DANTES

DEMONSTRATE AND ASSESS NEW TOOLS FOR ENVIRONMENTAL SUSTAINABILITY

LCC/LCA Tools

Dry fermentation.xls

- for dry fermentation to biogas

A biogas plant with 10 parallel fermenters

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ABSTRACT

This report was made within the project DANTES that is supported by the EU Life Environment Program.

This Dantes report is one in a series of five describing the LCC tools developed by ABB. The others Dantes reports are:

- DANTES - Wet fermentation.doc
- DANTES -LCP tool AX1.doc
- DANTES - LCC-LCA Battery.doc
- DANTES - Transformer.doc

A summary of the experience of developing these tools is presented in the Dantes report

- DANTES LCC-LCA tools.doc

The aim of this report is to describe the “Dry fermentation.xls” tool. The purpose of this excel tool is to allow designers to evaluate the cost and environmental impact of a potential biogas plant designs and do parameter studies. The evaluation results can be used for design optimization, in market communication and sales support, showing the advantages of dry fermentation.

The scope of the tool is to calculate the cash flow of the plant and evaluate the environmental impact of: different materials in the plant, emitted CO_2, saving of resources (natural gas, replacement of fertilizer) and use of electricity.

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1. INTRODUCTION

This report was made within the project DANTES that is supported by the EU Life Environment Program.

The scope of this report is to describe the LCC/LCA tool “Dry fermentation.xls”. The purpose of the LCC/LCA tool “Dry fermentation.xls” is to allow designers to evaluate the costs and environmental impact of a potential biogas plant designs and do parameter studies. The evaluation results can be used for design optimization, in market communication and sales support, showing the advantages of dry fermentation.

The intended users of this report are anyone interested in the LCC/LCA tool or the problem area of lifecycle cost calculation for plants or the problem area of biogas generation.

2. “DRY FERMENTATION” TOOL

The scope of the tool is to try to calculate the cash flow of the plant and to evaluate the environmental impact of; different materials in the plant, emitted CO2, saving of resources (natural gas, replacement of fertilizer) and use of electricity.

When the tool was developed it was expected that the inputs and the outputs would be mostly obvious to a user familiar with the dry fermentation process therefore the description of the fermentation process is minimal.

The pages (worksheets) are generally write-protected and only the yellow input fields, radio buttons and pull-down menus accept changes. The protection of pages can be removed by selecting “Protection” in the “Tools” menu in excel. The protection is only there to prevent accidental changes to functions in cells.

The plant is used for biological anaerobic digestion of organic material and it allows the energy recovery of solid organic waste, as opposed to throwing the waste in a landfill.

3. DESCRIPTION OF WORKSHEETS IN THE EXCEL TOOL

Below follows a brief description of the inputs and the results that are presented in different tabs.

3.1 Sheet: Summary

A one-page summary all plant data that have been entered to get a one-page overview of the plant data.

3.2 Sheet: Dry fermentation

The sheet presents an overall plant description and flowchart. Expected inputs by the user are: feed volume, ODS (organic dry substance) content and number and volume of the fermenters in the plant. Other expected inputs are the methane content of the produced biogas and the operating time of the plant. The operating time will be used for calculating the lifecycle environmental impact and the total cash flow. The resulting biogas and methane flow is also shown.

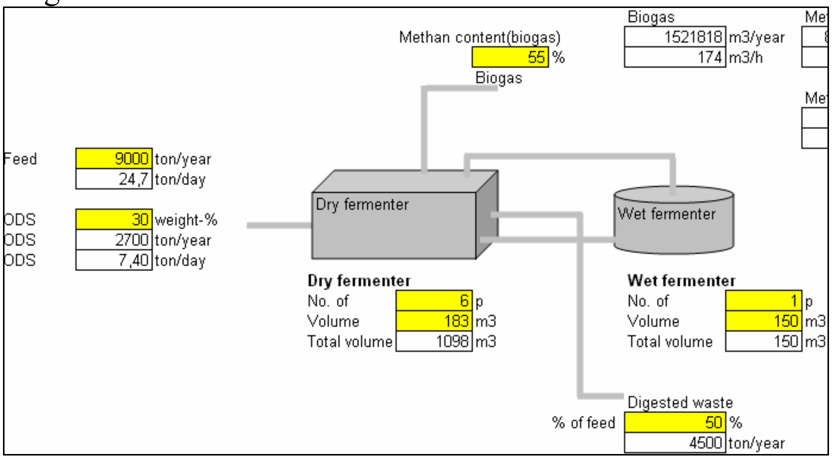

Figure 1 Flowchart of dry biogas plant

3.3 Sheet: Fermenter data

This tab allows the user to define the geometry, size and building material of fermenters. The input is used for calculating the material content of the fermenters. The resulting weights of the fermenters are shown.

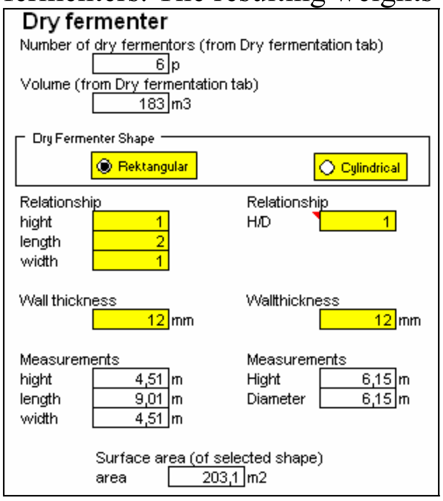

Figure 2 Part of the “Fermenter data” worksheet

3.4 Sheet: Other process parts

Expected inputs are data describing the piping, motors and pumps used in the plant. The user can also enter the material content of other process parts that are not included under the piping, motors and pump headlines. The material weights of process parts are displayed.

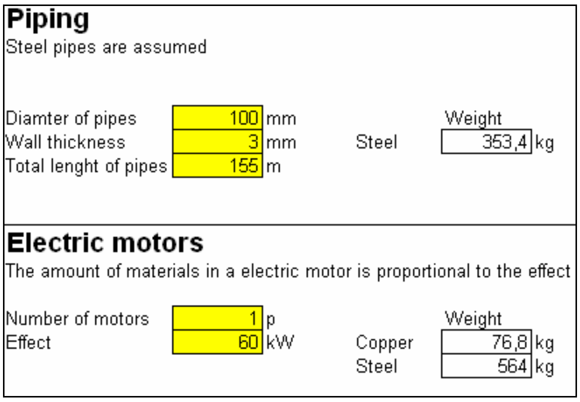

Figure 3 Part of the "other process parts" worksheet

3.5 Sheet: Operation data

The user can define how the cycle time (and batch size) of the plant should be calculated. There are two options: density of feed in a fermenter and cycle time of a batch.
If the density is given, the loading (weight of feed) in the fermenter can be calculated. With the yearly feed volume, the number of batches and thus the cycle time can be calculated.

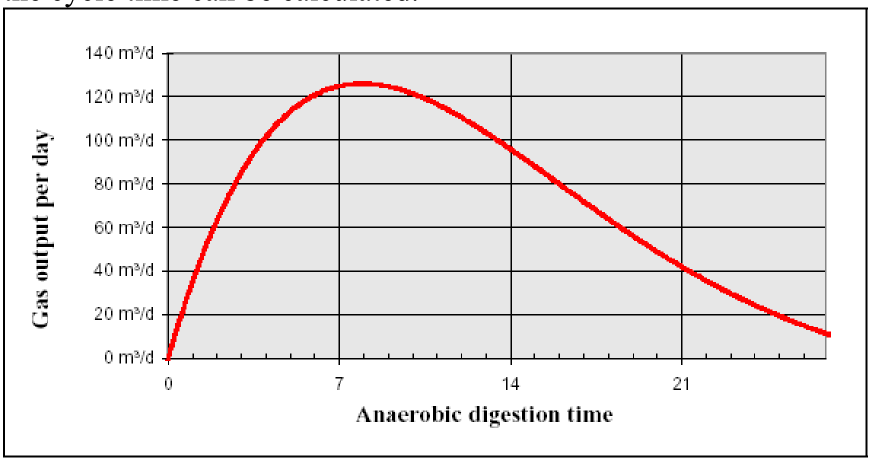

Figure 4 Time resolved biogas output from a biogas plant

If the cycle time is given, the number of batches required to process the yearly feed volume and the weight of batches can be calculated.
The data for calculating the output of biogas can be given in four different ways:

- m3 methane/ton ODS (organic dry substance)
- m3 methane/m3 fermenter
- m3 Biogas/ton feed
- m3 Biogas/ton feed (based on the cycle time and the time resolved biogas output data from the Hamburg-Bergendorf plant)

Data for the yearly electricity consumption of the plant can be entered in this tab.

3.6 Sheet: Cost data

Expected inputs in this tab are factors used for the lifecycle cost calculation, such as:

- Capital cost of plant
- Cost of feed material (can be negative if the plant operator gets paid to take care of waste.
- Selling price of biogas or electricity (choose one).
- Value of digested rest material (can possibly be sold as earth improvement material and/or fertilizer)
- Savings of CO2 tax from different European countries.
- Yearly operating cost of the plant

If one assumes that the produced biogas is replacing natural gas, which is penalized with CO2 tax, then the saved CO2 tax should be credited to the plant Biogas is not penalized with CO2 tax

3.7 Sheet Environmental data

In data in this tab are factors for the environmental impact calculation. One can select classification/evaluation methods. The tool includes 5 different methods:

- Global warming potential, GWP
- Acidification potential, AP
- Nutrification potential, NP
- Eco-indicator99
- EPS2000

The first three are classification methods, which summarizes the impact of different emissions to specific environmental problems. The Eco-indicator99 and EPS2000 are evaluation methods, which tries to summarize the impact of emissions and resource consumption on society. The production of electric energy generates emissions (and these emissions are different in different countries) that have to be included in the environmental evaluation of the plant. The user can select the electricity mix that the plant uses (the yearly electricity consumption is set in tab “Operation data”)
The digested waste can be used as soil improvement material and/or can be used to replace mineral fertilizer. This replaced mineral fertilizer can be credited in an environmental evaluation of the plant operation.

3.8 Sheet: Calc

Most of the calculations are done in this tab.

3.9 Sheet: Material

Summary of materials used in the plant

3.10 Sheet: Environmental calc

Environmental data and calculation

3.11 Sheet: Methane prod

Time resolved methane production from a biogas plant. Used to calculate the methane production based on the cycle time of batches (used in the last option in the Biogas production section on the “Operation data” tab)

3.12 Sheet: Electricity

Environmental data of the electricity mix from different countries.

4. BACKGROUND OF CALCULATION

This section contains the most important points and a brief discussion on calculations.

4.1 Plant components

The plant is modeled with only three materials; Steel - as construction material, Concrete - used as construction material and for the plant foundations and Copper - as electrical conductor in motors and other applications. These three materials are assumed to make up most of the plant.
The amount of a material, for example steel, is the sum of the steel content of all different components in the plant.

4.1.1 Fermenters

Fermenters can be rectangular or cylindrical and they can be constructed from either steel or cement. For a rectangular shape the user has to enter the relationship between height, length and width. For a cylindrical shape the user has to enter the relationship between diameter and height.
With the volume of the fermenter and relationships between the sides known the measurements of a fermenter can be calculated.
With the measurements known, the surface area can be calculated and this together with wall thickness and density of the construction material the weight of the fermenter is known.

4.1.2 Motors

Using the relations between output power and materials described in Environmental Product Declaration - AC machine type HXR 355 (http://search.abb.com/library/ABBLibrary.asp?DocumentID=FIEPD_3BFP000013R0101&LanguageCode=en&DocumentPartId=&Action=Launch)
A motor contains 9.4 kg steel/kW output power and 1.28 kg copper /kW output power.

4.1.3 Piping

If the wall thickness, diameter and total length of pipes is known then the amount of steel used in pipes can be calculated.
Steel in pipes = π * diameter * wall thickness * pipe length * density steel

4.1.4 Pumps

It is assumed that the pumps in the plant are constructed of steel. The user can enter the number and weight of pumps in the plant.

Steel in pumps = number of pumps * weight of a pump

4.1.5 Other materials

For components that are not fermenters, motors, pumps and pipes, the total material content of these can be entered in the tab “Other process parts” and the material weights are added to the others.

4.2 Biogas

The production of biogas can be calculated in different ways, depending on what data the user chooses to enter (ODS = organic dry substance):

- Biogas production = (m3 methane/ton ODS) * (ton ODS) / (methane content of biogas)
- Biogas production = (m3 methane/m3 fermenter) * (total fermenter volume) / (methane content of biogas)
- Biogas production = (m3 Biogas/ton feed) * (feed weight)

4.3 Cost

Cost data are summed over the life cycle. No present value calculations of future payments are performed. The sold product from the plant can be either biogas or electricity (produced from biogas).

4.4 Environment

The environmental impacts of material are calculated with pre-evaluated datasets from the ABB database in EcoLab.
As an example, the environmental impact 1 kg of steel is shown in the table below.

Evaluation methods	Impact
AP EPD	0,1444
GWP 100 EPD	2,0905
NP EPD	0,0177
Eco-indicator 99	0,0400
EPS 2000	1,3694

Table 1 Impact of steel according to different evaluation methods

Total impact of steel = total weight of steel * impact (according to selected evaluation method)
For more information on LCA methodology see www.dantes.info

5. AN EXAMPLE

To show the possibilities of the tool, the inputs and the results of an example is described below.

5.1 Inputs

Some of the process data for the example is taken from an ABB internal document. Other data (e.g. cost data) are assumed values to show the results of the tool.

5.1.1 Dry fermentation sheet

Input	**Value**
Feed weight	9000 ton/year
ODS content	30 %
Number of dry fermenters	6
Volume of a dry fermenters	183 m3
Number of wet fermenters	1
Volume of a wet fermenters	150 m3
Methane content of biogas	55 %
Weight of digested waste	50 % (of feed)
Years of operation	10 years

Table 2 Inputs in the "Dry fermentation" sheet

5.1.2 Fermenter data

Input	**Value**
Dry fermenter shape	Rectangular
Relationship; height: length: width	1:2:1
Wall thickness	12 mm
Dry fermenter material	Steel
Wet fermenter shape	Cylindrical
Relationship; height/diameter	0,5
Wall thickness	40 mm
Wet fermenter material	Concrete

Table 3 Inputs in the "Fermenter data" sheet

5.1.3 Other process parts

Input	**Value**
Diameter of pipes	100 mm
Wall thickness of pipes	3 mm
Total length of pipe	155 m
Number of motors	1
Effect of motor	60 kW
Number of pumps	1
Weight of pump	50 kg
Additional steel	10 kg
Additional copper	1 kg
Additional concrete	10 000 kg

Table 4 Inputs in "Other process parts" sheet

5.1.4 Operation data

Input	Value
Batch size calculated from:	Retention time
Retention time	21 days
Biogas production calculated from:	m3 Methane / ton ODS
m3 Methane / ton ODS	310 m3/ton
Yearly use of electricity	1000 kWh

Table 5 Inputs in "Operation data" sheet

5.1.5 Cost data

Input	Value
Capital cost of plant	2 000 000 $
Raw material cost	-10 $ /ton
Sold product	Electricity
Price for electricity	0,06 $/kWh
Value of rest product	10 $/ton
CO2 tax from	Sweden
Operating cost	200 000 $/year
Efficiency in electricity conversion	50 %

Table 6 Inputs in "Cost data" sheet

5.1.6 Environmental data

Input	Value
Evaluation method	Eco-indicator99
Electricity mix used	Germany
Mineral fertilizer replaced by digested waste	0,1 kg mineral fertilizer /kg waste
Mineral fertilizer replaced	TSP fertilizer

Table 7 Inputs in "Environmental data" sheet

5.2 Results

The results presented by the tool from the inputs in previous chapter.

5.2.1 Plant

Material	Value
Total amount of steel	19496 kg
Total amount of copper	77,8 kg
Total amount of concrete	33154 kg

Table 8 The amounts of material in plant as result of inputs

5.2.2 Plant output

Output	Value
Yearly volume of biogas	1 521 818 m3
Yearly volume of methane	837 000 m3
Yearly methane heat value	27605934 MJ or 7666 MWh
Yearly amount of digested waste	4500 kg

Table 9 The outflows from the plant as a result from inputs

5.2.3 Cost data

Total cash flow	Value
Capital cost	-2 000 000 $
Feed material	900 000 $
Electricity	2 299 850 $
Digested waste	450 000 $
Savings in CO2 tax	878 850 $
Total operating cost	-2 000 000 $
Total cash flow (life time)	528 700 $

Table 10 The cash flow from the plant as result from the inputs

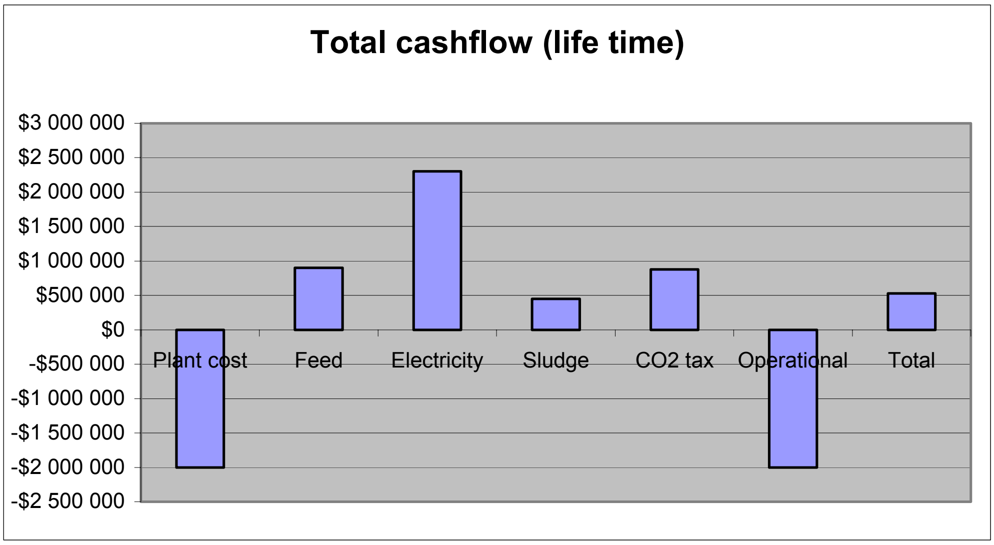

Figure 5. Total cash flow from plant (over 10 year operating time)

5.2.4 Environmental data

Environmental flow	Value
Steel	780
Copper	143
Concrete	97
Total CO2 emissions	163 410
Electric energy consumed	334
Replaced natural gas	-945 597
Replaced fertilizer	-185 085
Total lifecycle impact	-965 918

Table 11 The impact according to the selected evaluation method (Eco-indicator99)

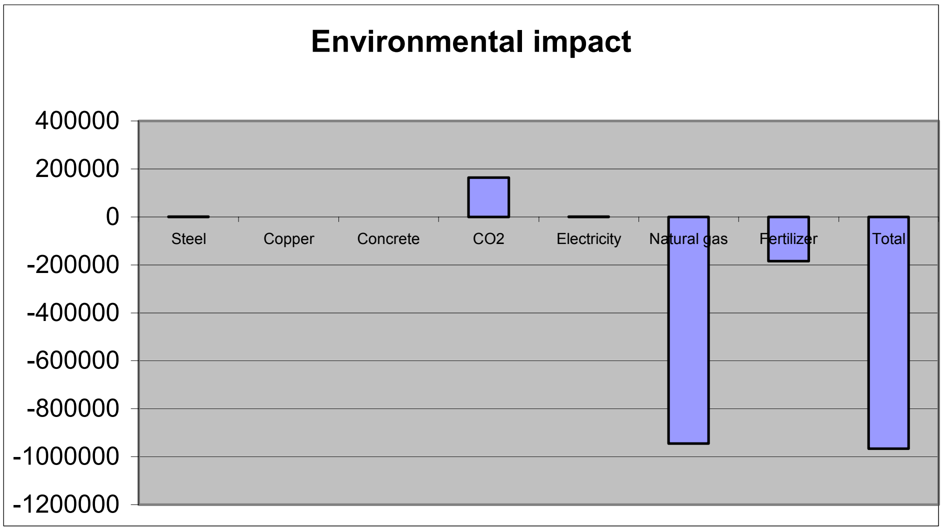

Figure 6 Environmental impacts of the different environmental flows over the life cycle (according to Eco-indicator99)

5.3 Discussion of results

The presented result is only one example and other process designs and biogas production levels will lead to different results.

5.3.1 Cost

With the input data used in the example, the plant shows a profit when the savings in CO_2 tax is included as a profit.

5.3.2 Environmental impact

With the input data used in the example, the environmental impacts of materials and electricity used do not have a significant impact. The replaced natural gas has the largest impact and the total emissions of CO_2 and the replacement of mineral fertilizer seems to be similar.