



Life cycle assessment of a biogas plant with biomethane as vehicle fuel and injected into the natural gas grid by CO₂ capture and storage technology

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Ángel M. Gutiérrez¹, A. Ortiz¹, J.R. Arraibi¹, V. Laura Barrio², I. García²,
M. Acosta³, G. Benito³, I. Díaz⁴, A. Domínguez⁴, M. Díaz⁴

¹ EDP Naturgas Energía, Spain, angel.gutierrez@edpenergia.es

² Bilbao School of Engineering, Spain, laura.barrio@ehu.es

³ IK Ingeniería, Spain

⁴ Biogas Fuel Cell, Spain

The following work is a task of the LIFE+ European project named **BIOGRID** developed with the economic backing of the European Commission:

“Biogas injection into natural gas grid and use as vehicle fuel by upgrading it with a novel CO2 capture and storage technology”

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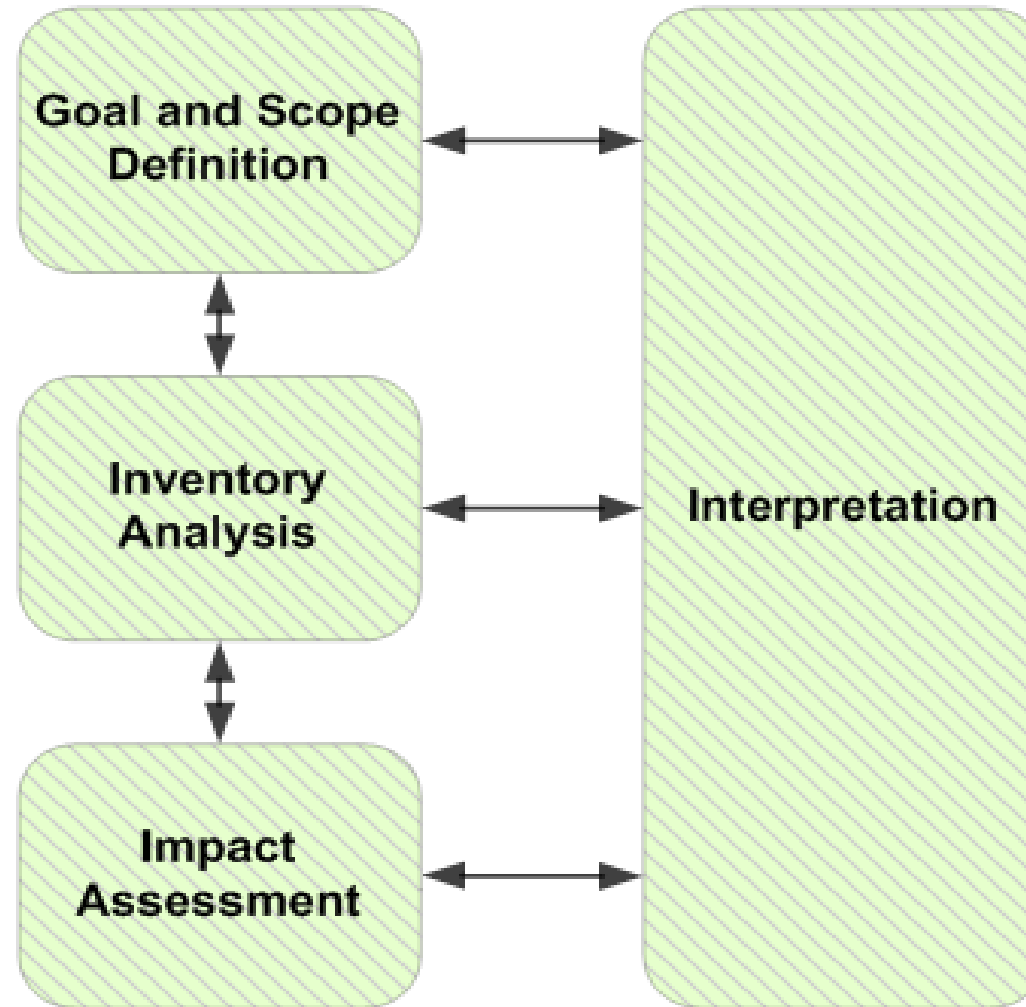
www.lifebiogrid.eu

There will be 1 LCA:

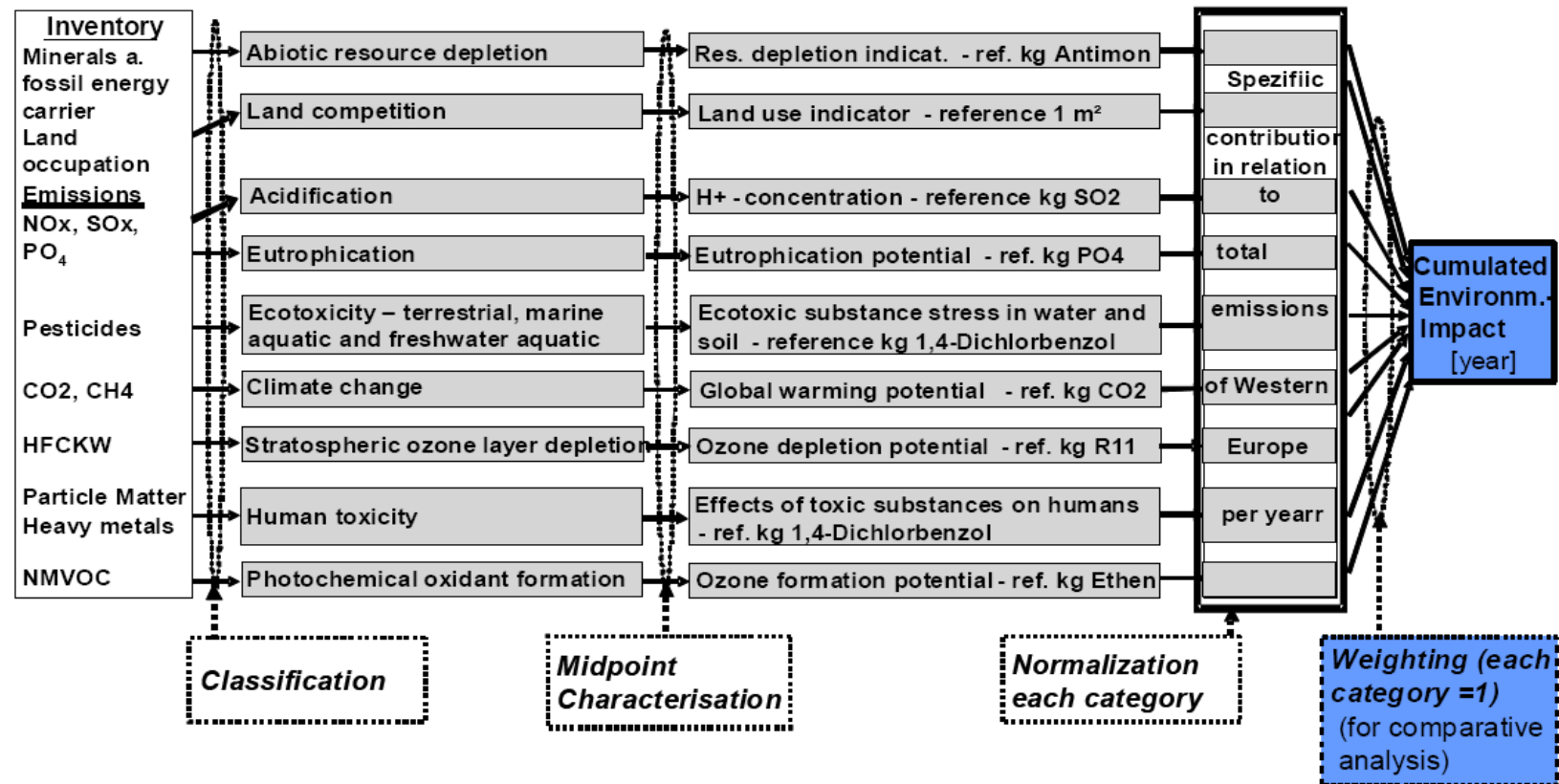
- Injection of biomethane into the Spanish distribution natural gas grid

Following the international regulations:

- ISO14040:2006. Environmental management. Life Cycle Assessment. Principals and framework
- ISO 14044:2006. Environmental management. Life Cycle Assessment. Requirements and guidelines



- **CML 2001: defines midpoint categories according to themes**
 - Data base: Ecoinvent 2.2



CATEGORIES CHOSEN

CATEGORY	REFERENCE
Global warming potential (Carbon footprint)	kg CO ₂
Ozone layer depletion	kg CFC11
Water acidification	kg SO ₂ eq. or mol H ⁺
Water eutrophication	kg PO ₄ ³⁻ or kg O ₂
Tropospheric ozone formation/Smog	kg C ₂ H ₄

- **RECIPE (2010): an update of the Eco-Indicator 99 with an endpoint approach**
 - It transforms the long list of Life Cycle Inventory results into a limited number of environmental indicator scores
 - Indicator levels:
 - **Eighteen robust midpoints, but not easy to interpret**
 - **Three easy to understand, but more uncertain, endpoints**
 - Damage to Human health
 - Damage to ecosystems
 - Damage to resource availability
 - **A single value score that represents the overall impact of the selected Life Cycle**

Life Cycle Assessment of 320 Nm³ of biomethane injection into natural gas grid



- **Goals:**

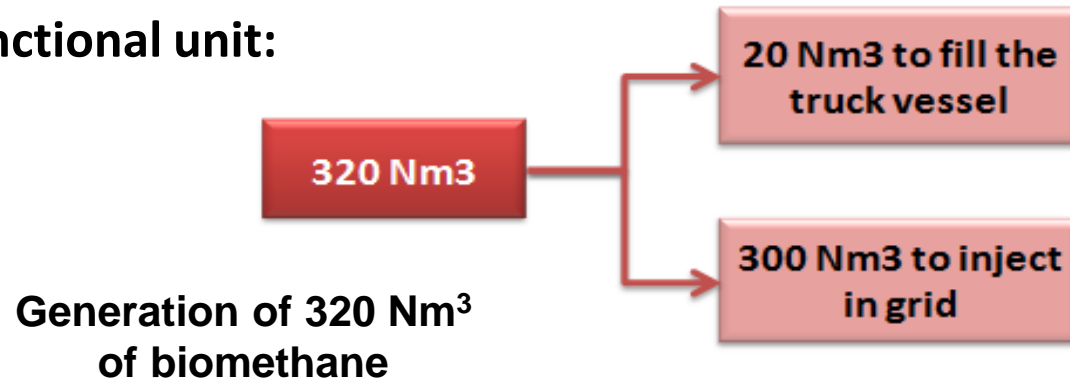
- To calculate the environmental impact associated with Biomethane and its injection in the natural gas grid from PURINES ALMAZAN biogas production plant.
- To demonstrate using the LCA method the carbon-negative-bioenergy concept, which consists in the combination of biogas production plant with two carbon capture and storage (CCS) prototype systems.

- **Scope:**

- Biomethane is a naturally occurring gas which is produced by the so-called anaerobic digestion of organic matter. The upgrading of the biogas resulted from anaerobic digestion produces a very high quality biomethane with different type of applications. In this study the biomethane injection in the grid has been considered.

	CH ₄	CO ₂	N ₂	CO	O ₂
Biogas	66.89%	31.37%	1.46%	0.01%	0.01%
Biomethane 1	92.0%	7.0%	1.0%	---	---
Biomethane 2	95.0%	4.0%	1.0%	---	---
Biomethane 3	96.5%	2.5%	1.0%	---	---

■ Definition of the functional unit:

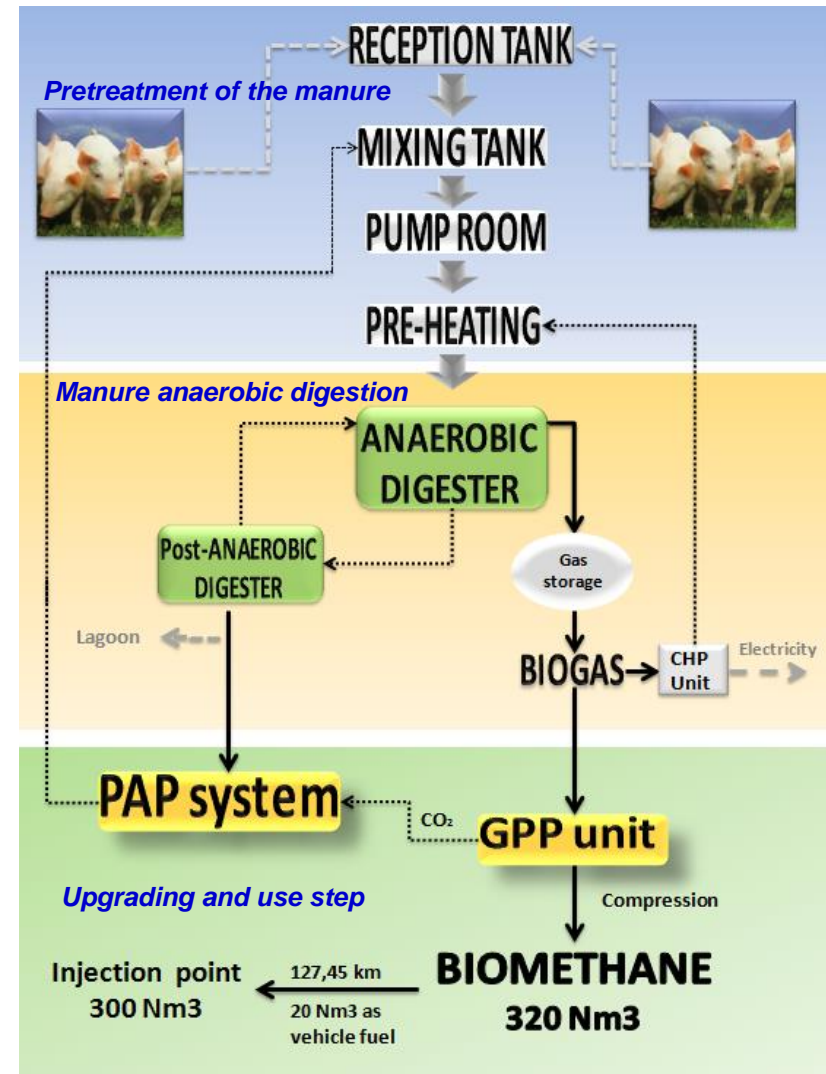


■ Data quality indicators:

Data quality indicator	Parameter
Time of period	The life cycle inventory (LCI) is made for daily average (based in annual data)
Geography	Almazan Biogas production plant
Type of representativeness	Mixed data, data from specific processes, average data from specific process with similar outputs and theoretical calculations has been used and done. Primary data are collected from Purines Almazan plant. Ecoinvent database has been used for generic data and environmental impact data.
System boundaries	Cradle to grave analysis with options (refer to “system limits” for detailed explanation)

■ System boundaries

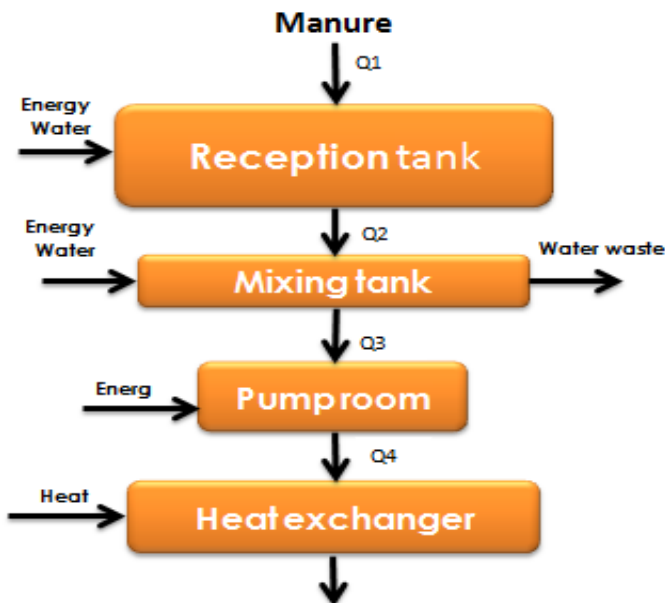
- Transport of the manure to the biogas production plant.
- Material and energy consumption of Pre-treatment (reception tank, mixing tank, pump room and pre-heating) and the digestion process of the manure.
- Material and energy consumption upgrading the biogas obtained from The Gastreatment Power Package (GPP system) and Pilot Algae plant (PAP system)
- Biomethane storage at biogas production plant
- Use stage of the biomethane as biofuel including its combustion emissions.
- Heat production in the CHP unit (recirculated to pre-heating in close loop).
- CO₂ captured by the manure.



LIFE CYCLE INVENTORY

■ Pretreatment of the manure

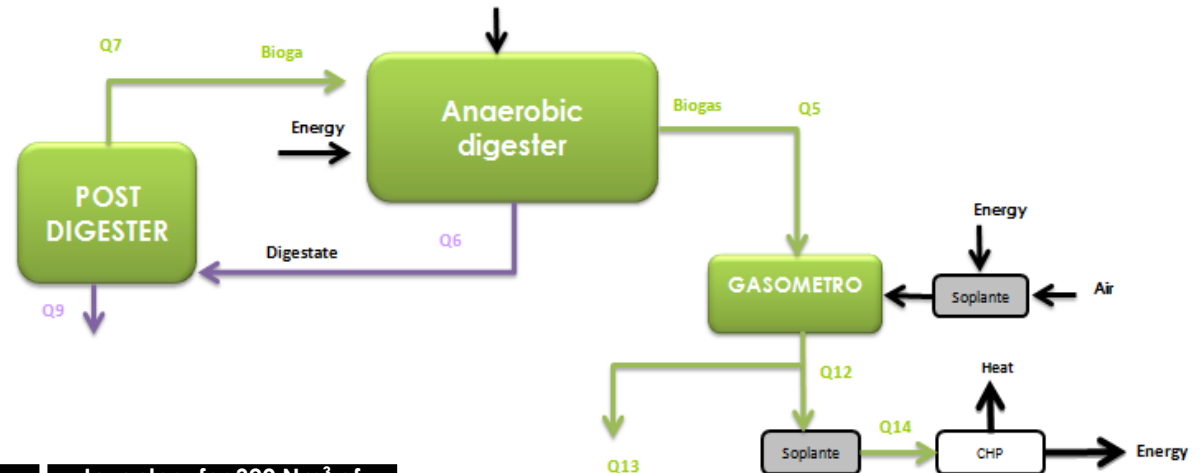
Characteristic	Data	Source
Pork manure dairy flow	120 m ³ /day	Purines Almazan
Manure origin	150 km	Purines Almazan
kg CO ₂ fixed/m ³ biogas	1.9648	Alvarez et al., 2010
Manure density (kg/m ³)	965	Purines Almazan



Reception tank			Inventory for 320 Nm ³ of biomethane	
Item	Dairy data consumption	Unit	Data	Unit
Input				
Motor consumption	66	kWh	20.0	kWh
Pump consumption	16.5	kWh	5.0	kWh
Manure	120	m ³	36.4	m ³
CO ₂ captured	3065.1	kg of CO ₂	929.9	kg of CO ₂
Manure transport	17370	t·km	5269.5	t·km
Water	463.2	m ³	140.5	m ³
Output				
Waste water	463.2	m ³	140.5	m ³
Manure	120	m ³	36.4	m ³

LIFE CYCLE INVENTORY

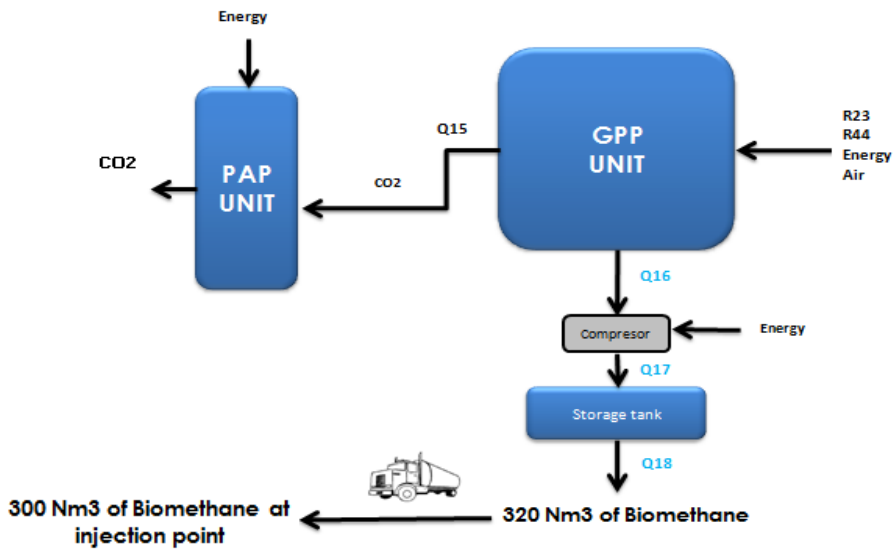
Manure anaerobic digestion



Digester			Inventory for 320 Nm ³ of biomethane	
Item	Dairy data consumption	Unit	Data	Unit
Input				
Manure	120.0	m3	36.4	m3
Digester agitator	180.0	kWh	54.6	kWh
Post digester fan	148.0	kWh	44.9	kWh
Air fan	18.0	kWh	5.5	kWh
Biogas fan	24.0	kWh	7.3	kWh
Air flow	24000.0	m3	7280.9	m3
Condensate wells	6.67E-04	kWh	2.1E-04	kWh
Output				
Biogas	1560	m ³	473.3	m ³
Digestate	120	m ³	---	---

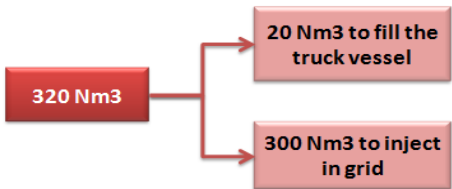
LIFE CYCLE INVENTORY

Upgrading and use step



Upgrading			Inventory for 320 Nm³ of biomethane	
Item	Dairy data consumption	Unit	Data	Unit
GPP				
Input				
Biogas flow	249.6	m³	473.3	m³
Electricity consumption	93.9	kWh	320	kWh
R23 Refrigerant	0.0049	kg	0.0094	kg
R404 Refrigerant	0.0049	kg	0.0094	kg
Air	168.0	m³	318.5	m³
Air compressor	4.7	kWh	8.9	kWh
PAP				
Input				
Electricity consumption	10.8	kWh	17.9	kWh
Water	0.18	m³	0.30	m³

Quantity of fuel consumption		
Average consumption	0.159	Nm³/km
Distance to RMS	127.4	km
Total biomethane volume	20.24	Nm³
Biomethane 1	16.2	kg Biomethane
Biomethane 2	15.6	kg Biomethane
Biomethane 3	15.2	kg Biomethane

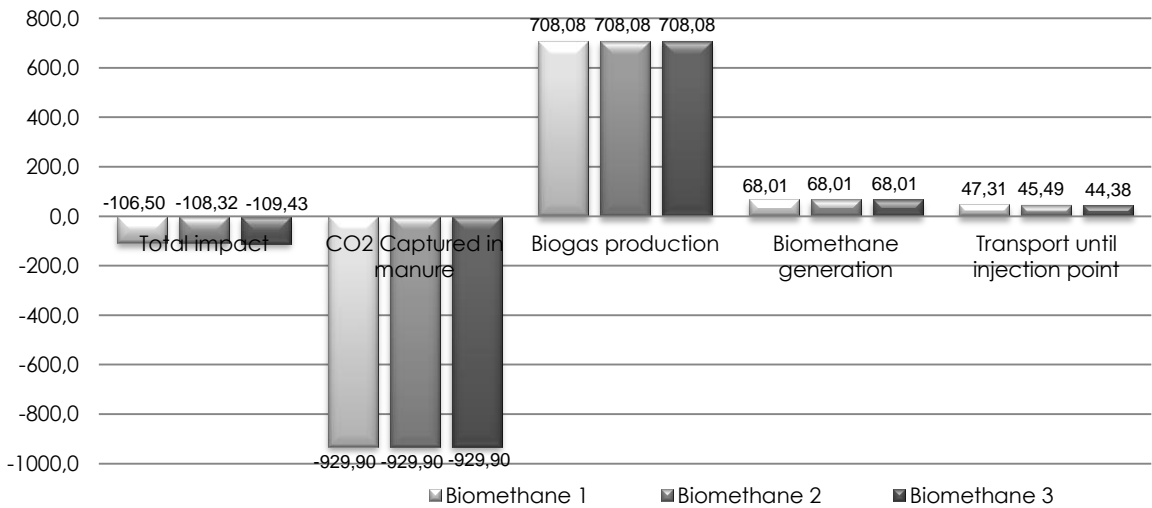


ENVIRONMENTAL IMPACT ASSESSMENT

Global Warming Potential kg CO₂ eq.

	Biomethane 1	Biomethane 2	Biomethane 3
Total impact	-106.5	-108.3	-109.4
CO ₂ Captured in manure	-929.9	-929.9	-929.9
Biogas production	708.1	708.1	708.1
Upgrading biogas	68.0	68.0	68.0
Distribution until injection point	47.3	45.5	44.4
Generation of 320 Nm ³ of Biomethane	-153.8	-153.8	-153.8

Comparison between different biomethane compositions



Other impact categories: Acidification (kg SO₂ e), Eutrophication (kg NO_x e), Photochemical oxidants (kg ethylene eq), Ozone layer depletion (kg CFC-11 eq), ReCiPe (PT)

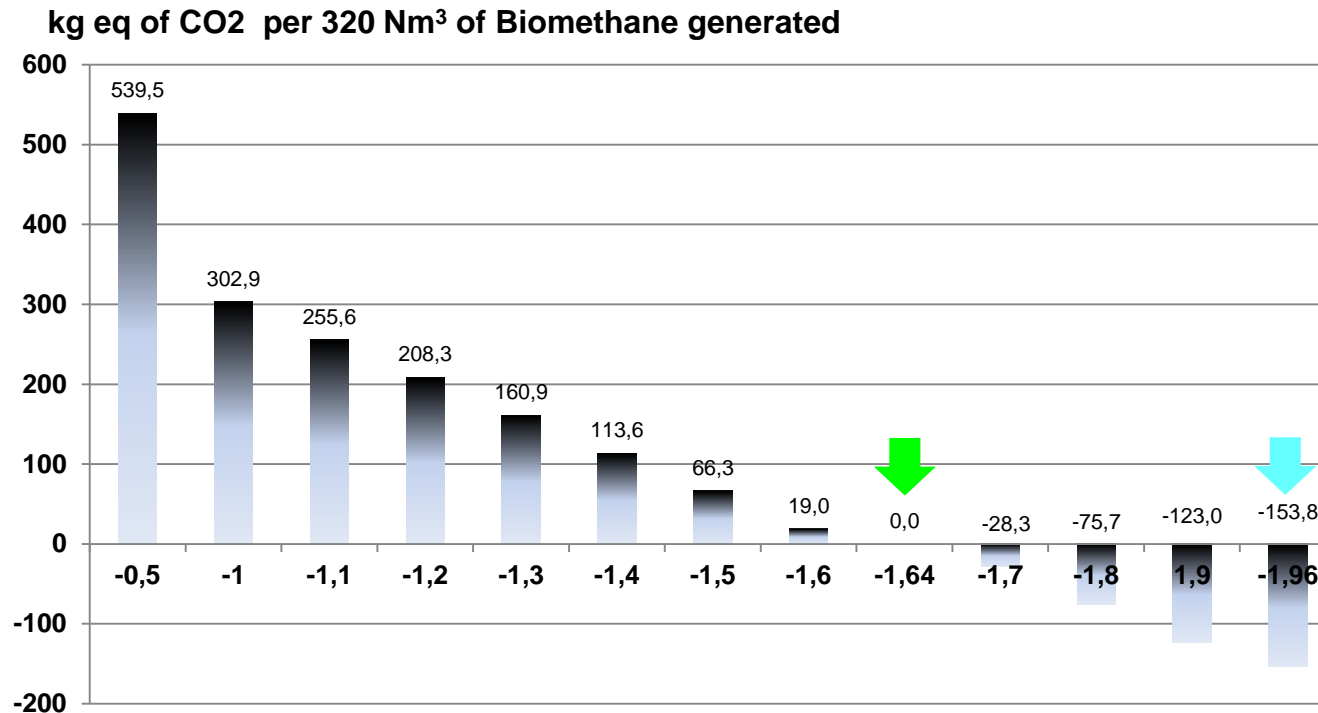
- Global Warming Potential kg CO₂ eq. BIOMETHANE 1

BIOMETHANE 1

Stage	Impact
TOTAL IMPACT	-106,5
CO2 capt.	-929,9
Biogas prod.	708,08
Reception	604,31
Mixing tank	67,6
Pump room	14,26
Digestor	21,91
Biogas upgr.	68,01
GPP	64,52
PAP	3,49
Transport	47,32

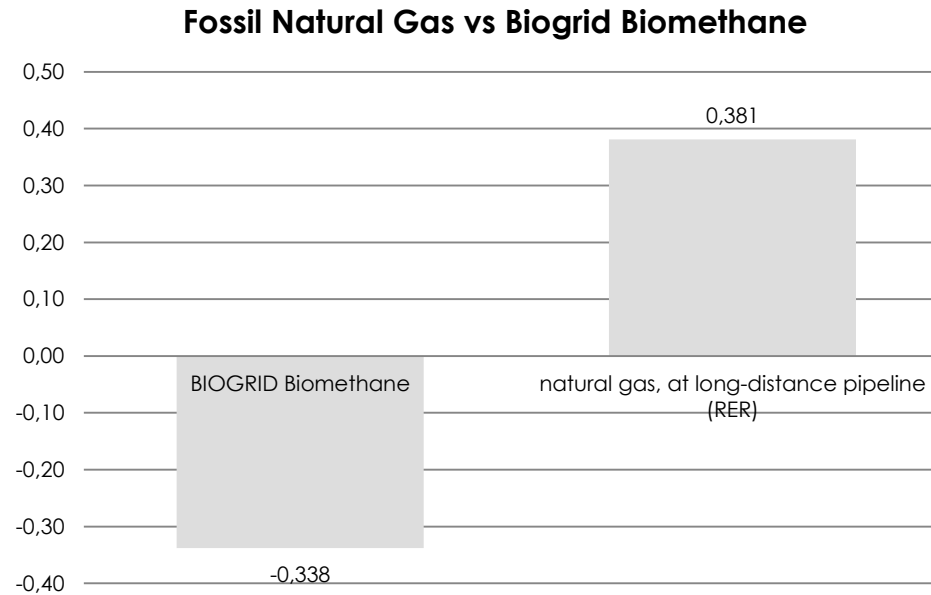
SENSITIVITY ANALYSIS

Different CO₂ content in pork manure



The process could be considered neutral in CO₂ emissions when pork manure content is 1.64 (kg/Nm³) approximately

COMPARISON WITH NATURAL GAS (kg CO₂/Nm³).



MAIN CONCLUSIONS OF THE STUDY

- The stage with a major environmental significance throughout the life cycle of the product under study is biogas production process with about the 86 % of the total impact (if not CO₂ captured is included). Especially it comes from manure transport which represents 78 % of the biogas production stage.
- The consumption of electricity during upgrading of biogas generated is the main environmental aspect that affects to the environmental impact in this module and it represents about 97 %.
- The use of the Biomethane obtained in the process represents a huge environmental benefit comparing with fossil natural gas.
- Taking manure CO₂ capture into account, the negative total impact of biogas production process and its upgrading means that the manure has captured more CO₂ than process consumptions (as electricity, water, chemical products) derived impacts do. Also, using PAP system CO₂ emissions to the atmosphere are avoided by algae sequestration. The rest of CO₂ that has not been captured is liquefied and storage for different application such as chemical and pharmaceutical industry among other.
- The transport of the 320 Nm³ until the injection point has been assessed taking into account 20 Nm³ as a vehicle fuel. The results show that the transport impact only represents 5.7 % of the global impact and the manure CO₂ capture is more representative than it does.

MANY THANKS YOU FOR YOUR
KIND ATTENTION



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