LIFE CYCLE ASSESSMENT OF A BIOGAS PLANT WITH BIOMETHANE AS VEHICLE FUEL AND INJECTED INTO THE NATURAL GAS GRID BY CO_2 CAPTURE AND STORAGE TECHNOLOGY

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1.-Introduction

The reduction of 20% in CO_2 emissions, raising the share of European Union energy consumption produced from renewable resources to 20% and a 20% improvement in the European's energy efficiency are the three keys goals of the European Commission's energy policy for the year 2020.

To fulfil these aforementioned objectives, the European Commission encourages the use of alternative bio-fuels to substitute diesel and petrol, one of them is biogas, a clean and renewable energy.

For this purpose, the LIFE BIOGRID European project has been developed: a highly innovative energy project that combines biogas production with carbon capture and storage technology. The project demonstrates the concept called "Carbon-negative-bio-energy".

Biogas, which is obtained from organic waste, is purified through a combination of biological and cryogenic technologies used to obtain "Biomethane": a renewable energy similar to natural gas that can be used both as a non-pollutant fuel and also to be injected into the Spanish distribution natural gas grid.

In the LIFE BIOGRID European project, starting from biogas as renewable energy, the concept of carbon-negative-bio-energy, which consists in the combination of bio-energy production with carbon capture and storage (CCS) is going to be demonstrated. Biogas is a CO_2 neutral source of energy; however the application of CCS technology converts the biogas into biomethane which could be considered as a CO_2-negative-biofuel.

2.-Background

In the LIFE BIOGRID project biogas is generated in an anaerobic digestion plant, which is then upgraded through both a cryogenic and a biological treatment removing all contaminants from the biogas and obtaining Biomethane and pure CO_2. The pure CO_2 will be used to enhance algae growth and the Biomethane is stored in a fuelling station. From this station a natural gas lorry can be refilled as well as a portable injection system in order to store and transport the renewable gas to a point where it can be injected into the Spanish distribution natural gas network for the first time in Spain. See **Figure 1**.

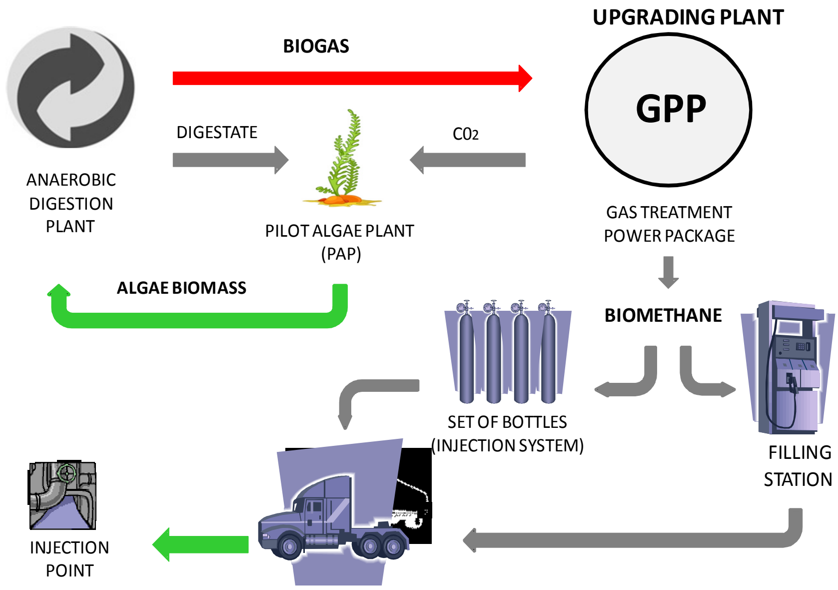

Figure 1- Scheme of the LIFE BIOGRID project

3.-Objectives and Methodology

The main objective of this work is to assess the environmental impact associated with Biomethane as transport fuel and its injection into the Spanish distribution natural gas network from a pig manure biogas production plant.

Another goal is to demonstrate the carbon-negative-bio-energy concept using the Life Cycle Assessment (LCA) method, which consists in the combination of biogas production plant with two carbon capture and storage (CCS) prototype systems: Gas treatment Power Package (GPP) and Pilot Algae Plant (PAP).

The present study is based on the international standards ISO 14040:2006 and ISO 14044:2006. There will be two LCA: Biomethane injection into the natural gas grid and Biomethane as transport fuel.

For the LCA procedure and according to ISO 14044:2006, the methodological framework for LCA consists of four steps which are outlined in the **Figure 2**.

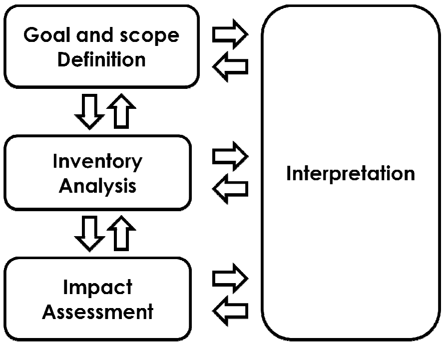

Figure 2- Life Cycle Assessment framework

1. *Goal and scope definition*: Defining the goal includes determining the reason for carrying out the LCA study, the intended audience, and the intended. Application while defining the scope involves setting the system boundaries and the level of detail.

2. *Inventory analysis*: The second phase of the LCA, the life cycle inventory analysis (LCI) phase, deals with collecting the necessary data to meet the objectives of the LCA study by inventorying the input and output data of the studied system.

3. *Impact assessment*: The purpose of the third phase of LCA, life cycle impact assessment (LCIA), is to convert the LCI results into the related environmental impacts.

4. *Interpretation*: The final phase of the LCA procedure is a life cycle interpretation, where the results of an LCI and LCIA are summarised and discussed to provide a basis for conclusions, recommendations and decision-making, depending on the goal and scope definition.

In the present methodology, the results are shown as endpoint indicator expressed in a single score (PT). The primary objective of the ReCiPe method is to transform the long list of Life Cycle Inventory results, into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category. ReCiPe determines indicators at two levels:

1. Eighteen midpoint indicators
2. Three endpoint indicators

Also, the CML methodology was used to define 5 impact categories and LCA Manager is the LCA software tool selected for the treatment of the LCI and its subsequent evaluation.

The functional unit of the system under investigation is the generation of 320 m^3N of Biomethane using, on one hand, 20 m^3N for transport and 300 m^3N for the injection into the natural gas grid and, on the other hand, using the whole generation of 320 m^3N of Biomethane only as vehicle fuel.

The process has been divided in three systems:

1. Pretreatment of the manure
2. Manure anaerobic digestion
3. Upgrading and use step.

If there is more than one product out of one process allocation must be used to distribute the input flows exactly to the single product.

In this project, the raw material used is biogas whose subsequently conversion into Biomethane mainly comes from pig manure but also comes from poultry manure.

The composition of the biogas and the three different biomethane compositions that have been considered in this study are shown in the **Table 1**:

	CH_4	CO_2	N_2	CO	O_2
Biogas	66.89%	31.37%	1.46%	0.01%	0.01%
Biomethane 1	92.411%	6.380%	1.209%	---	---
Biomethane 2	95.000%	4.000%	1.000%	---	---
Biomethane 3	96.500%	2.500%	1.000%	---	---

Table 1- Composition of biogas and Biomethane gases from LIFE BIOGRID project

4.-Main results and discussion

A. - Life Cycle Assessment of 320 m^3N of Biomethane injection into natural gas network

The processes that have been considered in the LCA of Biomethane injection into the natural gas grid are shown in the **Figure 3**.

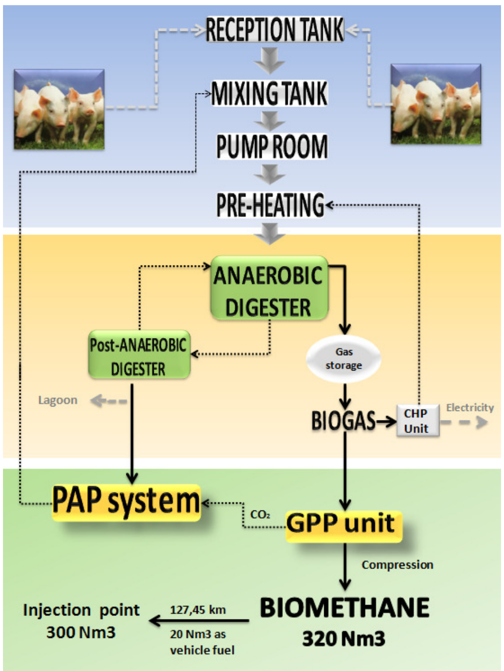

Figure 3- LCA processes of Biomethane injection into the natural gas grid

From the Life Cycle Inventory, the Life Cycle Assessment results are shown for the main stages of the product and for the environmental aspects. In the case of the Global Warming Potential (GWP) for the mentioned steps the results are done in the **Figure 4**.

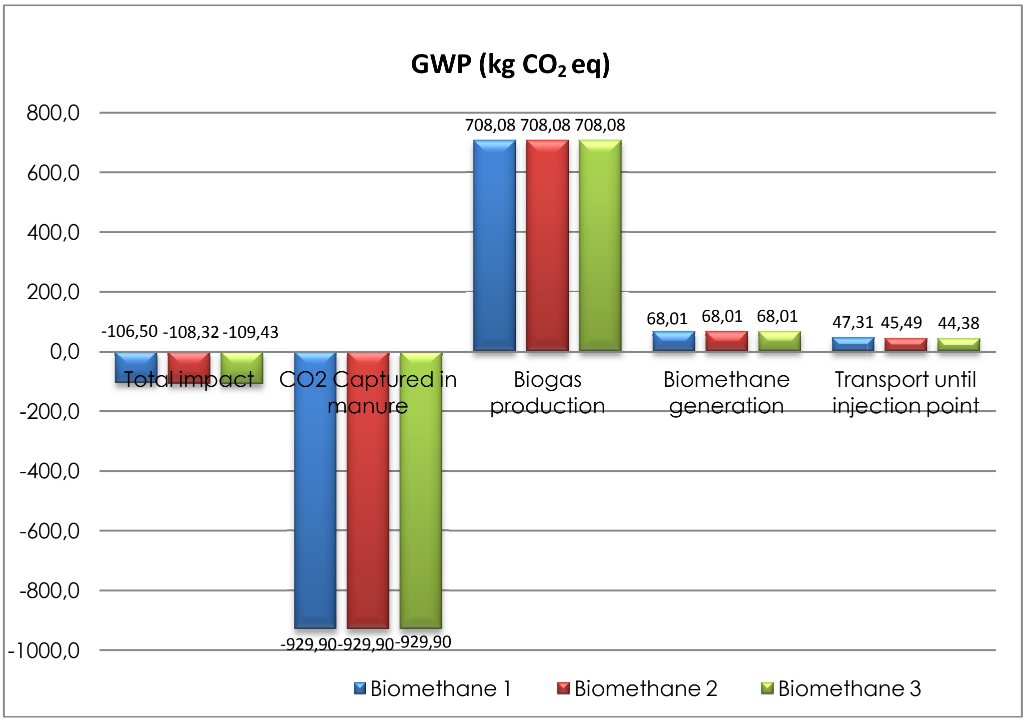

Figure 4- GWP: Comparison between different Biomethane compositions

In the specific case of Biomethane 2, that fulfils the European standards proposal for grid injection, the Global Warming Potential (GWP) is shown in the **Figure 5**.

BIOMETHANE 2	GWP kg CO_2 eq
Total impact	-108.32
CO_2 captured	-929.90
Biogas	708.08
Reception	604.31
Mixing tank	67.60
Pump room	14.26
Digester	21.91
Biogas Upgrading	68.01
GPP	62.76
PAP	3.49
Transport to Injection point	45.49

Figure 5- GWP for the Biomethane 2

Other environmental impact categories were also estimated as acidification, eutrophication, photochemical oxidants, ozone layer depletion and ReCiPe (pt) and not reflected in this work. The study was also performed for three different biomethane compositions with lower nitrogen and CO_2 contents to study other gas compositions. Afterwards, the sensitivity analyses were also performed taking into account the influence of the different CO_2 content in pig manure.

Moreover, natural gas is classified as fossil fuel, whereas Biomethane is defined as a green source of energy. Like its name suggests, fossil fuel derived methane is produced from thousands or millions of years in where old fossil remains of organic matter lies buried deep in the ground. Production of fossil fuel derived methane, however, depends exclusively on its natural reserves which vary greatly from one country to another and are not available in limitless amounts. The Biomethane, conversely, is produced from "fresh" organic matter which makes it a renewable source of energy that can be produced worldwide.

In the **Figure 6**, results obtained represent the comparison between two natural gases. The differences are shown up in GWP (kg CO_2/m^3N).

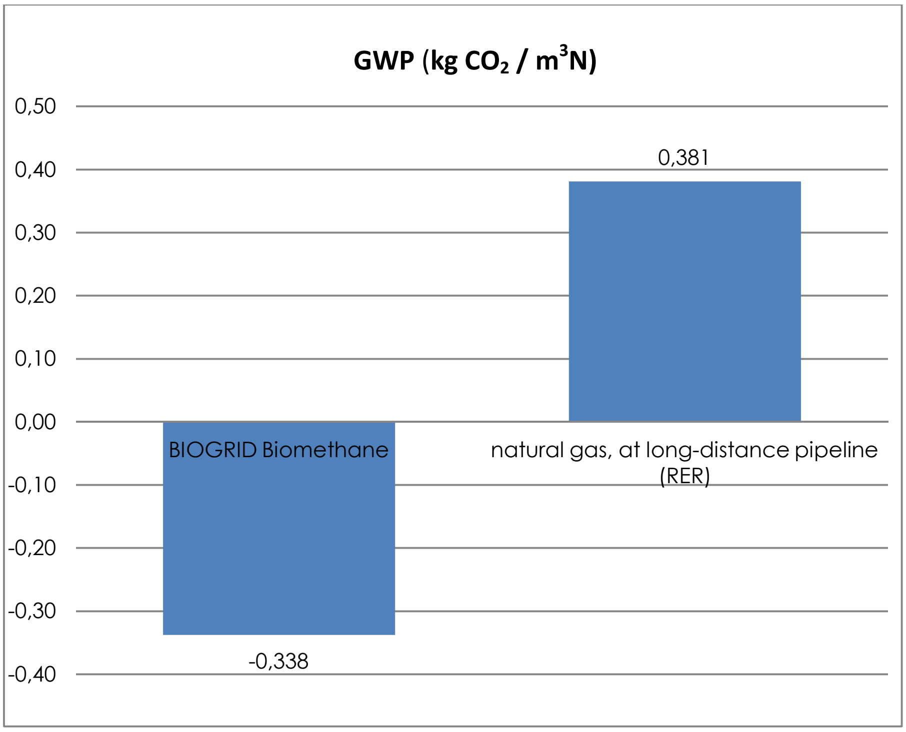

Figure 6- GWP: Fossil natural gas versus Biomethane from LIFE BIOGRID project

The use of the biomethane obtained in the process represents 52.2% of environmental benefit comparing with fossil natural gas.

B. - Life Cycle Assessment of 320 m³N of Biomethane as transport fuel

The processes that have been considered in the LCA of Biomethane as transport fuel are shown in the **Figure 7**.

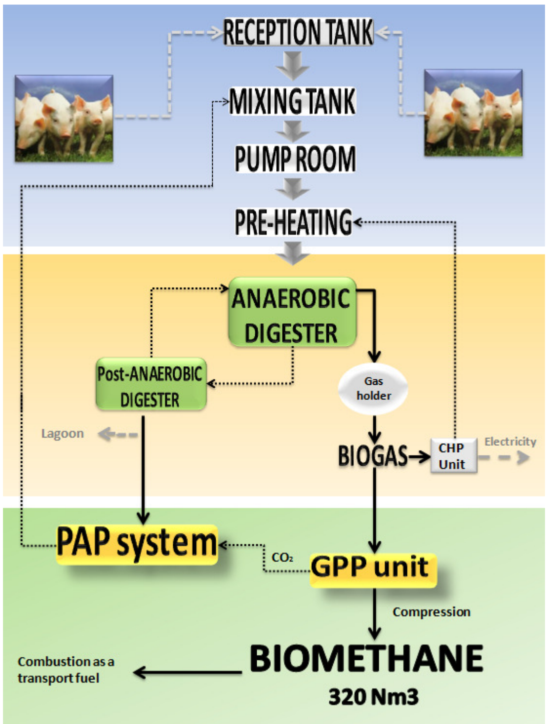

Figure 7- LCA processes of Biomethane as transport fuel

If all the 320 m³N of biomethane are used as a bio-fuel for transport, the LCA results show that Biomethane vehicles have substantial advantages compared to vehicles equipped with petrol engines. The **Figure 8** shows the GWP in *kg eq of CO_2 per km* for Biomethane from the LIFE BIOGRID project and petrol.

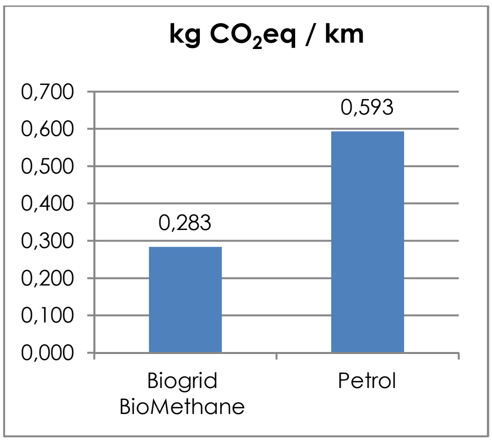

Figure 8- GWP: Comparison between Biomethane from LIFE BIOGRID project and Petrol

5.-Main conclusions

The utilisation of Biomethane or renewable natural gas has a great potential with important socio-economic benefits. Moreover, taking into account the environmental assessment, the main conclusions are the following:

- 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 is included the CO_2 captured). Especially it comes from manure transportation which represents 78.7% of the biogas production stage.
- The consumption of electricity during the 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 52.2% of environmental benefit comparing witch fossil natural gas.
- The use of the Biomethane as transport fuel has a positive environmental impact but the impact from the LIFE BIOGRID process represents 50% of environmental benefit comparing witch other alternative fuels, in terms of the kg eq of CO_2 per km.
- Taking into account the CO_2 capture from manure, the negative total impact of biogas production and upgrading processes means that the manure has captured more CO_2 than all the process consumptions together as electricity, water, chemical products, etc. Moreover, using the PAP system, the CO_2 emissions to the atmosphere are avoided by CO_2 sequestration from algae. The rest of CO_2 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 m^3N of Biomethane until the injection point has been assessed taking into account 20 m^3N as a vehicle fuel and 300 m^3N to be injected into the natural gas network. The results show that the transport impact only represents 5.7% of the global impact.
- The results for the life cycle assessment (LCA) of the system confirmed the negative total impact of the LIFE BIOGRID process with grid injection, in terms of the kg of CO2 eq. The LCA has verified the **carbon-negative-bio-energy** concept of the project.

Biomethane derived from biogas is an entirely renewable and readily available low carbon alternative fuel that can be produced locally from organic waste and capable to replace the fossil natural gas in the near future.

References

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and

Project diffusion: http://teknopolis.elhuyar.org/reportajes/biogas-de-la-granjala-red/?lang=es