERM.	33.100	33.100	33.100		VALUE PERIOD 15

The units of this flow are EUR million. The values have been taken from updated budget figures.

FLOW NO.: 5 NAME: Price of Carbon

Type of flow: Price.
This flow extends from period 10 to period 15 and is defined by the method of constant values.

The variables used in its definition are the following:

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR. COEF.	USE
29	TRIANG.	5.000	16.700	30.000		CONSTANT VALUE

The basis of the quantification of this benefit is the value of the traded CO_2 emission rights, often called the price of carbon. Notice that the unit price of carbon is represented by a triangular distribution, as shown above. This market price reflects the cost of GHG abatement. Given that at this cost GHG reductions can be achieved, it is not efficient to do so more expensively. This is why the price of carbon is a good measure of the benefits of GHG abatement. As this flow is multiplied by Flow 5, it effectively becomes the benefit of GHG abatement, and is expressed in million EUR.

FLOW NO.: 6 NAME: Vol Emiss avoid

Type of flow: Benefit (Situation with the project)
This flow is multiplied by flow No. 5.
This flow extends from period 10 to period 15 and is defined by the method of varied flow.

The variables used in its definition are the following:

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR. COEF.	USE
30	TRIANG.	15.320	23.830	28.930		VALUE PERIOD 10
31	TRIANG.	68.180	106.060	128.780		VALUE PERIOD 11
32	TRIANG.	69.280	107.770	130.860		VALUE PERIOD 12
33	TRIANG.	66.480	103.420	125.580		VALUE PERIOD 13
34	TRIANG.	63.950	99.470	120.790		VALUE PERIOD 14
35	TRIANG.	61.060	94.980	113.330		VALUE PERIOD 15

The units of this flow are million MT of CO_2 equivalent avoided. These values are based on converting the technical forecast of landfill gas developed by COWI's technical expert (the results of which are in broad agreement with the values found in the feasibility study) to millions of tons of CO_2 equivalent. This involves a string of technical conversions, from volume to weight and then the GHG equivalency factor. Methane is 21 times as potent as CO_2. The factor that adjusts for all these unit changes is 1.37445 times 10^{-7}.

```
FLOW  NO.:   7           NAME:  Willingness to P
 ================================================

 Type of flow:  Intermediate flow.
 This flow extends from period 10 to period 15 and is defined by the method
 of constant values.


 The variables used in its definition are the following:
```

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR. COEF.	USE
36	TRIANG.	1.000	12.740	24.480		CONSTANT VALUE

Because in the ex-ante analysis there was no specific justification assigning a benefit to the sealing off of the landfills, a documented study was used as a basis for applying the benefit transfer. The case used was the same used by the ex-post analysis of the Valdemingómez Landfill sealing and Biogas production Unit (ES-13), the Hiriya Landfill in Israel.[48] As in the Spanish case the frequency distribution, reflecting the uncertainty of the willingness-to-pay value, was a triangular probability distribution with a lower bound of 0, a mode of 4 and an upper bound of 34. This also has an expected value of USD 12.7, which is equivalent to EUR 10.1. Upon further adjustment by the ratio of GDPs of Portugal to Israel, which was 0.86, and to the ratio of regional to country GDPs (0.98) we obtained the values given above that define this flow.
This is expressed in EUR per affected household per year

```
FLOW  NO.:   8           NAME:  Population
```

[48] O. Ayalon, N. Becker and E. Shani, "Economic aspects of the rehabilitation of the Hiriya landfill", *Waste Management* 26 (2006) pp. 1313-1323.

```
================================================

Type of flow:  Benefit                (Situation with the project)
This flow is multiplied by flow No.  7.
This flow extends from period 10 to period 15 and is defined by the method
of constant values.


The variables used in its definition are the following:

VAR. DISTRIB.              VALUES                CORRELATION:
NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
--------------------------------------------------------------------------------
 37 DETERM.      228.000     228.000     228.000               CONSTANT VALUE
```

The final calculation that needs to be made is to multiply this by the number of affected households. From a site survey and using geographic information on the households distributions in a radius of 3.4 km the number of affected households was estimated in 228 thousand.

2. Results of the calculations

SENSITIVITY ANALYSIS OF

LIPOR Sealing Component

(REF. = 736.97)

VARIABLE		% OF CHANGE				ELASTICITIES			
		CHANGES				CHANGES			
NO.	NAME	-25	-10	+10	+25	-25	-10	+10	+25
7	Adjust INV	316.1	126.4	*****	*****	-12.643	-12.643	-12.643	-12.643
36	Willingness to P	*****	-92.0	92.0	230.0	9.201	9.201	9.201	9.201
37	Population	*****	-92.0	92.0	230.0	9.201	9.201	9.201	9.201
3	DISCOUNT RATE	227.5	82.4	-72.4	*****	-9.100	-8.240	-7.243	-6.593
12	Investment	141.5	56.6	-56.6	*****	-5.662	-5.662	-5.662	-5.662
29	Price of Carbon	*****	-45.1	45.1	112.7	4.507	4.507	4.507	4.507
11	Investment	46.1	18.5	-18.5	-46.1	-1.846	-1.846	-1.846	-1.846
16	Investment	36.0	14.4	-14.4	-36.0	-1.440	-1.440	-1.440	-1.440
10	Investment	30.1	12.0	-12.0	-30.1	-1.202	-1.202	-1.202	-1.202
13	Investment	25.9	10.3	-10.3	-25.9	-1.035	-1.035	-1.035	-1.035
31	Vol Emiss avoid	-25.8	-10.3	10.3	25.8	1.030	1.030	1.030	1.030
32	Vol Emiss avoid	-24.1	-9.6	9.6	24.1	0.964	0.964	0.964	0.964
33	Vol Emiss avoid	-21.3	-8.5	8.5	21.3	0.851	0.851	0.851	0.851
34	Vol Emiss avoid	-18.8	-7.5	7.5	18.8	0.753	0.753	0.753	0.753
35	Vol Emiss avoid	-16.4	-6.6	6.6	16.4	0.657	0.657	0.657	0.657
15	Investment	12.8	5.1	-5.1	-12.8	-0.511	-0.511	-0.511	-0.511
17	Investment	6.7	2.7	-2.7	-6.7	-0.268	-0.268	-0.268	-0.268
20	Investment	6.3	2.5	-2.5	-6.3	-0.253	-0.253	-0.253	-0.253
30	Vol Emiss avoid	-6.3	-2.5	2.5	6.3	0.252	0.251	0.252	0.252
8	Investment	2.9	1.2	-1.2	-2.9	-0.116	-0.116	-0.116	-0.116
19	Investment	2.7	1.1	-1.1	-2.7	-0.109	-0.109	-0.109	-0.109
14	Investment	2.7	1.1	-1.1	-2.7	-0.108	-0.108	-0.108	-0.108
9	Investment	2.3	0.9	-0.9	-2.3	-0.093	-0.093	-0.093	-0.093
21	Adjust COST	1.6	0.6	-0.6	-1.6	-0.064	-0.064	-0.064	-0.064
23	Costs	0.3	0.1	-0.1	-0.3	-0.012	-0.012	-0.012	-0.012
24	Costs	0.3	0.1	-0.1	-0.3	-0.012	-0.012	-0.012	-0.012
25	Costs	0.3	0.1	-0.1	-0.3	-0.011	-0.011	-0.011	-0.011
26	Costs	0.3	0.1	-0.1	-0.3	-0.010	-0.010	-0.010	-0.010
27	Costs	0.2	0.1	-0.1	-0.2	-0.010	-0.010	-0.010	-0.010
28	Costs	0.2	0.1	-0.1	-0.2	-0.009	-0.009	-0.009	-0.009
22	Costs	0.0	0.0	0.0	0.0	-0.001	-0.001	-0.001	-0.001
18	Investment	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000

1	SH PR FCTR FEXCH	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
2	SH PR FCTR LABOR	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
4	%WORKING CAPITAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
5	DOMEST RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
6	FOR EX RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000

1PT-50S: LIPOR Sealing Component

RISK ANALYSIS

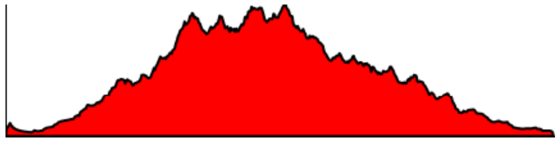
RESULT NO.	NAME	MEAN VALUE	CUMULATIVE PROBABILITY DISTRIBUTION 10%	50%	90%
1	NET PRES VAL	708.	-2882.	594.	4529.
2	INT R OF RET	9.23	2.81	9.64	15.17
3	NPV / PV INV	0.0760	-0.3112	0.0639	0.4847
4	TOTAL FX INV	0.0000	0.0000	0.0000	0.0000
5	FX INV YEAR 1	0.0000	0.0000	0.0000	0.0000
6	FX INV YEAR 2	0.0000	0.0000	0.0000	0.0000
7	FX INV YEAR 3	0.0000	0.0000	0.0000	0.0000
8	FX INV YEAR 4	0.0000	0.0000	0.0000	0.0000
9	FX INV YEAR 5	0.0000	0.0000	0.0000	0.0000
10	FX INV YEAR 6	0.0000	0.0000	0.0000	0.0000
11	FX INV REST	0.0000	0.0000	0.0000	0.0000
12	TOTAL DOM INV	13901.	13761.	13908.	14028.
13	DOM INV YR 1	85.45	84.59	85.49	86.23
14	DOM INV YR 2	74.58	73.82	74.61	75.26
15	DOM INV YR 3	1046.	1035.	1046.	1055.
16	DOM INV YR 4	1744.	1726.	1745.	1760.
17	DOM INV YR 5	5812.	5754.	5815.	5865.
18	DOM INV YR 6	1154.	1143.	1155.	1165.
19	DOM INV REST	3985.	3945.	3987.	4021.
20	FX NET FLOW 1	0.0000	0.0000	0.0000	0.0000
21	FX NET FLOW 2	0.0000	0.0000	0.0000	0.0000
22	FX NET FLOW 3	0.0000	0.0000	0.0000	0.0000
23	FX NET FLOW 4	0.0000	0.0000	0.0000	0.0000
24	FX NET FLOW 5	0.0000	0.0000	0.0000	0.0000
25	FX NET FLOW 6	0.0000	0.0000	0.0000	0.0000
26	FX NET FLOW 7	0.0000	0.0000	0.0000	0.0000
27	FX NET FLOW 8	0.0000	0.0000	0.0000	0.0000
28	FX NET FLOW 9	0.0000	0.0000	0.0000	0.0000
29	FX NET FLOW 10	0.0000	0.0000	0.0000	0.0000

30 DOM NET FLOW 1	-85.45	-86.23	-85.49	-84.59
31 DOM NET FLOW 2	-74.58	-75.25	-74.61	-73.82
32 DOM NET FLOW 3	-1046.	-1055.	-1046.	-1035.
33 DOM NET FLOW 4	-1744.	-1760.	-1745.	-1726.
34 DOM NET FLOW 5	-5812.	-5865.	-5815.	-5753.
35 DOM NET FLOW 6	-1154.	-1165.	-1155.	-1143.
36 DOM NET FLOW 7	-131.	-132.	-131.	-130.
37 DOM NET FLOW 8	-673.	-679.	-673.	-666.
38 DOM NET FLOW 9	-2061.	-2080.	-2062.	-2040.
39 DOM NET FLOW 10	2829.	1355.	2748.	4448.

1PT-50S: LIPOR Sealing Component

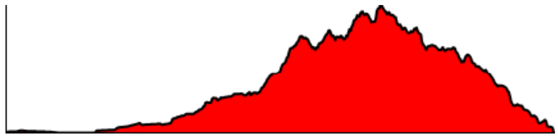
HISTOGRAMS

NET PRES VAL	
Expected value	708
10%	-2882
50%	594
90%	4529



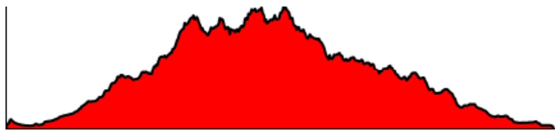
-6448 8368

INT R OF RET	
Expected value	9.2271
10%	2.8141
50%	9.6440
90%	15.17



-9.5528 19.31

NPV / PV INV	
Expected value	0.0760
10%	-0.3112
50%	0.0639
90%	0.4847



-0.6937 0.8989

ANALYTICAL TABLE

ANALYSIS OF COURSES OF ACTION

ACTION	EXP. OPTY. LOSS
ACCEPTANCE	805.03
REJECTION	1513.1

THIS PROJECT SHOULD BE ACCEPTED ASSUMING RISK NEUTRALITY

THE COST OF UNCERTAINTY IS 805.03

THE COST OF IRRATIONALITY IS 708.11

DETAILED RISK ANALYSIS

POSSIBLE LOSSES		
FROM	TO	PROBABILITY
0.00	1289.63	18.00 %
1289.63	2579.26	12.40 %
2579.26	3868.88	8.80 %
3868.88	5158.51	3.00 %
5158.51	6448.14	0.80 %
TOTAL PROBABILITY OF LOSSES		43.00 %

POSSIBLE GAINS

FROM	TO	PROBABILITY
0.00	1673.57	23.20 %
1673.57	3347.15	14.40 %
3347.15	5020.72	11.60 %
5020.72	6694.30	6.20 %
6694.30	8367.88	1.60 %
TOTAL PROBABILITY OF GAINS		57.00 %

3. Detailed flow values using the expected values of the data employed

NET PRESENT VALUE: 762.29

INTERNAL RATE OF RETURN 9.91

NET FLOWS

=========

	FOREIGN EXCHANGE	LOCAL CURRENCY	TOTAL
0	0.0	0.0	0.0
1	0.0	-85.8	-85.8
2	0.0	-74.9	-74.9
3	0.0	-1050.1	-1050.1
4	0.0	-1751.5	-1751.5
5	0.0	-5837.2	-5837.2
6	0.0	-1159.3	-1159.3
7	0.0	-131.8	-131.8
8	0.0	-675.6	-675.6
9	0.0	-2069.8	-2069.8
10	0.0	2865.4	2865.4
11	0.0	4655.6	4655.6
12	0.0	4483.7	4483.7
13	0.0	4104.8	4104.8
14	0.0	4544.8	4544.8
15	0.0	4469.4	4469.4

Values in EUR million. As the shadow price of foreign exchange was not used, the net flow appears in the local currency column.

FLOWS, in EUR million:

	Adjust I NV	Investme nt	Adjust C OST	Costs	Price of Carbon	Vol Emis s avoid	Willingn ess to P	Populati on
		inv		op cost		benefit		benefit
1	0.78017	85.819	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.78017	74.896	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.78017	1050.1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.78017	1751.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.78017	5837.2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.78017	1159.3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.78017	131.85	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.78017	675.63	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.78017	2069.0	0.64975	0.77320	0.0000	0.0000	0.0000	0.0000
10	0.78017	418.17	0.64975	19.103	16.700	397.96	12.740	2904.7
11	0.78017	0.42909	0.64975	19.882	16.700	1771.2	12.740	2904.7
12	0.78017	200.50	0.64975	20.272	16.700	1799.8	12.740	2904.7
13	0.78017	506.33	0.64975	20.662	16.700	1727.1	12.740	2904.7
14	0.0000	0.0000	0.64975	21.117	16.700	1661.1	12.740	2904.7

15	0.0000	0.0000	0.64975	21.507	16.700	1586.2	12.740	2904.7

D.Component D: Electricity generation

1. Descriptions of flows employed and the assumptions underlyingthem

SUMMARY OF FLOWS USED:

Number	Name	Kind	Comment
1	Investment	inv	Investment of the project
2	Efficiency fact		Multiplies all values of the electricity flow, below. It is used to gauge their aggregate sensitivity in sensitivity analysis
3	E avoided cost		Avoided cost of energy generation represented by a triangular distribution
4	Energy Benefit	benefit	Energy fed into the national grid
5	Cost Fact MAT		Adjustment of flow 6 by a triangular distribution
6	Cost MAT		Operating costs of Matosinhos landfill
7	Cost Fact VAL	benefit	Adjustment of flow 8 by a triangular distribution
8	Cost VAL	op cost	Operating costs of Valongo landfill

In what follows the definitions of the above 8 flows is presented in detail. Following the specification, relevant assumptions and explanations are provided.

```
PROJECT NO.: PT-50d           (ECONOMIC ANALYSIS)
PROJECT NAME: LIPOR Municipal waste, energy component



                    BASIC VARIABLES USED
                    ====================

VAR.             DISTRIB.                VALUES                  CORRELATION
NO.   NAME         TYPE       LOW         MID         HIGH     TO VAR. COEF.
---------------------------------------------------------------------------
1  SH PR F FEXCH DETERM.        0.000       0.000       0.000
2  SH PR F LABOR DETERM.        0.000       0.000       0.000
3  DISCOUNT RATE DETERM.        8.650       8.650       8.650
4  % WORKING CAP DETERM.        0.000       0.000       0.000
5  DOMES RES VAL DETERM.        0.000       0.000       0.000
6  FEXCH RES VAL DETERM.        0.000       0.000       0.000
```

No shadow prices are used in this analysis, but for certain inputs (investment and operating costs) were used sectoral adjustment factors based on estimates of long run marginal costs ("best", "high" and "low" estimates). Working capital adjustment is not made. The projection period is of 15 years and a residual value of zero was assumed. Exploitation of the LFG ends when gas generation falls below the threshold that makes operation technically unfeasible.

```
                   DESCRIPTION OF THE FLOWS USED
                   =============================

FLOW  NO.:   1           NAME:  Investment
 ================================================

 Type of flow:  Investment             (Situation with the project)
 This flow extends from period  1 to period  6 and is defined by the method
 of varied flow.


 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
   7 DETERM.      778.000     778.000     778.000              VALUE PERIOD   1
   8 DETERM.       14.800      14.800      14.800              VALUE PERIOD   2
   9 DETERM.      419.700     419.700     419.700              VALUE PERIOD   3
  10 DETERM.     1428.000    1428.000    1428.000              VALUE PERIOD   4
  11 DETERM.      693.000     693.000     693.000              VALUE PERIOD   5
  12 DETERM.       28.400      28.400      28.400              VALUE PERIOD   6
```

The investments have been completed, so no uncertainty has been associated with them. We have taken the figures from the reports received.

```
FLOW  NO.:   2           NAME:  Efficiency fact.
 ================================================

 Type of flow:  Intermediate flow.
 This flow extends from period  1 to period 13 and is defined by the method
 of constant values.


 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  13 DETERM.        1.000       1.000       1.000              CONSTANT VALUE
```

This is an artificial variable that serves the purpose of establishing the joint sensitivity of the variables of the next flow, which are used to define electricity produced. As this flow multiplies the next one, changes to the variable that defines it results effectively in simultaneous changes in all of those defining the next one.

```
FLOW  NO.:   3          NAME:  E avoided cost
 ================================================

 Type of flow:  Price.
 This flow is multiplied by flow No.  2.
 This flow extends from period  1 to period 13 and is defined by the method
 of constant values.

 The variables used in its definition are the following:

 VAR. DISTRIB.              VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  14 TRIANG.        0.057       0.081       0.139              CONSTANT VALUE   24 TRIANG.
```

The units of this flow are EUR/kWh. These unit values are based on the published market prices of the Iberian Energy Market (MIBEL)[49], from which the negative externalities of energy production by the Portuguese electricity overall generation system[50] were deducted. This way the market price of electricity generation net of environmental externalities was estimated (the best estimate amounts to EUR 0.081/kWh).

```
FLOW  NO.:   4          NAME:  Energy Benefit
 ================================================

 Type of flow:  Benefit               (Situation with the project)
 This flow is multiplied by flow No.  3.
 This flow extends from period  5 to period 13 and is defined by the method
 of varied flow.


 The variables used in its definition are the following:

 VAR. DISTRIB.              VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  15 DETERM.     3308.000    3308.000    3308.000              VALUE PERIOD   5
  16 DETERM.    14725.000   14725.000   14725.000              VALUE PERIOD   6
  17 DETERM.    14963.000   14963.000   14963.000              VALUE PERIOD   7
  18 DETERM.    14359.000   14359.000   14359.000              VALUE PERIOD   8
  19 DETERM.    13811.000   13811.000   13811.000              VALUE PERIOD   9
  20 DETERM.    13187.000   13187.000   13187.000              VALUE PERIOD  10
  21 DETERM.    12715.000   12715.000   12715.000              VALUE PERIOD  11
```

49 Source: http://www.erse.pt/pt/electricidade/mibel/Paginas/default.aspx, accessed on October 2010.

50 Source: European Environment Agency: http://www.eea.europa.eu/data-and-maps/figures#c15=all&c5=&c9=&c0=15&b_start=0, acessed on October 2010.

22	DETERM.	12181.000	12181.000	12181.000				VALUE PERIOD 12
23	DETERM.	3367.000	3367.000	3367.000				VALUE PERIOD 13

The units of this flow are million kWh. The values have been estimated from gas availability estimates and are therefore subject to the estimation errors. This uncertainty is dealt with by variables no 5 and 7, as explained below.

```
FLOW  NO.:   5           NAME:  Cost Fact MAT
 ================================================

 Type of flow:  Intermediate flow.
 This flow is multiplied by flow No.  2.
 This flow extends from period  5 to period 13 and is defined by the method
 of constant values.


 The variables used in its definition are the following:
```

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR.	COEF.	USE
24	TRIANG.	0.031	0.036	0.037			CONSTANT VALUE

This variable represents the uncertainty of the operating costs of one of the 2 landfills where LFG is collected to generate energy. These uncertainties concern the efficiency of LFG extraction and of energy generation which affects both costs and benefits.

.

```
FLOW  NO.:   6           NAME:  Cost MAT
 ================================================

 Type of flow:  Operating cost         (Situation with the project)
 This flow is multiplied by flow No.  5.
 This flow extends from period  5 to period 13 and is defined by the method
 of varied flow.


 The variables used in its definition are the following:
```

VAR. NO.	DISTRIB. TYPE	VALUES LOW	MID	HIGH	CORRELATION: TO VAR.	COEF.	USE
25	DETERM.	491.000	491.000	491.000			VALUE PERIOD 5
26	DETERM.	4296.000	4296.000	4296.000			VALUE PERIOD 6
27	DETERM.	4280.000	4280.000	4280.000			VALUE PERIOD 7
28	DETERM.	4112.000	4112.000	4112.000			VALUE PERIOD 8
29	DETERM.	3951.000	3951.000	3951.000			VALUE PERIOD 9
30	DETERM.	3796.000	3796.000	3796.000			VALUE PERIOD 10

```
 31 DETERM.     3647.000    3647.000    3647.000               VALUE PERIOD  11
 32 DETERM.     3504.000    3504.000    3504.000               VALUE PERIOD  12
 33 DETERM.     3367.000    3367.000    3367.000               VALUE PERIOD  13
```

The units of this flow are EUR thousand and refer to the landfill of Matosinhos. They have been taken from updated budget figures.

```
FLOW  NO.:   7           NAME:  Cost Fact VAL
 ================================================

 Type of flow:  Intermediate flow.
 This flow is multiplied by flow No.  2.
 This flow extends from period  5 to period 13 and is defined by the method
 of constant values.


 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  34 TRIANG.        0.023       0.027       0.028               CONSTANT VALUE
```

This variable is similar to variable 5 in this case applying to the landfill of Valongo.

```
FLOW  NO.:   8           NAME:  Cost VAL
 ================================================

 Type of flow:  Operating cost         (Situation with the project)
 This flow is multiplied by flow No.  7.
 This flow extends from period  5 to period 12 and is defined by the method
 of varied flow.


 The variables used in its definition are the following:

 VAR. DISTRIB.               VALUES                CORRELATION:
 NO.    TYPE       LOW         MID       HIGH      TO VAR. COEF.   USE
 --------------------------------------------------------------------------------
  35 DETERM.     2817.000    2817.000    2817.000               VALUE PERIOD   5
  36 DETERM.    10429.000   10429.000   10429.000               VALUE PERIOD   6
  37 DETERM.    10683.000   10683.000   10683.000               VALUE PERIOD   7
  38 DETERM.    10247.000   10247.000   10247.000               VALUE PERIOD   8
  39 DETERM.     9860.000    9860.000    9860.000               VALUE PERIOD   9
  40 DETERM.     9391.000    9391.000    9391.000               VALUE PERIOD  10
  41 DETERM.     9068.000    9068.000    9068.000               VALUE PERIOD  11
  42 DETERM.     8677.000    8677.000    8677.000               VALUE PERIOD  12
```

This variable is similar to variable 7 in this case applying to the landfill of Valongo.

2. Results of the calculations

SENSITIVITY ANALYSIS OF

LIPOR Municipal waste, energy

(REF. = 694.74)

VARIABLE		% OF CHANGE				ELASTICITIES			
		CHANGES				CHANGES			
NO.	NAME	-25	-10	+10	+25	-25	-10	+10	+25
14	E avoided cost	*****	-72.1	72.1	180.3	7.210	7.210	7.210	7.210
13	Efficiency fact.	*****	-50.0	50.0	124.9	4.997	4.997	4.997	4.997
3	DISCOUNT RATE	63.2	23.7	-21.8	-51.1	-2.526	-2.367	-2.175	-2.046
10	Investment	40.1	16.0	-16.0	-40.1	-1.603	-1.603	-1.603	-1.603
34	Cost Fact VAL	35.2	14.1	-14.1	-35.2	-1.408	-1.408	-1.408	-1.408
16	Energy Benefit	-32.3	-12.9	12.9	32.3	1.292	1.292	1.292	1.292
17	Energy Benefit	-30.2	-12.1	12.1	30.2	1.208	1.208	1.208	1.208
7	Investment	28.0	11.2	-11.2	-28.0	-1.120	-1.120	-1.120	-1.120
18	Energy Benefit	-26.7	-10.7	10.7	26.7	1.067	1.067	1.067	1.067
19	Energy Benefit	-23.6	-9.4	9.4	23.6	0.945	0.945	0.945	0.945
20	Energy Benefit	-20.8	-8.3	8.3	20.8	0.830	0.830	0.830	0.830
24	Cost Fact MAT	20.1	8.1	-8.1	-20.1	-0.805	-0.805	-0.805	-0.805
21	Energy Benefit	-18.4	-7.4	7.4	18.4	0.737	0.737	0.737	0.737
11	Investment	17.9	7.2	-7.2	-17.9	-0.716	-0.716	-0.716	-0.716
22	Energy Benefit	-16.2	-6.5	6.5	16.2	0.650	0.650	0.650	0.650
9	Investment	12.8	5.1	-5.1	-12.8	-0.512	-0.512	-0.512	-0.512
15	Energy Benefit	-7.9	-3.2	3.2	7.9	0.315	0.315	0.315	0.315
36	Cost VAL	6.4	2.5	-2.5	-6.4	-0.255	-0.255	-0.255	-0.255
37	Cost VAL	6.0	2.4	-2.4	-6.0	-0.240	-0.240	-0.240	-0.240
38	Cost VAL	5.3	2.1	-2.1	-5.3	-0.212	-0.212	-0.212	-0.212
39	Cost VAL	4.7	1.9	-1.9	-4.7	-0.188	-0.188	-0.188	-0.188
23	Energy Benefit	-4.1	-1.7	1.7	4.1	0.165	0.165	0.165	0.165
40	Cost VAL	4.1	1.6	-1.6	-4.1	-0.164	-0.165	-0.165	-0.165
41	Cost VAL	3.7	1.5	-1.5	-3.7	-0.146	-0.146	-0.146	-0.146
26	Cost MAT	3.5	1.4	-1.4	-3.5	-0.141	-0.141	-0.141	-0.141
27	Cost MAT	3.2	1.3	-1.3	-3.2	-0.130	-0.130	-0.130	-0.130
42	Cost VAL	3.2	1.3	-1.3	-3.2	-0.129	-0.129	-0.129	-0.129
28	Cost MAT	2.9	1.1	-1.1	-2.9	-0.115	-0.115	-0.115	-0.115
29	Cost MAT	2.5	1.0	-1.0	-2.5	-0.101	-0.101	-0.101	-0.101
30	Cost MAT	2.2	0.9	-0.9	-2.2	-0.090	-0.090	-0.090	-0.090
31	Cost MAT	2.0	0.8	-0.8	-2.0	-0.079	-0.079	-0.079	-0.079

35	Cost VAL	1.9	0.7	-0.7	-1.9	-0.075	-0.075	-0.075	-0.075
32	Cost MAT	1.8	0.7	-0.7	-1.8	-0.070	-0.070	-0.070	-0.070
33	Cost MAT	1.5	0.6	-0.6	-1.5	-0.062	-0.062	-0.062	-0.062
12	Investment	0.7	0.3	-0.3	-0.7	-0.027	-0.027	-0.027	-0.027
8	Investment	0.5	0.2	-0.2	-0.5	-0.020	-0.020	-0.020	-0.020
25	Cost MAT	0.4	0.2	-0.2	-0.4	-0.018	-0.018	-0.018	-0.018
1	SH PR FCTR FEXCH	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
2	SH PR FCTR LABOR	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
4	%WORKING CAPITAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
5	DOMEST RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000
6	FOR EX RESID VAL	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000

1PT-50d: LIPOR Municipal waste, energy component

RISK ANALYSIS

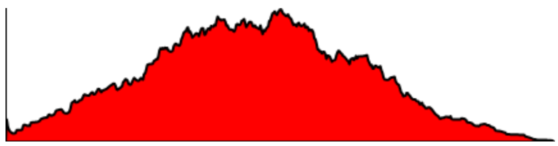
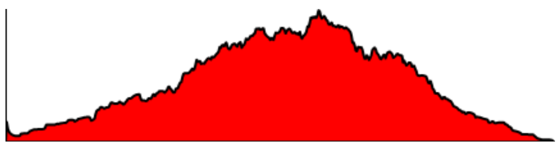
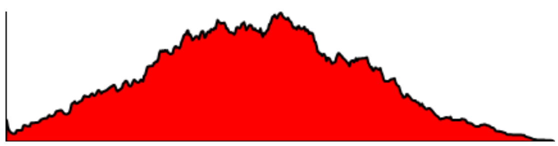
RESULT NO.	NAME	MEAN VALUE	CUMULATIVE PROBABILITY DISTRIBUTION 10%	50%	90%
1	NET PRES VAL	634.	-464.	518.	1949.
2	INT R OF RET	12.45	4.96	12.27	20.46
3	NPV / PV INV	0.2284	-0.1672	0.1864	0.7020
4	TOTAL FX INV	0.0000	0.0000	0.0000	0.0000
5	FX INV YEAR 1	0.0000	0.0000	0.0000	0.0000
6	FX INV YEAR 2	0.0000	0.0000	0.0000	0.0000
7	FX INV YEAR 3	0.0000	0.0000	0.0000	0.0000
8	FX INV YEAR 4	0.0000	0.0000	0.0000	0.0000
9	FX INV YEAR 5	0.0000	0.0000	0.0000	0.0000
10	FX INV YEAR 6	0.0000	0.0000	0.0000	0.0000
11	FX INV REST	0.0000	0.0000	0.0000	0.0000
12	TOTAL DOM INV	3362.	3362.	3362.	3362.
13	DOM INV YR 1	778.	778.	778.	778.
14	DOM INV YR 2	14.80	14.80	14.80	14.80
15	DOM INV YR 3	420.	420.	420.	420.
16	DOM INV YR 4	1428.	1428.	1428.	1428.
17	DOM INV YR 5	693.	693.	693.	693.
18	DOM INV YR 6	28.40	28.40	28.40	28.40
19	DOM INV REST	0.0000	0.0000	0.0000	0.0000
20	FX NET FLOW 1	0.0000	0.0000	0.0000	0.0000
21	FX NET FLOW 2	0.0000	0.0000	0.0000	0.0000
22	FX NET FLOW 3	0.0000	0.0000	0.0000	0.0000
23	FX NET FLOW 4	0.0000	0.0000	0.0000	0.0000

24 FX NET FLOW 5	0.0000	0.0000	0.0000	0.0000
25 FX NET FLOW 6	0.0000	0.0000	0.0000	0.0000
26 FX NET FLOW 7	0.0000	0.0000	0.0000	0.0000
27 FX NET FLOW 8	0.0000	0.0000	0.0000	0.0000
28 FX NET FLOW 9	0.0000	0.0000	0.0000	0.0000
29 FX NET FLOW 10	0.0000	0.0000	0.0000	0.0000
30 DOM NET FLOW 1	-778.	-778.	-778.	-778.
31 DOM NET FLOW 2	-14.80	-14.80	-14.80	-14.80
32 DOM NET FLOW 3	-420.	-420.	-420.	-420.
33 DOM NET FLOW 4	-1428.	-1428.	-1428.	-1428.
34 DOM NET FLOW 5	-481.	-548.	-489.	-401.
35 DOM NET FLOW 6	898.	600.	866.	1254.
36 DOM NET FLOW 7	942.	639.	910.	1304.
37 DOM NET FLOW 8	904.	613.	873.	1252.
38 DOM NET FLOW 9	869.	590.	840.	1204.
39 DOM NET FLOW 10	830.	563.	802.	1149.

1PT-50d: LIPOR Municipal waste, energy component

HISTOGRAMS

Probability distributins of the results

NET PRES VAL		
Expected value	-693	
10%	-1118	
50%	-687	
90%	-279	-1436 … 201
INT R OF RET		
Expected value	2.7804	
10%	-1.2801	
50%	2.9991	
90%	6.4955	-5.0077 … 10.11
NPV / PV INV		
Expected value	-0.2495	
10%	-0.4027	
50%	-0.2473	
90%	-0.1004	-0.5171 … 0.0723

ANALYTICAL TABLE

ANALYSIS OF COURSES OF ACTION

ACTION	EXP. OPTY. LOSS
ACCEPTANCE	111.42
REJECTION	745.50

THIS PROJECT SHOULD BE ACCEPTED ASSUMING RISK NEUTRALITY

THE COST OF UNCERTAINTY IS 111.42

THE COST OF IRRATIONALITY IS 634.09

DETAILED RISK ANALYSIS

POSSIBLE LOSSES FROM	TO	PROBABILITY
0.00	240.05	8.40 %
240.05	480.10	8.80 %
480.10	720.16	4.40 %
720.16	960.21	3.80 %
960.21	1200.26	1.20 %

TOTAL PROBABILITY OF LOSSES 26.60 %

POSSIBLE GAINS

FROM	TO	PROBABILITY
0.00	576.51	27.40 %
576.51	1153.02	18.20 %
1153.02	1729.52	13.40 %
1729.52	2306.03	9.80 %
2306.03	2882.54	4.60 %

TOTAL PROBABILITY OF GAINS 73.40 %

3. Detailed flow values using the expected values of the data employed

NET PRESENT VALUE: 44.85

INTERNAL RATE OF RETURN 8.98

NET FLOWS

=========

	FOREIGN EXCHANGE	LOCAL CURRENCY	TOTAL
0	0.0	0.0	0.0
1	0.0	-778.0	-778.0
2	0.0	-14.8	-14.8
3	0.0	-419.7	-419.7
4	0.0	-1428.0	-1428.0
5	0.0	-516.4	-516.4
6	0.0	738.0	738.0
7	0.0	779.5	779.5
8	0.0	748.0	748.0
9	0.0	719.5	719.5
10	0.0	686.8	686.8
11	0.0	662.3	662.3
12	0.0	634.4	634.4
13	0.0	153.1	153.1

Values in EUR million. As the shadow price of foreign exchange was not used, the net flow appears in the local currency column.

FLOWS, in million EUR:

	Investment	Efficiency fact.	E avoided cost	Energy Benefit	Cost Fact MAT	Cost MAT	Cost Fact VAL	Cost VAL
	inv			benefit		op cost		op cost
1	778.00	1.0000	0.81432E-01	0.0000	0.0000	0.0000	0.0000	0.0000
2	14.800	1.0000	0.81432E-01	0.0000	0.0000	0.0000	0.0000	0.0000
3	419.70	1.0000	0.81432E-01	0.0000	0.0000	0.0000	0.0000	0.0000
4	1428.0	1.0000	0.81432E-01	0.0000	0.0000	0.0000	0.0000	0.0000
5	693.00	1.0000	0.81432E-01	269.38	0.35963E-01	17.658	0.26679E-01	75.156
6	28.400	1.0000	0.81432E-01	1199.1	0.35963E-01	154.50	0.26679E-01	278.24
7	0.0000	1.0000	0.81432E-01	1218.5	0.35963E-01	153.92	0.26679E-01	285.02
8	0.0000	1.0000	0.81432E-01	1169.3	0.35963E-01	147.88	0.26679E-01	273.38
9	0.0000	1.0000	0.81432E-01	1124.7	0.35963E-01	142.09	0.26679E-01	263.06
10	0.0000	1.0000	0.81432E-01	1073.8	0.35963E-01	136.52	0.26679E-01	250.55
11	0.0000	1.0000	0.81432E-01	1035.4	0.35963E-01	131.16	0.26679E-01	241.93
12	0.0000	1.0000	0.81432E-01	991.92	0.35963E-01	126.01	0.26679E-01	231.50
13	0.0000	1.0000	0.81432E-01	274.18	0.35963E-01	121.09	0.26679E-01	0.0000

D. The global analysis

This analysis is not presented out because it was not possible to carry out one of the components of the project, as explained in the main report under section 10.3.3 Economic analysis, Component A – Recycling.

GENERAL Annex X

interpretation of PROPLAN inputs and outputs

A. Introduction

This Appendix describes how inputs and outputs of PROPLAN are specified.

B. Presentation of the Data

1. Introduction

The computer program used to carry out this analysis is not unlike many of the popular spreadsheet programs, in the sense that it operates on rows of data which can be used to represent financial flows. Thus, investments, when they take more than one period to be carried out, or revenues, operating costs, etc., are flows in the sense that they are made up of different values at different points of time. The computer program uses variables to define these flows. In Section 2 below, we will specify the types of flow specification methods that are available in the program, some of which were used in this report, and in Section 3 below, we will explain how the probabilistically defined data can be specified.
The terms presented in the following two sections will be useful in understanding the descriptions of the data employed in the analyses presented in this report.

2. Specification of flows

The ways in which flows can be specified within the computer program are the following:

(1) *Constant value*: The flow will have the same value in each period.

(2) *Divided sum:* The flow has a constant value which is calculated by dividing a given amount by the number of periods between the initial and final periods of the flow.

(3) *Growth*: The flow is defined by an initial value and an annual growth rate which is applied to the initial value in compound form.

(4) *Varied flow*: Each value of the flow is individually specified, period by period.

(5) *Linear transformation of another flow:* This method allows the definition of a flow as a linear transformation of a previously specified flow.

(6) *Varied flow followed by constant:* This method is a variant of method (4). Individual values of the flow are specified for a number of periods, and the final value is held constant for the remaining periods.

3. Specification of probabilistic variables

There are five types of probability distributions that can be used to characterize the uncertainty associated with a given variable. Figure 1 illustrates the different types of probability distributions available and the paragraphs below explain the parameters used to define each type of these distributions.

(1) *Deterministic Variable* (Type 0): In this case no probability distribution is desired, a single value (P1) is assigned to the variable. The program uses the single value in all the simulations and in deterministic calculations.

(2) *Uniform Distribution* (Type 1): The uniform distribution is defined by its minimum and maximum values (P1 and P2 in Figure 1). The values outside the interval thus defined have a probability equal to zero, and the values within the interval have equal probability.

(3) *Normal Distribution* (Type 2): This distribution is also known as the "Gaussian Distribution" which is usually defined by its mean and variance. For reasons of uniformity, the program requires that this distribution be defined by means of the low and high values (P1 and P2 in Figure 1), from which the program calculates the mean and the variance. The required parameters (the low and high values) are specified so that the probability is 80% that the actual value lies somewhere in between, leaving 10% within each of the tails of the distribution. Since the normal distribution is symmetrical, the program assumes that the mean is in the middle of the interval defined by the low (P1) and high (P2) values. It should also be clear that the low and high values are not minimum or maximum values: a total of 20% of the probability is either above or below these limits.[51]

(4) *Triangular Distribution* (Type 3): This distribution has lower and upper limits. The minimum and the maximum values define these limits. The middle value defines the mode of the distribution (*i. e.,* neither the mean nor the median, unless the distribution is defined symmetrically). The density function of this distribution is illustrated in Figure 1. There is no symmetry restriction; therefore, the triangle may have a right angle (if the mode coincides with one of the extremes).

(5) *Trapezoidal Distribution* (Type 4): This distribution is defined by minimum (P1), low (P2), high (P3) and maximum (P4) values. (See Figure 1.)

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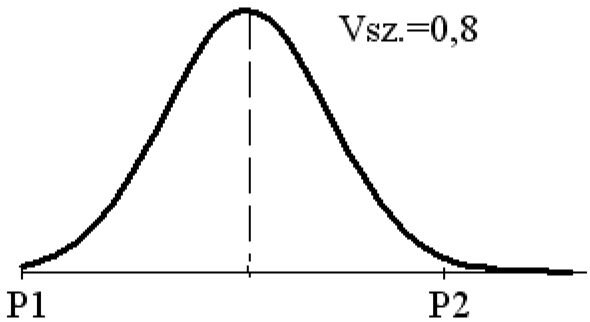
[51] In the actual probabilistic simulations, all values selected are confined within an interval defined by plus or minus six standard deviations from the mean.

Many of the variables simulated in risk analysis are not independent of each other. Therefore, when they are modeled as random variables, it is crucial to specify the correlations between them. If correlations are not specified, the simulation process will incorrectly estimate the variance of the results and may lead to biases. The proper procedure in risk analysis is to specify the degree of positive (or negative) correlation whenever it exists.
Each correlation is defined by three values; the first value is the variable number of the dependent variable, the second is the variable number of the independent variable and the third value is the correlation coefficient.

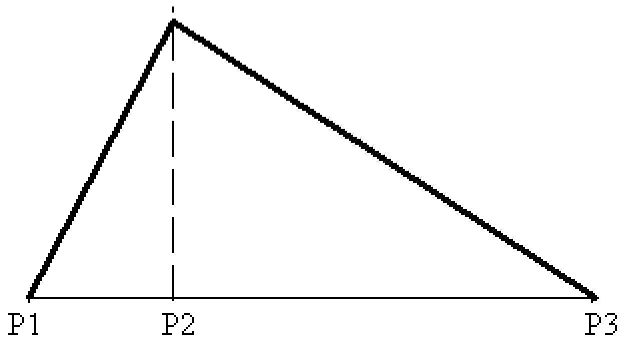
FIGURE 1
TYPES OF PROBABILITY DISTRIBUTION

Uniform Distribution

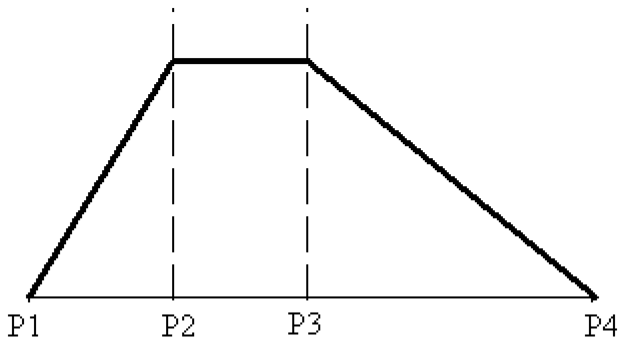
Normal distribution



Triangular distribution



Trapezoidal distribution



C. Presentation of the Results

1. Sensitivity analysis

This analysis is so named because it measures the effect of changes in the values assumed for each of the project's variables on the net present value (NPV) of the project.

The program performing the sensitivity analysis is set up to change the value of each variable while holding all others constant. First, it reduces it by 25% and 10%, after which it increases it by the same magnitudes. Once a change in value has been accomplished, the corresponding NPV is calculated. These changes are done one at a time, so that the changes observed in the NPV show the consequences of changing a single variable in a project. That is, it shows the effect of partial changes of the variables of the project.

Once the NPV corresponding to each of the changes in each of the variables has been obtained, the percentage changes of the NPV are calculated. Finally, the quotient of the percentage change in the NPV and the percentage change of the individual variables of the project is computed, which gives the elasticity. This is defined as follows:

$$\text{Elasticity} = \frac{\text{Percentage change of the NPV}}{\text{Percentage change of the variable}}$$

This elasticity is a standardized sensitivity measure which is independent of the magnitude of the variables. The greater the value of the elasticity of a variable, the greater the degree of sensitivity of the NPV to changes in this variable. Moreover, the sign of elasticity shows the relation which exists between the variable and the NPV. If the elasticity has a negative sign, this shows that the greater the value of the variable the lower the value of the NPV will be. In other words, if the sign is negative, there is an inverse relation, and if the sign is positive, there is a direct relation between the variable and the NPV. In terms of the project, the variables with greater elasticity are the most important.

The sensitivity analysis table (Table1) ranks the variables according to the absolute value of their average elasticity (corresponding to changes of -10, -25, 10 and 25%). It is organized as follows:

(a) On the left-hand side the number and the name of the variables is shown.

(b) The percent changes in NPVs appear next, for each of the percentage changes of the variable, as given by the heading of each column.

(c) On the right-hand side the corresponding values of the elasticities are shown.

TABLE 1

SENSITIVITY ANALYSIS

VARIABLE		PERCENTAGE CHANGE CHANGES				ELASTICITIES CHANGES			
NUM.	NAME	-25	-10	+10	+25	-25	-10	+10	+25
22	MARGIN	-71.4	-28.6	28.6	71.4	2.856	2.857	2.856	2.856
21	CROPS PER YEAR	-27.3	-10.9	10.9	27.3	1.094	1.094	1.094	1.094
3	DISC RATE	28.1	10.6	-9.9	-23.5	-1.125	-1.065	-.992	-.941
57	VARIABLE COST	25.8	10.3	-10.3	-25.8	-1.030	-1.030	-1.030	-1.030
51	HECT. MANAGED	-23.2	-9.3	9.3	23.2	.929	.929	.929	.929
63	CURRENT CAP	23.0	9.2	-7.3	-19.0	-.920	-.920	-.725	-.761
45	OFFICIAL X R	10.7	4.3	-4.3	-10.7	-.430	-.430	-.430	-.430
12	FARM YIELD/HA	-4.9	-2.0	2.0	4.9	.197	.197	.197	.197
13	FARM YIELD/HA	-4.8	-1.9	1.9	4.8	.191	.191	.191	.191
14	FARM YIELD/HA	-4.6	-1.9	1.9	4.6	.186	.186	.186	.186
15	FARM YIELD/HA	-4.5	-1.8	1.8	4.5	.182	.182	.182	.182
16	FARM YIELD/HA	-4.3	-1.7	1.7	4.3	.174	.174	.174	.174
11	FARM YIELD/HA	-4.1	-1.6	1.6	4.1	.164	.164	.164	.164
50	HECT. MANAGED	-4.1	-1.6	1.6	4.1	.164	.164	.164	.164
10	FARM YIELD/HA	-3.4	-1.3	1.3	3.4	.135	.135	.135	.135
20	CROPS PER YEAR	-3.4	-1.3	1.3	3.4	.135	.135	.135	.135
49	HECT. MANAGED	-3.4	-1.3	1.3	3.4	.135	.135	.135	.135
58	FIXED COST	3.2	1.3	-1.3	-3.2	-.128	-.128	-.128	-.128
41	SALES PRICE	3.2	1.3	-1.3	-3.2	-.128	-.128	-.128	-.128
9	FARM YIELD/HA	-2.7	-1.1	1.1	2.7	.108	.108	.108	.108
19	CROPS PER YEAR	-2.7	-1.1	1.1	2.7	.108	.108	.108	.108
48	HECT. MANAGED	-2.7	-1.1	1.1	2.7	.108	.108	.108	.108
32	FARM SH PURCH	-2.6	-1.1	1.1	2.6	.105	.105	.105	.105
31	FARM SH PURCH	-2.6	-1.0	1.0	2.6	.104	.104	.104	.104
30	FARM SH PURCH	-2.5	-1.0	1.0	2.5	.101	.101	.101	.101
29	FARM SH PURCH	-2.4	-1.0	1.0	2.4	.096	.096	.096	.096
28	FARM SH PURCH	-2.3	-.9	.9	2.3	.092	.092	.092	.092
43	OFFICIAL X R	2.3	.9	-.9	-2.3	-.090	-.090	-.090	-.090
61	INV EQUIP	2.3	.9	-.9	-2.3	-.090	-.090	-.090	-.090
27	FARM SH PURCH	-2.1	-.9	.9	2.1	.085	.085	.085	.085
59	INV BPDGS	2.1	.8	-.8	-2.1	-.084	-.084	-.084	-.084
38	SALES PRICE	1.8	.7	-.7	-1.8	-.071	-.071	-.071	-.071
39	SALES PRICE	1.8	.7	-.7	-1.8	-.070	-.070	-.070	-.070
44	OFFICIAL X R	1.7	.7	-.7	-1.7	-.069	-.069	-.069	-.069
8	FARM YIELD/HA	.6	-.8	.8	2.1	-.024	.084	.084	.084
18	CROPS PER YEAR	.6	-.8	.8	2.1	-.024	.084	.084	.084
47	HECT. MANAGED	.6	-.8	.8	2.1	-.024	.084	.084	.084
40	SALES PRICE	1.7	.7	-.7	-1.7	-.068	-.068	-.068	-.068
26	FARM SH PURCH	-1.6	-.6	.6	1.6	.065	.065	.065	.065
62	INV EQUIP	1.6	.6	-.6	-1.6	-.065	-.065	-.065	-.065
56	BOAT SH PURCH	-1.6	-.6	.6	1.6	.063	.063	.063	.063

2. Risk analysis

a. Cumulative probability distributions

The computer prepares a table which shows a cumulative probability distribution for each of the results of the simulation, as well as their expected values (Table 2). Each line in the table refers to one of the results and provides the number of the result, the name of the result variable, its expected value, and the cumulative probability values of 10, 50, and 90 percent.

TABLE 2
ENACA -- PROCESSING PLANT
RISK ANALYSIS

RESULT NUMBER	NAME	MEAN VALUE	CUMULATIVE PROBABILITY DISTRIBUTION 10%	50%	90%
1	NET PRES VAL	811,401	-389,657	802,279	2,075,159
2	INT R OF RET	19.32	1.77	20.15	37.61

The values defining the cumulative probability distribution should be interpreted as follows: The value under the heading of 10% is such that 10% of the simulations yielded results lower than or equal to it. The value under the heading of 90% is such that 90% of the simulations yielded results that were lower than or equal to it. Hence, the cumulative distribution values of 10% and 90% define an 80% confidence interval. The 50% value gives the median of the distribution. The results that appear in this table are the net present value of the project and its internal rate of return.

b. Analytical table

This table is derived from the probability distribution of the project's net present value and is affected, therefore, by the choice of discount rate. The table consists of two parts. The upper part analyzes the consequences of accepting or rejecting the project. The lower part provides detail of possible gains and losses. (See Table 3).

One consequence of undertaking a project is running the risk of possible losses. Rejecting a project, on the other hand, results in the possible loss of the benefits that could have been gained from the project. To make these two consequences comparable, we use the concept of opportunity loss. An opportunity loss is the difference between the consequence of following a certain course of action and the consequence of following a different course of action which, with hindsight, turns out to have had been better given the outcome of events. For example, the opportunity loss of rejecting a project, given it would have been profitable, is equal to the foregone benefits (in net present value terms). The opportunity loss of accepting a bad project is the present value of the net losses suffered[52]. The course of action with the lowest opportunity loss is the preferred one.

TABLE 3

ANALYTICAL TABLE

ANALYSIS OF COURSES OF ACTION

ACTION	EXP. OPTY. LOSS

[52] The program calculates these values in the following way: the expected value of the opportunity loss of accepting the project is the expected value of the negative NPVs obtained in the simulation (the sum of all the negative NPV's expressed in absolute value, divided by their number). The expected value of the opportunity loss of rejecting the project is similarly derived from the positive NPVs obtained in the course of the simulation.

```
        ACCEPTANCE     .10614E+06

        REJECTION      .91754E+06


    THIS PROJECT SHOULD BE ACCEPTED ASSUMING RISK NEUTRALITY

    THE COST OF UNCERTAINTY IS  .10614E+06
    THE COST OF IRRATIONALITY IS  .81140E+06


    DETAILED RISK ANALYSIS


                 POSSIBLE LOSSES
                                                 PROBABILITY
                FROM           TO

                0.00         358285.12            11.40 %
           358285.12         716570.25             5.00 %
           716570.25        1074855.50             2.40 %
          1074855.50        1433140.70             2.00 %
          1433140.70        1791426.00              .80 %

                 TOTAL PROBABILITY OF LOSSES      21.60 %


                 POSSIBLE GAINS
                                                 PROBABILITY
                FROM           TO

                0.00         813559.00            29.20 %
           813559.00        1627118.00            29.20 %
           813559.00        1627118.00            29.20 %
          1627118.00        2440677.00            14.60 %
          2440677.00        3254236.00             4.80 %
          3254236.00        4067795.00              .60 %

                 TOTAL PROBABILITY OF GAINS       78.40 %
```

Since we don't know a priori what the opportunity loss of a project will be, we have to make our decisions on the basis of the expected value of the opportunity loss. The recommended course of action is the one that minimizes the expected opportunity loss, as long as the decision maker is risk neutral. This is the decision rule on which the program bases its recommendations that a given project should be accepted "assuming risk neutrality."[53]

The figures followed by expressions such as "E+06", as in the example of the preceding page, mean that the number should be multiplied by ten raised to the exponent shown after the letter "E". For instance, .10614E+06 means 0.10614 multiplied by 10^6, that is, 106,140.

The cost of uncertainty, given next in the table, is the lowest of the two expected opportunity losses. When project acceptance is recommended, as in this case, the cost of uncertainty is the expected value of the possible losses. Hence, it is the maximum amount that can be paid for perfect information regarding the project's future performance. (Paying more than the expected value of losses for information that serves to avoid those losses makes no sense to

[53] Risk neutrality is defined as behavior which aims for the highest possible expected value of gains. Such would be the case of someone who is indifferent between betting or not a thousand dollars on a head or tails coin toss-up (same probability of winning or losing the money).

someone who is risk neutral). By a similar reasoning it can be shown that when a project is to be rejected, the cost of uncertainty is the opportunity loss of rejecting the project, *i.e.*, the expected value of the foregone gains. The value of the cost of uncertainty is helpful in determining whether additional studies are worth undertaking. For a study to be worthwhile, it should cost less than the reduction of the cost of uncertainty that it can produce.

The cost of irrationality is the difference between the two expected opportunity losses. It is the expected cost of making the wrong decision. For this reason, it is also equal to the absolute value of the expected value of the net present value of the project.

The lower half of the analytical table gives a detailed analysis of the risk of the project. First it divides the interval of the possible negative NPV values into five segments and calculates for each the probability of observing values in it. This is the same as the number of simulations in which the NPV falls into that particular segment, divided by the total number of simulations.

In the same manner, the positive values of the NPV are used for the calculation of probabilities corresponding to the five segments in which the interval of possible positive values of NPV is divided.

c. Histograms

The histograms shown in Figure 2 give a graphic depiction of the results obtained by the probabilistic simulations. These can be generated for any of the standard output variables, and are commonly shown for the net present value and for the internal rate of return.

FIGURE B.2

HISTOGRAMS

```
1 NET PRES VAL
------------------

  +                        *****
  +                  ***** ***** *****
  +                  ***** ***** *****
  +                  ***** ***** *****
  +            ***** ***** ***** *****
  +            ***** ***** ***** *****
  +            ***** ***** ***** ***** *****
  +            ***** ***** ***** ***** *****
  +            ***** ***** ***** ***** ***** *****
  +      ***** ***** ***** ***** ***** ***** *****
  +***** ***** ***** ***** ***** ***** ***** ***** *****

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     I     I     I     I     I     I     I     I     I     I
-.1791E+07        -.3366E+05         .1724E+07
.3482E+07
```

```
2 INT R OF RET
------------------

  +                              *****
  +                              ***** *****
  +                              ***** *****
  +                              ***** *****
  +                        ***** ***** *****
  +                        ***** ***** *****
  +                        ***** ***** ***** *****
  +                  ***** ***** ***** ***** *****
  +                  ***** ***** ***** ***** ***** *****
  +                  ***** ***** ***** ***** ***** *****
  +            ***** ***** ***** ***** ***** ***** *****
  +***** ***** ***** ***** ***** ***** ***** ***** ***** *****

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     I     I     I     I     I     I     I     I     I     I
-25.27            -1.878             21.52              44.91
```