THE MICROPHILOX PROJECT

ENERGY RECOVERY FROM LANDFILL'S BIOGAS BY THE USE OF **MICRO**TURBINES AND BIOLOGICAL REMOVAL OF HYDROGEN SUL**PHI**DE AND SI**LOX**ANES

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Table of contents

- **Situation previous to the project**
- **Microturbines**
  - Characteristics
  - Technology
  - Microturbines vs CHP units
  - Selected technology
- **Biogas energy recovery installation in Orís**
  - Installation design
  - Operation
- **Environmental Economic Analysis**
  - Objectives
  - Methodology
  - Results
- **Conclusions**

Table of contents

Orís landfill

Situation previous to the project

- **Landfill managed by CESPA and owned by Consell Comarcal d'Osona.**
- **Gives service to 175.000 people and receives 50.000 $t_{urban\ waste}$/year.**
- **Biogas generation data (in 2005):**
  - Q_{biogas}= 80 m³/h
  - 40% CH_4
- **Biogas was being flared**
- **Power consumption: leachate plant**

Microturbines are a suitable option for biogas recovery

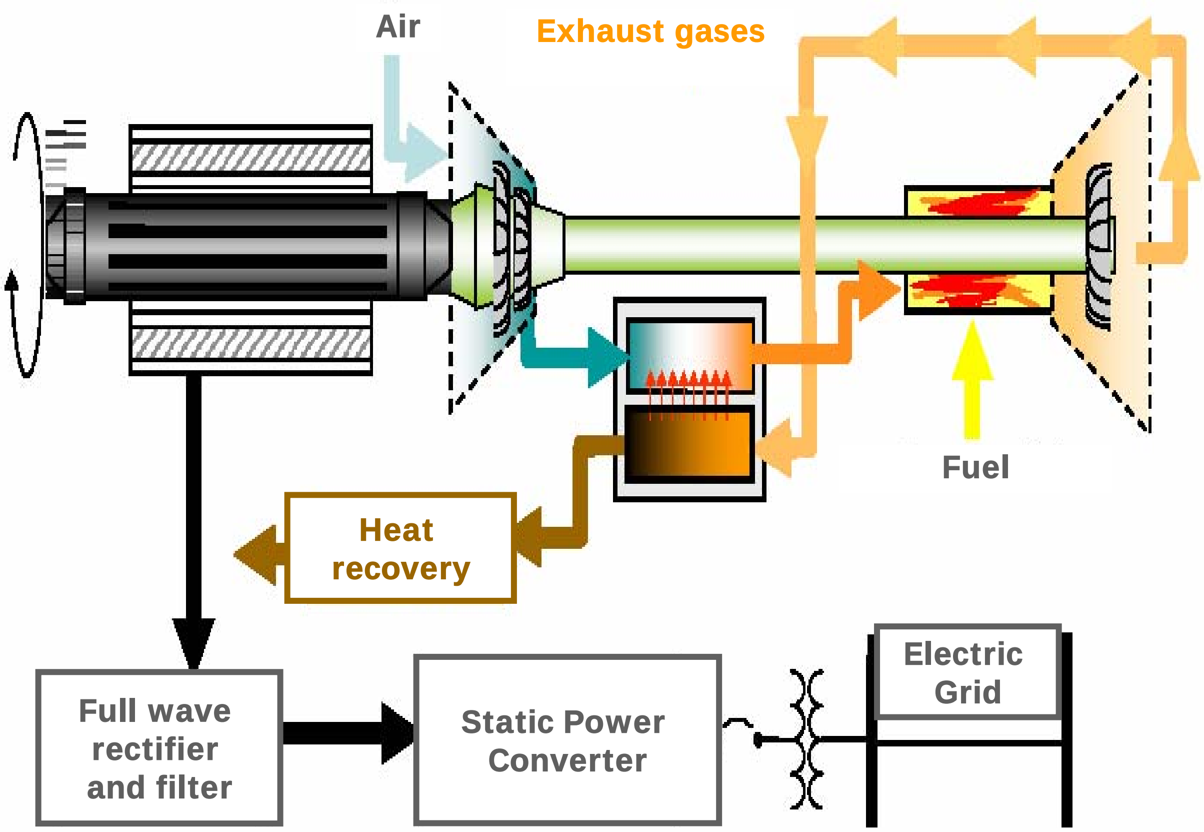
Table of contents

Microturbines

Characteristics

- Modular equipment from 30 kW-200 kW, that can be connected in series
- Able to operate with low heating value fuels
- Able to operate with acid gases
- Only one moving part
- Air bearing
- Low NOx and CO_2 emissions
- Process efficiency can be improved by using exhaust gases energy

Microturbines
Technology



Microturbines

Microturbine vs CHP units

	1 MW CHP	30 kW MICROTURBINE
ELECTRIC EFFICIENCY	38%	26%
THERMAL EFFICIENCY	40%	57%
Min. CH_4 CONCENTRATION	40%	35%
MAINTENANCE	High requirement due to mobile parts	Low requierement. Only one moving part
BEARINGS	Oil	Air. No lubricants
ECONOMIC VIABILITY	> 600 kW	30-800 kW

Microturbines

Selected technology

CAPSTONE C30 microturbine™	
Power:	30 kWe
Electrical efficiency:	26±2 %
Exhaust energy:	327.000 kJ/h
Exhaust temperature:	275^{0}C
Min. CH_4 content:	35%
Max. H_2S content:	70.000 ppm
Max. Siloxane content	5 ppb

Capstone dealer in Spain: Micropower Europe

Table of contents

Biogas recovery
Installation design

- **Design parameters:**

	Orís Biogas		Capstone limits
Q	80 m³/h		
$[CH_4]$	40%		
$[H_2S]$	12,9 ppm	<	70.000 ppm
[Siloxanos]	3 ppm	>	5 ppb

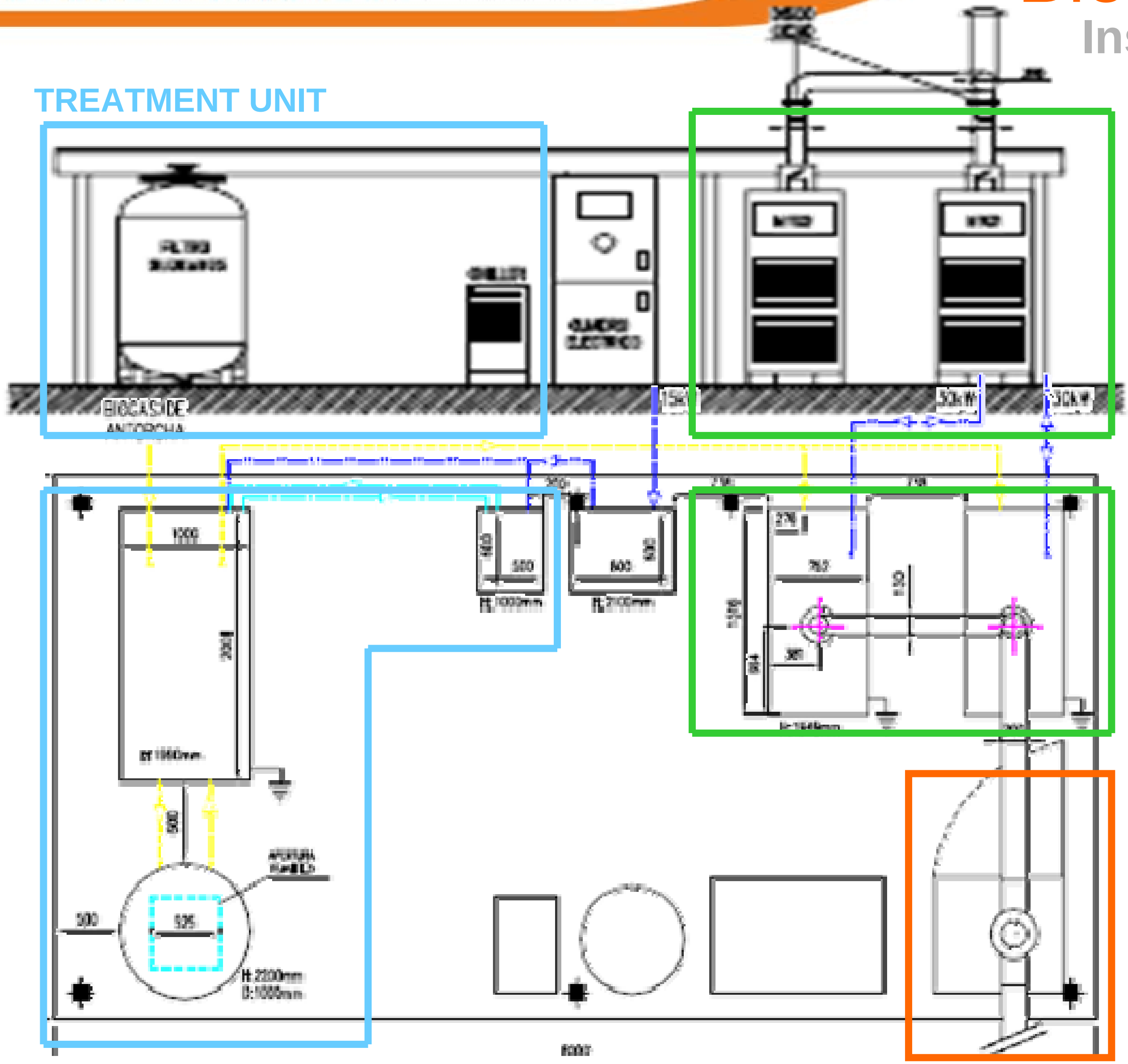
→ **2x 30 kWe Capstone C30**
Q = 60 Nm³/h

→ **Activated Carbon filter**

- **Energy recovery installation**

- Biogas degasification plant
- Treatment Unit
- Microturbines
- Heat recovery from exhaust gases application
- Autoconsumption of generated power

Biogas recovery
Installation design



Phase I. Installation of the 1st microturbine: **21st February 2006**

Phase II. Installation of the 2nd microturbine: **3rd October 2007**

Biogas recovery

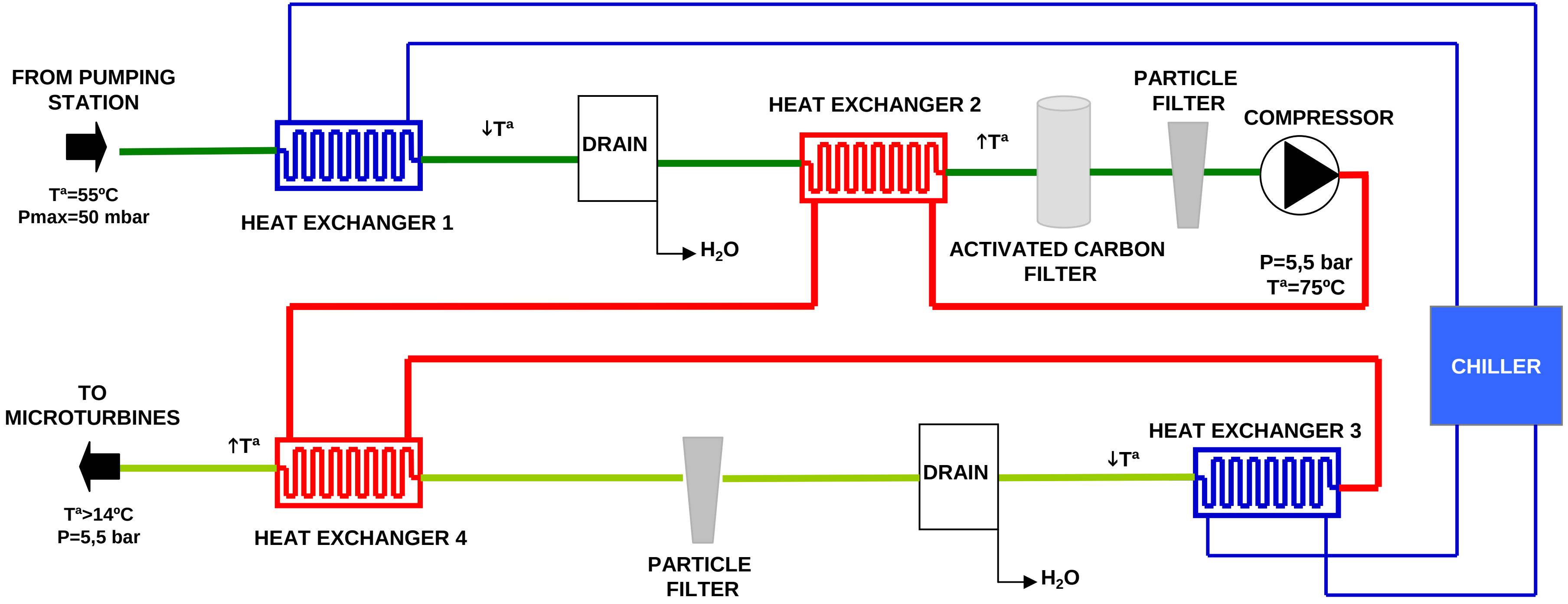
Operation

BIOGAS PUMPING AND CONDITIONING

Biogas recovery

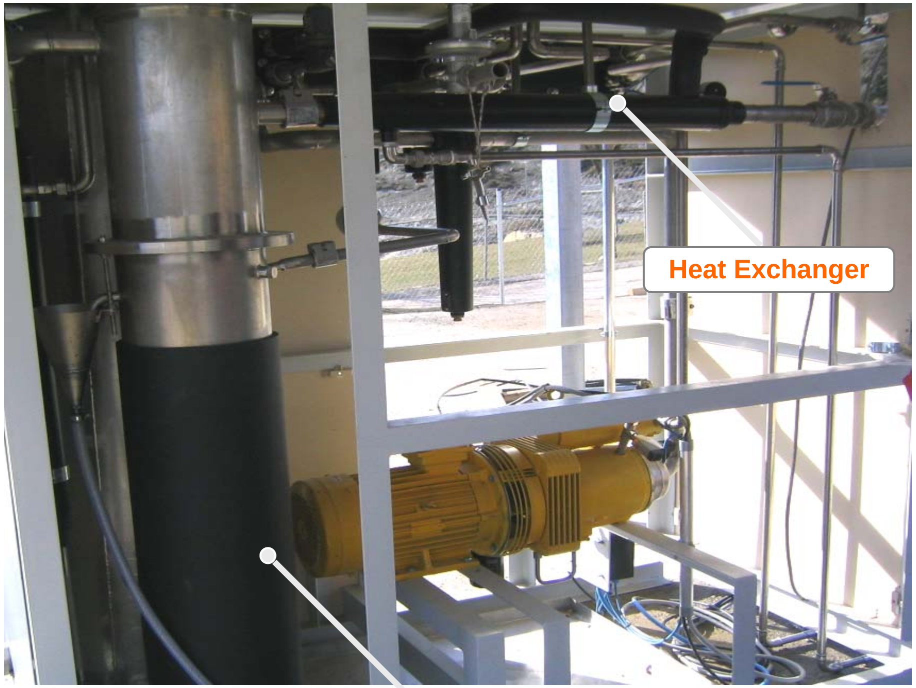
Operation

TREATMENT UNIT



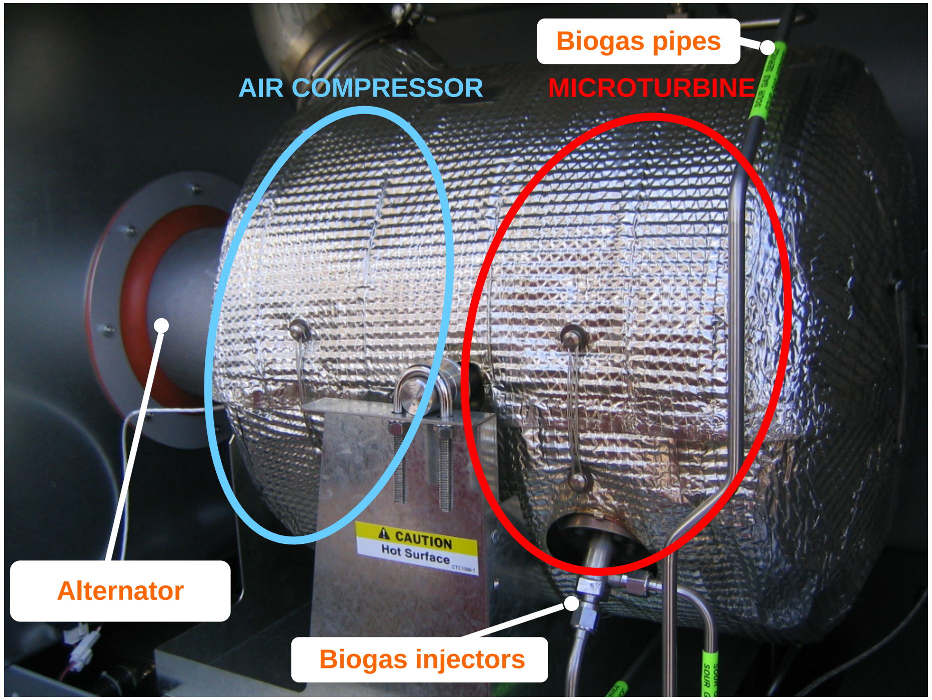
Biogas recovery
Operation

TREATMENT UNIT



Biogas recovery
Operation

MICROTURBINES



Biogas recovery

Operation

HEAT RECOVERY

- Use of microturbine exhaust gases in a landfill thermal drying process

LIFE 2003

CLONIC PROJECT

CLOSING THE NITROGEN CYCLE FROM URBAN LANDFILL LEACHATE BY BIOLOGICAL NITROGEN REMOVAL OVER NITRITE AND THERMAL TREATMENT

Biogas recovery

Operation

OPERATION INCIDENTS

INCIDENTS	ADJUSTMENTS
Over pressure in the Treatment Unit.	Pressure regulator limit valve.

TREATMENT UNIT

INCIDENTS	ADJUSTMENTS
Increase of siloxane content in biogas	Increase of activated carbon replacement frequency. Installation of a bigger filter
Methane content in biogas decreased previous connection of a new cell	Increase of engine compressor power
High Tª. Chiller couldn't achieve designed efficiency	Increase of chiller power

Biogas recovery

Operation

OPERATION INCIDENTS

INCIDENTS	ADJUSTMENTS

PLANT AUTOMATION

- **Water drops in the microturbine biogas line**
- **When microturbine stops, compressor and chiller continue working.**

- **Detection of chiller outlet Tª**
- **Automatic stop of all devices**

INSTRUMENTATION AND PLC

- **Decrease of cosφ**

- **Filter capacitor banks**

Biogas recovery

Operation

OPERATIONAL PARAMETERS OF MICROTURBINES (2 X 30 kWe)	
Availability Microturbine 1:	90%
Availability Microturbine 2:	89%
Average generated power:	26 kW
Min. CH_4 worked with:	31%
Maintenance costs:	0,029 €/kWh

1 MW CHP Unit	
Availability :	90%
Min. CH_4 worked with:	40%
Maintenance costs:	0,027 €/kWh

Biogas recovery

Operation

BIOGAS FOLLOW-UP

- 12 biogas analysis during the whole project period (Task B and G)

AVERAGE BIOGAS COMPOSITION		
CH_4:	%vol	46,30
CO_2	%vol	35,25
O_2:	%vol	2,80
NH_3:	mg/Nm³	3,70
H_2S:	mg/Nm³	18,33
Temperature:	ºC	47,50
Trimethylsilanol	mg/Nm³	9,14
Hexamethyldisiloxane (M2)	mg/Nm³	0,91
Hexamethylcyclotrisiloxane (D3)	mg/Nm³	0,26
Octamethyltrisiloxane (MDM)	mg/Nm³	0,02
Octamethylcyclotetrasiloxane (D4)	mg/Nm³	5,5
Decamethyltetrasiloxane (MD2M)	mg/Nm³	0,00
Decamethylcyclopentasiloxane (D5)	mg/Nm³	1,48
Dodecamethylcyclohexasiloxane (D6)	mg/Nm³	0,06
Σorg Si compounds (siloxanes)	**mg/Nm³**	**17,19**

- Siloxane content in biogas always over manufacturer limit (5 ppb)
- 4,8 times initial siloxane concentration

Increase activated carbon filter size

Biogas recovery

Operation

EXHAUST GASES FOLLOW-UP

- 12 exhaust gas analysis during the whole project period (Task B and G)

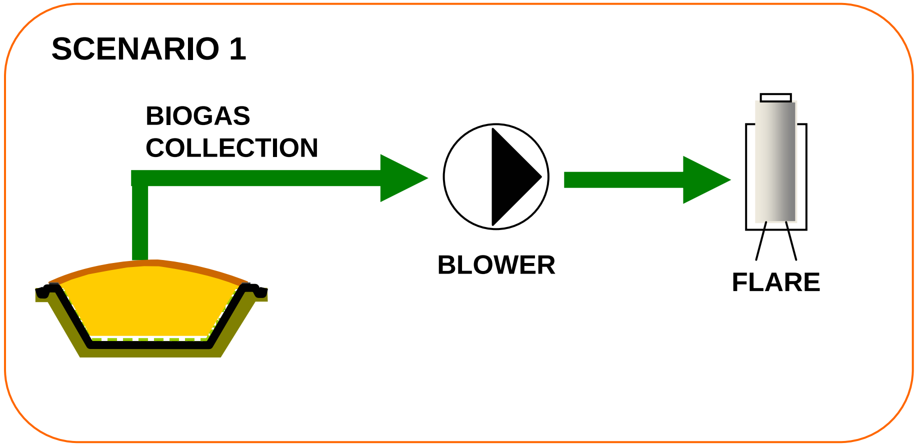
AVERAGE MICROTURBINE EXHAUST GASES COMPOSITION

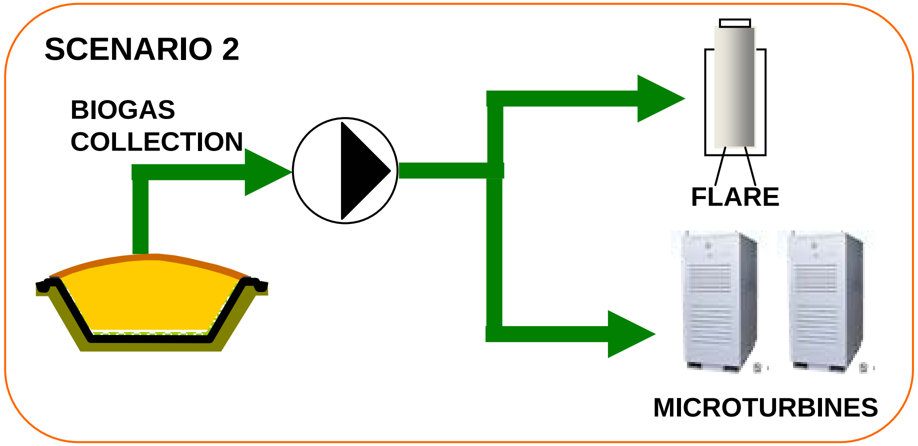
	CO (mg/Nm³)			NOx (mg/Nm³)			SO_2 (mg/Nm³)		
	Real	5% O_2	15% O_2	Real	5% O_2	15% O_2	Real	5% O_2	15% O_2
Microturbine 1	994	5.618	2.096	9	51	19	159	944	352
Microturbine 2	**228**	**1.139**	**425**	**21**	**104**	**39**	**50**	**253**	**95**
Average Exhaust gases for < 1MW CHP unit	**936**			**578**			**0**		
RD 319/1998 (Turbines, Natural gas, 1 to 50 MWe)			**100**			**450**			**300**
TA LUFT (Biogas, SI engines, < 3MW)		**1.000**			**500**			**350**	

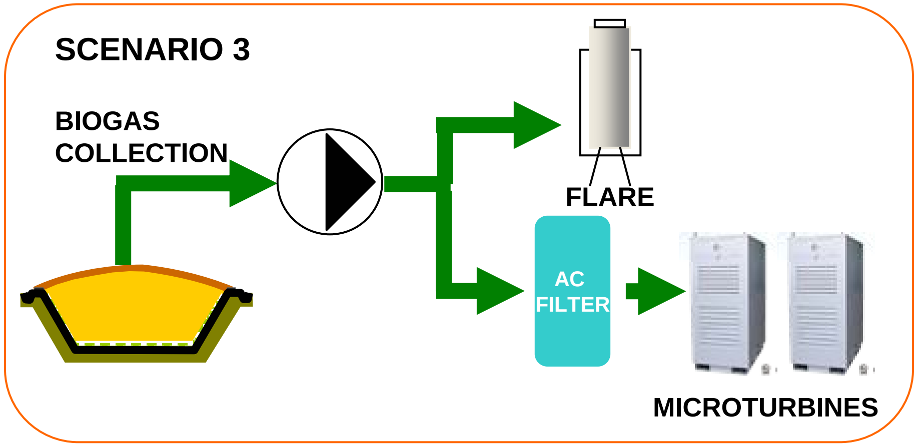
Table of contents

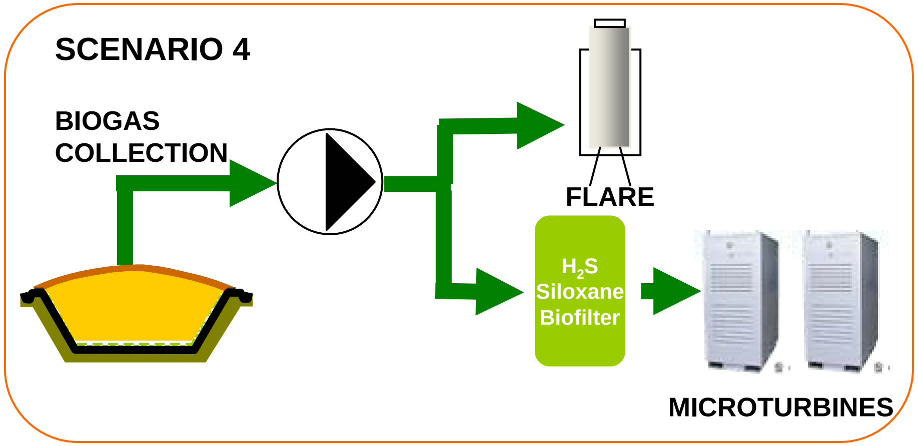
EEA
Objectives

To assess technical, economic and environmental quality of biogas management in Orís landfill for different scenarios









COST-BENEFIT ANALYSIS

Maximization of the difference between the income and the costs associated to the biogas management system:

- Private Impacts: costs and revenues
- External Impacts: costs and revenues

Considered impacts:

- Infrastructure: investment, maintenance costs and power generation savings
- Opportunity costs: value of the best alternative forgone
- Pollution from biogas: related to the combustion of biogas
- Highly hazardous gas emissions: direct CH_4 emissions

EEA
Results

	SCENARIO 1 (Flaring)	SCENARIO 2 (No treatment)	SCENARIO 3 (AC filter)	SCENARIO 4 (Biofilter)
	Balance (€/year)	Balance (€/year)	Balance (€/year)	Balance (€/year)
Economical costs	-45.184	-21.216	-7.379	-21.117
Environmental costs	33.591	33.591	33.592	33.592
	-11.593 €/year	12.375 €/year	26.213 €/year	12.475 €/year
Avoided emissions due to fossil fuels*	--	101 teqCO_2/year	135 teqCO_2/year	135 teqCO_2/year

*Source: Observatorio eléctrico 2008 WWWF/Adena

EEA
Production costs

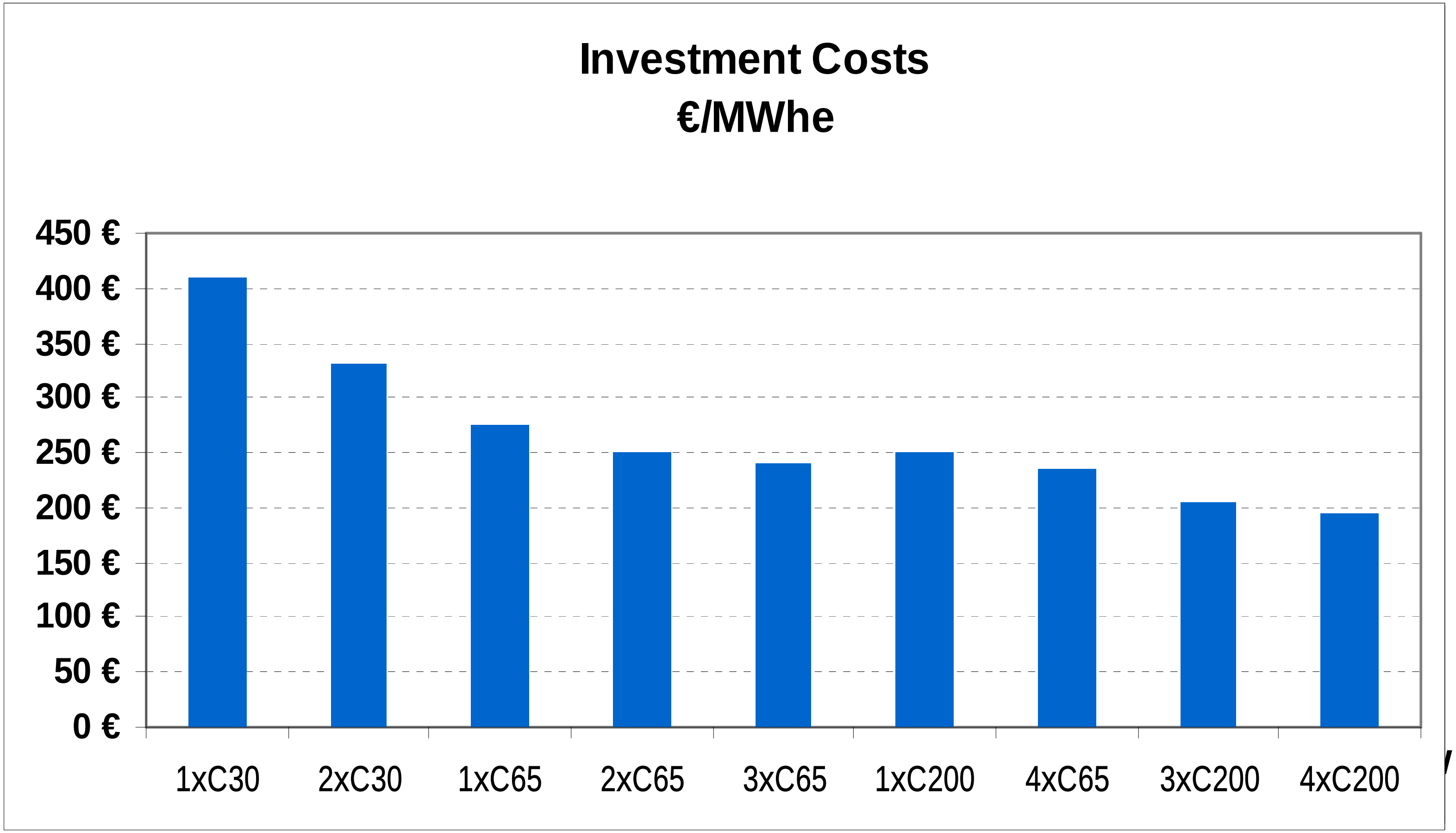


Table of contents

Conclusions

- **Microturbines are a technically feasible for power generation with landfill biogas.**
- **Biogas upgrading is a key point for the correct microturbine operation as well as for the economical viability of the plant**
- **Microturbines are able to work with biogas with very low methane content (31%)**
- **Microturbines have low exhaust gases emissions compared to CHP units**
- **Regarding environmental-economical impacts, recovering biogas for power generation with previous biogas upgrading is the best choice .**
- **Adjustments in investment and maintenance costs can turn a negative economical balance into positive.**

THANK YOU FOR YOUR ATTENTION