'smallBIOGAS'

Usage guide to use the software and interpret the results

BIOGAS³
Sustainable small-scale biogas production from agro-food waste for energy self-sufficiency

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1. Use of the interface

The software tool smallBIOGAS requires the selection or entry of a set of data by the user. Listed below are the data required in each of the five display screens of the application. The tool provides, for each country where the possible location of the biogas plan is studied, guideline data adapted to the situation of the country, which the user may modify if he so deems necessary.

This usage guide is supplemented with information in the interface of the tool on the different items. This information can be viewed if the user places the cursor over the word in question.

The symbol used as decimal mark in the data or numerical results of the smallbiogas tool is the "comma".

1.1. Interface display screens

1.1.1. Screen 1: Where?

General data

It is possible for the user to identify his/her studies ("Name of the study") and store them in an organized manner. Once the study is finalized, it is possible to view all the studies made in "My studies".

In order to do this, the user must click on the study he/she wants to view, and then click on "View report". This allows the studies made to be viewed in pdf format.

It is also possible to view the data entered and to modify any previous study with the "Edit report" button. This makes it possible to view in the application the data entered from stored previous reports.

Figure 1.   My studies

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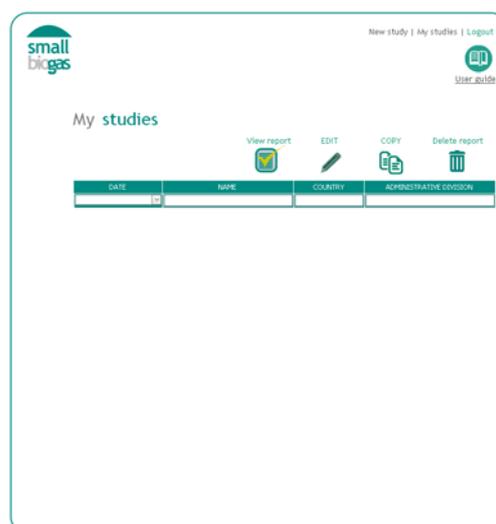
General data. Administrative division

Subsequently, the user must select on the interface the country and the administrative division where the biogas is to be located. The tool will provide the average annual temperature of the administrative division selected, but the user can modify it. This temperature can be used for the calculation of the thermal energy needs for the biogas production process; that is to say, for heating of digesters.

Figure 2.   Display screen 1

1.1.2.   *Screen 2: Type of substrate*

Substrate data

It is possible to select the type and subtype of substrate, together with its main physicochemical characteristics. The user must enter the "Quantity of substrate" of each subtype that he/she wishes to use in the biogas plant, the cost of "Acquisition" of the substrate if there is, as well as the "Distance" at which the substrate is located with respect to the biogas plant.

The characteristics of the substrates are editable; thus, if the user knows the characteristics of the substrate in question that he wishes to use the characteristics can be modified on any subtype offered by smallbiogas. The tool will take the characteristics of the substrate in question modified by the user.

List of substrates

The user must click on "Add substrate", to add materials to the mixture that is to be used for the production of biogas. This will be reflected in the "List of substrates".

To make changes in any substrate added on the list, the user must click on the substrate in the "List of substrates", click on the "pencil" icon, modify what he/she considers necessary (properties, quantities, etc.) and click on "Edit substrate".

Moreover, to eliminate any substrate added on the list, the user must click on the substrate in the "List of substrates" and click on the icon "recycle bin".

In the event that the user obtains a mixture with a C/N ratio outside the range 20-30, the tool marks in red the calculation of the C/N ratio of the mixture of substrates included by the user.

The user can manually modify the C/N ratio of a mixture, balancing the proportions of the different substrates (increasing the proportion of substrates with high C/N if it is too low or increasing the proportion of substrates with low C/N if the C/N ratio of the mixture is too high).

He/she can also "click" on "See C/N Proposal", to view the quantities of mixture provided by the tool as an alternative. It is recommended that more than 3 substrates be entered in order to view alternative mixtures that have a C/N ratio within the range 20-30.

If the user is not able to obtain a mixture within the range 20-30, contact is recommended with some of the expert centres involved in the BIOGAS3 project.

Figure 3.   Display screen 2

1.1.3. Screen 3: Use of biogas

Technology of digestion

The user can choose between digestion by wet system or dry system. The tool performs the balance of material of the digester in a different way depending on whether one system or the other is selected. By the wet system, generally the process of anaerobic digestion is carried out with a concentration of total solids in the digester that is lower than in the case of the dry system. Therefore, the tool has internal values which fix the total solids in the mixture entering the digester both for the first case and for the second. In particular, in digestion by the wet system, it has been fixed in the tool that in the event of the total solids of the mixture entering the digester being higher than 14%, they will appear in the report "Needs of dilution water". Likewise, in digestion by dry system, in the event of being lower than 20% total solids in the mixture entering the digester, some "Needs of dry material for concentration" will appear. The

quantities of digestate in terms of mass (tonnes fresh material) will be modified in accordance with this in each case.

New scenario

Later, the user can enter the scenario of use of biogas that he/she is interested in analyzing. It is possible to select between use of biogas in boiler, cogeneration engine, natural gas network injection or use as fuel in vehicles. For the first two uses it is possible to choose, in turn, between "Sale" or "Self-consumption" or the energy produced.

In case of self-consumption, it is necessary to quantify needs. Nevertheless, it is important to indicate that if the user needs to compare scenarios of use with different energy needs for self-consumption and/or the number of hours of energy demand they are not the same for thermal and electric energy; the creation of a new study is required. The user may use previous studies, enter a new "Name" (display screen 1) and modify the self-consumption energy needs.

Needs

The user is provided with the possibility of choosing between different ranges of energy needs; based on these ranges, the tool takes the average value of the range for the calculations. It is possible for the user to modify this value (annual needs) if this exact data is known for the study in particular. With regard to these total annual energy needs or demand, it is possible to specify the number of months of the year and number of hours per day in which it is produced.

It is also possible to modify the number of months in which there is biogas production. By default, 12 months are provided, being considered continuous plant operation during the entire year.
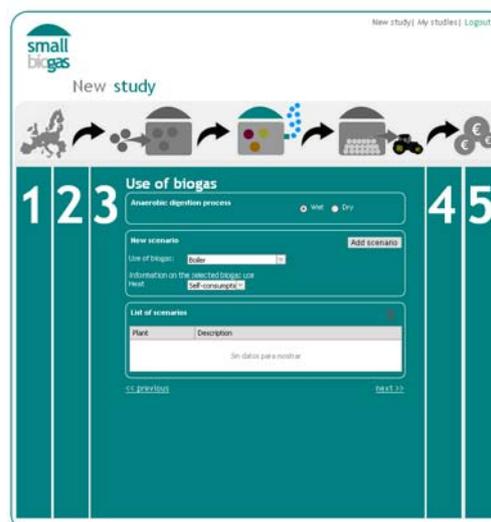
Figure 4.   Display screen 3

1.1.4. *Screen 4: Use of digestate*

Quantity of digestate

Based on the substrates entered, the tool calculates the quantity of digestate produced (tonnes of fresh material produced annually) and the nitrogen content in it.

Utilization of the digestate

The user may them choose between two scenarios of use of the digestate:

• Sale

• Self-consumption

If "Sale" is selected, the tool considers the income from sale of digestate, according to the price of the display screen 5 ("Selling price of digestate"). In this scenario the cost of transport to field of the digestate is not taken into account. For the calculation of the number of hectares required for application of the digestate, the user is not allowed to select if the application is carried out in a vulnerable or non-vulnerable zone. The tool, by default, takes the case of use in a vulnerable zone, the limitation being 170 kg N/ha and year (maximum quantity of nitrogen to be provided annually in farm plots located in zones classified as vulnerable to contamination by nitrates from agricultural sources).

If "Self-consumption" is selected, the tool allows entry of the distance it is estimated that the digestate transport trucks would travel from the biogas plant to the farm plots ("Transport to farm plots"). In this scenario, the cost of transport to field and the savings in fertilizers due to their substitution with digestate are taken into account. These savings are quantified in screen 5 ("Selling price of digestate"). It is important to underscore that the tool by default does not take into account the cost of application of the digestate, once it has been transported to the farm plot. In the event of wanting to take into account this cost in the viability study, it can be included in "Other costs" (display screen 5).

Additionally, if cost is foreseen associated with the transport of digestate but not savings for self-consumption in own plots (the management of the digestate only supposes transport cost and there are no savings in fertilizers), it is recommended, after the selection of self-consumption (display screen 4) and entry of the distance of "Transport to farm plots" (screen display 4), that a value of 0 euros (display screen 5) be entered in "selling price of digestate".

Vulnerability

Within "Self-consumption" of the digestate, the user is allowed to select between application in vulnerable zone ("Vulnerability": Yes) and non-vulnerable zone ("Vulnerability": No). This classification comes from European law relating to the contamination of nitrates from agricultural sources (Directive 91/676/EEC) and implemented in member countries.

If the user selects "Yes", the tool considers as maximum value of application of nitrogen for the calculation of hectares required for utilization of the nitrogen of digestate the value of 170 kgN/ha and year, as well as the total nitrogen contained in the digestate.

If the user selects "No", the tool considered as maximum value of application of nitrogen for the calculation of hectares required, the demand in nitrogen of "Crop" (kgN/ha and year) selected by the user, as well as the total nitrogen contained in the digestate. It is possible for the user to modify these annual needs in nitrogen of the crop.

In both cases, it should be noted that this calculation of "Cultivation area required for application of digestate" does not substitute a complete balance de nutrients. This only makes it possible to obtain an order of magnitude on the cultivation area required to utilize the total nitrogen of the digestate obtained and thus cover the annual demand in nitrogen of the crop in question chosen by the user.

Figure 5.   Display screen 4

1.1.5.   Screen 5: Financing. Creation of the report

Income

Prices are included, modifiable by the user, which are expected to be applicable to the sale of the different products of the biogas plant.

In addition, it is possible to include in "Other incomes" any other income derived from the production of biogas (waste management, sale of carbon credits, etc.).

Expenses

The user may increase or reduce the expenses, if he/she considers that others fit the specific situation. All the values are modifiable by the user. The following have been included as modifiable expenses in the interface:

- "Operating and maintenance expenses". Estimated as a percentage of the income obtained from the products obtained (sale of heat, electricity or biomethane) or from energy savings (self-consumption).

- "Labour cost" or cost of personnel required in the biogas plant. An average cost has been entered for the European countries included in the project.

- "Labour intensity". Time dedication of personnel per tonne of fresh material processed by the biogas plant and per day. An average value has been entered for small biogas plants with wet system digestion and with a high degree of automation.

- "Unit handling cost". Makes it possible to quantify the cost associated with the loading and unloading of substrates in the biogas plant.

- "Other expenses"

If the substrates used for production are located at a certain distance from the biogas plant, the tool takes into account the transport costs according to the value entered in "Distance (km)" (display screen 2), as long as this value is different from zero.

Financing structure

It is possible for the user to enter the "Part of the investment" (expressed as a percentage) that is non-repayable subsidy, loan and equity. If subsidy is entered, the tool considers that the remaining part is covered up to 100% of the investment through equity and loan.

With regard to investment, the following items are included when a new study is begun; "Other investments" and "Storage cost". The latter is the cost of storage of the biogas per unit of gasometer volume required; it supposes the investment in the system for storage of biogas while there is no energy demand by the agro-food company. This investment in equipment will be applied whenever "Self-consumption" has been selected on display screen 2. Subsequently, once the user creates the report, it will be included within the category "Biogas plant".

It is possible to fix the "Lifetime" of the project at up to 20 years.

Figure 6.   Display screen 5

1.2. Interface signals

If the user enters a mixture with a C/N ratio outside the range 20-30 (display screen 2), the tool marks in red the value of the C/N ratio (-) that the user has in the mixture entered (substrate or substrates added) and which he/she will utilize for the production of biogas (see section "List of substrates" where it is indicated how to modify up to values within the advised range).

If the user does not enter any "Amount of substrate" (screen 2) and/or does not select any "New scenario" (display screen 3), the tool shows the following notice: "The report cannot be created without scenarios or substrates". The application does not generate any report.

2. Contents of the report

Listed below are the parts and terms of the report created after the entry of data by the user. The tool will include in pink colour the data entered by the user and the results obtained in green colour.

The report includes two pdf documents. The first with the actual report, and the second with a summary of the substrates entered by the user.

2.1. Parts of the report

The report (first pdf document) includes the parts described below:

General data

According to the data provided in the user register, the tool personalizes the initial descriptive data of the report, including the name of the agro-food company entered in the "Registry Form" of the tool. Moreover, the report includes the data of performance of the study in question.

Location data

Data relating to the location of the biogas plant (administrative division, annual average temperature) and percentages of waste or substrates located at a distance of fewer than and/or more than 10 km with respect to the biogas plant.

Biogas production process data

Data relating to the production process: quantities of incoming material, needs of dilution water (in some cases, after selection as digestion technology, wet system) or of dry material to concentrate (in some cases, after selection as digestion technology, dry system), quantity of digestate produced and digestate recirculation rate (in digestion by wet system).

Basic guideline data regarding the volume of digesters, the hydraulic retention time and the thermal energy required for heating of digesters.

Annual biogas and methane production data.

In addition, in relation to possible problems in the biogas production process, the tool includes the following types of notices:

- Notice due to possible excessive recirculation. Only for the case of wet system digestion technology. This notice of excessive recirculation is activated ("Yes" is indicated on the report) when the recirculation rate exceeds 30%.

- Notice due to possible risk of inhibition by ammonia. The notice of risk of inhibition by ammonia is activated ("Yes" is indicated on the report) when the content in ammoniacal nitrogen ($N\text{-}NH_4^+$) of the material entering the digester exceeds the threshold of 3 kgN/t.

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- Notice C/N out of range. The notice of C/N out of range is activated ("Yes" is indicated on the report) when the C/N ratio of the material entering the digester is out of the fixed range 20-30. The notice indicates if the C/N ratio is excessive or too low. The acceptable threshold of C/N is normally fixed between 20 and 30.

Use of biogas

Descriptive data entered by the user on the selected scenario, such as boiler, cogeneration, biomethane for injection in natural gas network, biomethane for use in vehicles. Moreover, data are included associated with the use of the products obtained (sale or self-consumption in the agro-food company) and the energy needs in case of self-consumption.

System data for utilization of biogas (for each use in question)

Boiler

- Recoverable thermal energy in boiler: This is obtained from the methane produced, taking into account the lower heating value or LHV of the methane (9,95 kWh/Nm^3) and a boiler efficiency of 85%.

- Thermal power installed in boiler: This is obtained from the recoverable thermal energy in the boiler, taking into account a boiler operating time of 8000 hours/year and a point coefficient fixed at 1,05.

- Unrecovered thermal energy in boiler: Unused thermal energy once the heating needs of digesters and the needs for self-consumption fixed by the user have been covered. If the scenario selected is "sale", it is supposed that it is totally recovered and there is no unrecovered thermal energy.

- Investment in boiler system: This is obtained from a function that takes into account the power of the boiler (see section "Investment project").

- Income or savings due to substitution of unrenewable fuel (natural gas). In case of "sale", the user has entered a "Selling price of thermal energy" and the income is calculated from this information, along with the amount of heat available for sale once the heating needs of digesters are satisfied. In the case of "self-consumption", the savings are calculated according to the thermal energy needs of the agro-food industry fixed by the user and the "savings due to substitution" (see "Investment project. Income" section). These savings are calculated once the heating needs of digesters have been satisfied.

Cogeneration

- Production of electricity in cogeneration: It is obtained from the methane produced, taking into account the lower heating power of methane (9,95 kWh/Nm^3) and an electrical efficiency in small-scale cogeneration of 35%.

- Electric power installed in cogeneration system: It is obtained from the production of electricity in cogeneration, taking into account a system operating time of 8000 hours/year and a point coefficient fixed at 1,05.

- Thermal energy production in cogeneration: It is obtained from the methane produced, taking into account the lower heating power of methane (9,95 kWh/Nm^3) and a thermal efficiency in small-scale cogeneration of 50%.

- Unrecovered thermal energy in cogeneration system: Unused thermal energy, once the heating needs of digesters and the self-consumption needs fixed by the user have been covered. If the selected scenario is sale, it is supposed that it is totally recovered and that there is no unrecovered thermal energy.

- Thermal recovery coefficient of the cogeneration system: It is obtained by making the quotient between the thermal energy produced (discounting heat required in process) and the primary energy which enters the cogeneration unit. This primary energy which enters the cogeneration unit takes into account the lower heating power of methane, the gross annual production of methane and a percentage of availability for use of the cogeneration unit of 91%.

- Energy efficiency coefficient of the cogeneration system: It is an indicator of the gross overall energy efficiency and it is calculated making the quotient between energy obtained in cogeneration unit (once process needs are satisfied) and the energy contained in the methane from the biogas (from the gross annual production of methane and the lower heating power of the methane).

- Investment in cogeneration system: It is obtained from a function that takes into account the power of the system (see section "Investment Project").

- Income or savings. In case of "sale", the user has entered a "Selling price of the electric or thermal energy" and this income is calculated from this data together with the amount of heat and electricity sold. In the case of "self-consumption", savings are calculated according to the electric or thermal energy needs of the agro-food industry fixed by the user and the "savings due to substitution" (see "Investment project. Income"). This income or the savings are calculated once the heating needs of digesters have been satisfied.

Energy storage

For scenarios of use of biogas in "Boiler" or "Cogeneration engine", in the event that the user has selected "Self-consumption", the volume of the gasometer is provided to store the biogas and the percentage of electric or thermal energy self-consumed as compared to the electric or thermal energy produced. In the self-consumed thermal energy the thermal energy consumed

for heating of digesters has been included, as well as the thermal energy self-consumed by the agro-food company.

The abbreviations that appear are listed as follows:

Ne=Electric energy needs

Pe=Production of electric energy from biogas

Nt=Thermal energy needs

Pt=Production of thermal energy from biogas

In this section some of the following comments will appear relating to the volume required to store the biogas in case of selection of the "self-consumption" scenario:

- Storage volume is at least 25% of the daily production of biogas. 100% of the energy available from the biogas is utilized and the self-consumption energy time demand is 100% satisfied.

- Storage volume calculated to cover hours in which biogas is not utilized. There is unused biogas in self-consumption by the agro-food company (Pe>Ne y/o Pt>Nt) and which could be assigned to sale to third parties.

- If it is not possible to satisfy, from biogas energy, the electric energy or thermal energy needs fixed by the user (Ne>Pe and/or Nt>Pt), under the conditions of the study in question, the tool cannot calculate the gasometer volume and it appears as a comment "--". This indicates to the user that it is not possible to satisfy the self-consumption needs fixed by the user and therefore, gasometer volume is not provided.

Biomethane injection in natural gas network or use in vehicles

- Thermal energy in the biomethane obtained: It is the thermal energy of the biomethane; it is calculated from the higher heating power of the methane and the annual amount of methane produced.

- Losses of energy in the purification process: it is calculated as a percentage of consumption of the biogas produced and of the availability of the equipment for utilization of the biomethane. This consumption is produced in the purification process.

- Thermal output energy of the purifier: thermal energy once the losses are discounted in the process of purification.

- Biomethane output flow rate of the purifier: calculated according to the availability of the equipment (8000 hours/year).

- Installed capacity of the purifier: It is obtained from the flow rate of biomethane and of the point coefficient of the installation (1,05).

- Higher heating power of the biomethane produced: from the thermal output energy of the purifier and taking into account the self-consumption of the process. In particular,

this takes into account as self-consumption in the injection-compression process, a value of 2% on the thermal output energy of the purifier.

- Annual net amount of biomethane produced: It is calculated from the higher heating power or HHV of the biomethane produced and the higher heating value of the methane per volume unit (11,06 kWh/Nm^{3}CH$_4$).

- Flow rate of biomethane produced: It is obtained from the higher heating power of the biomethane produced, the higher heating power of the methane per volume unit (11,06 kWh/Nm^{3}CH$_4$) and the time of availability (8000 h).

- Investment in biomethane system: It is obtained from a function that takes into account the flow rate of biomethane produced by the purifier (see "Investment Project" section).

- Income due to sale of biomethane: This income is calculated from the "Selling price of biomethane" entered by the user and from the higher heating power of the biomethane produced.

Economic viability analysis

Investment project

This includes the data relating to initial investment in the biogas plant project, as well as income and expenses associated with the investment project.

Investment. The initial investment includes the "Biogas plant" (equipment without taking into account the biogas recovery system), the "Biogas recovery systems" (boiler, cogeneration or biomethane engine) and "Others" (Other investments that the user has entered in the display screen 5).

Both the investment in the "Biogas plant" and the investment in the "Recovery system" have been calculated from functions. The function used in both cases is of the potential type:

$$y = a \cdot x^b$$

This function takes as "x": the tonnes of fresh material processed annually in the case of calculation of the investment in "Biogas plant", and the installed power (thermal, electric or the flow rate of the biomethane produced by the purifier) in the case of the investment of the "Biogas recovery system".

From these functions, the tool provides as guideline results of the investment ("Biogas plant", "Biogas recovery system"). These last values, being editable once the report has been created, can be modified by the user if he/she deems it necessary (click on "Edit investment", display screen 5). The tool has taken into account average costs associated with small-scale biogas plants, with wet system digestion technology, in the different countries included in the BIOGAS3 project in 2014.

In the case of self-consumption, the biogas plant item includes investment in equipment for storage of the biogas (gasometer, etc.). This equipment allows the storage of biogas to cover disparities between energy demand in agro-food industry and biogas production. The user can modify on the "display screen 5" the unit cost of the storage of biogas (€/m^3 of gasometer for

storage of biogas). So that this investment in storage of biogas is included under the item "Biogas plant", calculation must be possible of the volume of the gasometer for storage of biogas. If this is not possible, in the section "Energy storage"" the indication "--" will appear in "Comments (see "Energy storage" section).

Income. In addition to the data entered by the user, the following results are included relating to annual income:

- "Sale of energy": It is calculated, according to the scenario of use selected, from the "Recoverable thermal energy in boiler", "Thermal energy production in cogeneration", "Electricity production in cogeneration" or "Higher heating power of the biomethane produced" (biomethane production). The "Selling price of electric energy", "Selling price of thermal energy" or "Selling price of biomethane" are applied according to the scenario.

- "Energy savings": Income derived from self-consumed energy. For the calculation of the savings, the purchase prices of electricity or natural gas for heat production have been taken into account, with the purpose of calculating the savings according to the scenario. These purchase prices are particularized for the countries included in the project. Included below is a table summarizing the prices that are considered. Before calculating the income from energy savings, the thermal energy needs for the process have been discounted (energy consumed in heating of digesters).

Table 1. Energy savings

Country	Purchase price of electricity (c€/kWh)	Savings due to substitution natural gas for heating (€/MWh PCI)
Spain	15	59
France	11,5	59
Italy	18,5	80
Germany	15	63
Poland	11,1	60
Ireland	14	67
Sweden	7,5	55

- "Waste management": Calculated if the user has entered a value with a negative sign for any substrate, within the item "Acquisition" (display screen 2). In this case, the tool considers that using the substrate in question supposes income for waste management for the biogas plant.

- "Sale or savings of digestate": It is calculated from the "Selling price of digestate" entered by the user and the total quantity of nitrogen obtained in the digestate.

Expenses. In addition to the data entered by the user, the following results are included relating to annual expenses:

- "Operation and maintenance": Associated to the operation and maintenance of the biogas plant. They are calculated as a percentage of the income due to sale or savings of energy.

- "Staff": Associated with the personnel who operate the biogas plant.

- "Transport and handling of waste": Associated with the loading and unloading of substrates, as well as with the transport of waste or substrates to the biogas plant, in the event that the user has entered for any substrate a value in the item "Distance" (display screen 2). The "Unit handling cost" (cost of loading/unloading of substrates) is modifiable by the user. With regard to the unit cost of transport, the tool considers for each country a specific value and a variable cost according to the distance. Shown below is a summary of the transport costs considered.

Table 2. Transport cost

Country	Base cost of transport (€/km·t)	Distance from biogas plant to farm plots			
		1 to 5 km (€/km·t)	6 to 10 km (€/km·t)	11 to 20 km (€/km·t)	More than 20 km (€/km·t)
Spain	2,00	0,20	0,20	0,20	0,20
France	1,95	0,29	0,29	0,29	0,29
Italy	3,90	0,21	0,36	0,33	0,33
Germany	1,50	0,15	0,13	0,11	0,09
Poland	0,60	0,60	0,15	0,15	0,15
Ireland	1,76	0,11	0,11	0,11	0,11
Sweden	2,27	0,17	0,17	0,17	0,17

- "Cost of waste (co-substrates)": Cost of the actual substrate; they appear in the event that the user has entered for any substrate a value with a positive sign in the item "Acquisition" (display screen 2).

- "Transport of the digestate": Costs associated with the transport of digestate. The tool considers unit costs similar to the transport of substrates.

- "Other expenses": These will appear if the user has entered any value in this item (display screen 5).

- "Days worked per year": The tool provides the work days per year in the biogas plant.

Financial study of the investment project

Includes the data in reference to the financing of the investment as well as various financial indicators.

Financing. According to the percentages entered by the user and the interest rate of the loan, calculation is made of the total subsidy, the equity and the loan that make it possible to finance the investment. The user can see expressed in the same base, what percentage of the investment corresponds to subsidies, equity and loan.

Economic indicators:

- Gross operating profit or earnings before interest, taxes, depreciation and amortization (EBITDA): Corresponds to the difference between income and annual expenses; that is, the cash flow.

- Net present value (NPV): Value of the cash flows expected in the course of the life of the project ("n" years) and updated at the time of the start of the project. The "Discount coefficient" (t) has been used as updating rate. A value with positive sign of NPV implies that the project generates value.

$$NPV = -Investment + \sum_{t=1}^{n} \frac{Cash\,Flows}{(1+t)^n}$$

- Wealth index (NPV/Initial investment) or Profitability Index (PI): It is calculated as the ratio between the NPV and the initial investment (equity plus loan). If this value is greater than zero, it will be indicative of profitability of the investment for the lifetime of the project.

- Internal rate of return (IRR): This is the discount rate with which the NPV is equal to zero. It is used to decide whether or not to accept an investment project.

- Payback period or return period (RP): This is the length of time necessary to recover the initial investment. It is calculated as the ratio between the initial outlay (equity plus loan) and the EBITDA. When the EBITDA has a value with a negative sign or the recovery time is longer than the life of the project, there is no value of "return period" and the user is notified, indicating ">15 years" or another value used as lifetime of the investment project. In the latter case, the investment would not be recovered before the lifetime of the project reaches its end.

$$RP = \frac{(E+D)}{EBITDA}$$

Thus:

E = equity

D = debt or loan

EBITDA = Gross operating profit or earnings before interest, taxes, depreciation and amortization

- Discount coefficient (t) or Weighted Average Cost of Capital (WACC): This is the discount rate used in the tool to update the expected cash flows of the investment project during the lifetime of the project. This coefficient is a weighted average between a cost (the cost of the debt or loan) and a required profitability (Ke). This coefficient is used for the calculation of the NPV and IRR. Included below is the formula for the calculation of the discount coefficient. The subsidy is excluded in this calculation.

$$WACC = Ke \cdot \frac{E}{E+D} + Kd \cdot (1-T) \cdot \frac{D}{E+D}$$

Thus:

Ke = rate of return on equity

Kd = interest rate of the debt or loan

T = tax rate on the earnings. The taxes are included as they carry a fiscal benefit. As the interest of the debt is deductible from the corporate tax, "Kd" must be multiplied by one less the tax rate to take into account the tax savings this carries

E = equity

D = debt or loan

Regarding the calculation of the "Discount coefficient", the user can modify the "Loan interest rate", the "Part or percentage of equity of the investment" and the "Part or percentage of loan". Nevertheless, the user cannot modify the following data which influence the calculation of the "Discount coefficient" and which have been fixed to simplify the use of the tool:

Return rate on equity (Ke): 12 %

Tax rate (T): 30%

- Capital recovery coefficient or Capital Recovery Factor (CRF): This is the discount coefficient updated to the lifetime of the project ("n" being the years of lifetime of the investment). Included below is the formula for its calculation.

$$Ka = \frac{t \cdot (1+t)^n}{(1+t)^n - 1}$$

Analysis of environmental viability

The following parameters are included:

- Primary energy obtained from the recovery of the biogas: This is the renewable energy from the recovered biogas in form of heat, electricity or biomethane, according to the scenario selected. Not included in this primary energy is the energy used for heating of digesters.

- Savings of CO_2 emissions: This is calculated from the primary energy obtained and an emissions savings factor, a factor of 278 gCO_2/kWh.

- Savings in artificial fertilizers: The value included is the content in total annual nitrogen in the digestate produced. It is considered that this is the potential savings in total nitrogen that could replace nitrogen from non-renewable sources.

- Utilization of the digestate in area that is "Vulnerable" or "Non-vulnerable" to contamination by nitrates from agricultural sources. According to the selection made by the user, one indication or another will appear in the report.

- Cultivation area required for application of digestate: Hectares of agricultural plots required to utilize the nitrogen of the digestate, obtained after the production of biogas, in the fertilization of crops (cereals, maize, etc.).

Overview.

This includes graphs for each scenario on the total "Investment" of the project, the "Investment Payback period", the "$CO_{2\text{-eq}}$ emission savings" and the "Self-consumed energy (needs of energy/production from biogas)". The latter, in the event that the user has selected as a scenario "self-consumption" of the energy produced from the biogas. The different scenarios of use of the biogas (boiler, cogeneration, etc.) are indicated in the axis of ordinates as "Use".

If the "Payback period" is longer than the lifetime of the project, the graph provided will appear empty. Moreover, the graph "Self-consumed energy" will appear empty if self-consumption of the energy produced is not carried out in any scenario selected by the user.

To differentiate the percentages of self-consumed energy, either electric or thermal, in the graph corresponding to "Self-consumed energy" the following abbreviations appear:

e=electric energy

t=thermal energy

2.2. Summary of substrates

The summary of substrates entered by the user in the study in question and the composition of the final mixture put into the digester makes up the second pdf document that accompanies each study.

In particular, the properties and data included for each substrate are as follows:

- Quantity (t/year): Tonnes of fresh material of the substrate put into the digester.

- Cost (€/year): Cost of the actual substrate per unit of mass (tons fresh material). A value with a negative sign indicates that acquiring the material supposes income for the biogas plant.

- Distance (km): Distance between the location of the substrate and the biogas plant.

- MS (%): Percentage of dry material as compared to the fresh material of the substrate.

- OM/DM (%): Percentage of organic material as compared to the dry material of the substrate.

- DOM/OM (%): Percentage of organic material that is degraded in the production of biogas as compared to the initial organic material of the substrate.

- CH_4/OM (m^3CH_4/t_{OM}): Methane production potential of the substrate per unit of mass (tonnes of organic material) of the substrate.

- CH_4 (%): Percentage of methane in the biogas produced from the substrate.

- N (kgN/t): Total nitrogen content of the substrate per unit of mass (tonnes of fresh material).

- C/N ratio (-): Carbon-nitrogen ration of the substrate.

- $N-NH_4^+$ (kgN/t): Content in ammoniacal nitrogen of the substrate per unit of mass (tonnes of fresh material).

The calculation of the total C/N ratio in the mixture is obtained from the total quantity of organic material processed and an estimate is made of the carbon contained in the mixture. Subsequently, with this data of carbon of the mixture and the total content of nitrogen of the mixture, the C/N ratio is obtained.