WGCPARIS2015
WORLD GAS CONFERENCE
"GROWING TOGETHER TOWARDS A FRIENDLY PLANET"

26th World Gas Conference | 1-5 June 2015 | Paris, France

# Life cycle assessment of a biogas plant with biomethane as transport fuel from pig manure

Authors:

A. M. Gutiérrez[1], J.R. Arraibi[1],
V. L. Barrio[2], I. García García[2],
M. Acosta[3], G. Benito[3],
I. Díaz[4], A. Domínguez[4], M. Díaz[4]

(1): EDP Naturgas Energía, S.A., Spain,
(2): Bilbao School of Engineering, Spain
(3): IK Ingeniería, Spain
(4): Biogas Fuel Cell, S.L., Spain

Table of Contents

Background ........ 2
Aims ........ 2
Methods ........ 4
Results ........ 4
Main Conclusions ........ 6
References ........ 11

## Background

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 fulfill these aforementioned objectives, the European Commission encourages the use of alternative biofuels to substitute diesel and petrol, one of them being biogas, a cleaner and renewable energy.

Biogas is already used as vehicle fuel in countries like Sweden, Germany and Switzerland. The number of private cars, public transportation vehicles and lorries driven on biogas is constantly increasing. Biomethane can be used as fuel in the same way and by the same vehicles as natural gas. An increasing number of European cities are exchanging their diesel buses with biomethane driven ones.

In the LIFE BIOGRID European project starting from biogas as a renewable energy, the concept of carbon-negative-bio-energy, which consists of the combination of bio-energy production with carbon capture and storage (CCS), has been 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 to be used as a transport fuel.

In the case of biogas, when comparing different types of transport fuels, two variables are particularly important:

- The efficiency in which biogas is converted into its product.
- The extent of emissions which are avoided by using the biogas.

## Aims

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 by 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. In this case, it will be used as a fuel for sustainable transport. See Figure 1.

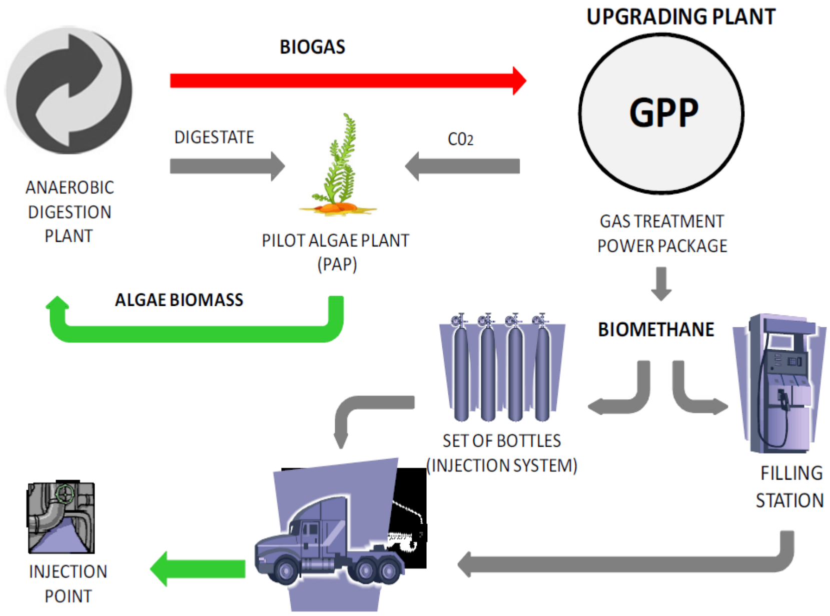


Figure 1- Scheme of the LIFE BIOGRID project

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 the biogas production plant with two carbon capture and storage (CCS) prototype systems: Gas treatment Power Package (GPP) and Pilot Algae Plant (PAP).

## Methods

The present study is based on the international standards ISO 14040:2006 and ISO 14044:2006. There will be one LCA: 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 Figure 2.

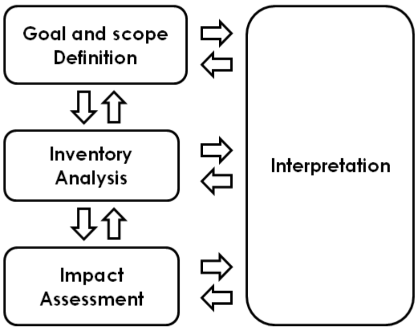


Figure 2. Life Cycle Assessment framework

1). Definition of goal and scope: 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 the definition of the scope.

In the present methodology, the results are shown as an 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 and 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 $Nm^3$ of Biomethane as a 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 Table 1:

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

| | $CH_4$ | $CO_2$ | $N_2$ | CO | $O_2$ |
|---|---|---|---|---|---|
| **Biogas** | 66.89% | 31.37% | 1.46% | 0.01% | 0.01% |
| **Biomethane 1** | 92.411% | 6.380% | 1.209% | --- | --- |
| **Biomethane 2** | 95.00% | 4.00% | 1.00% | --- | --- |
| **Biomethane 3** | 96.50% | 2.50% | 1.00% | --- | --- |

## Results

The processes that have been considered in the LCA of Biomethane production used as a vehicle fuel are shown in Figure 3.

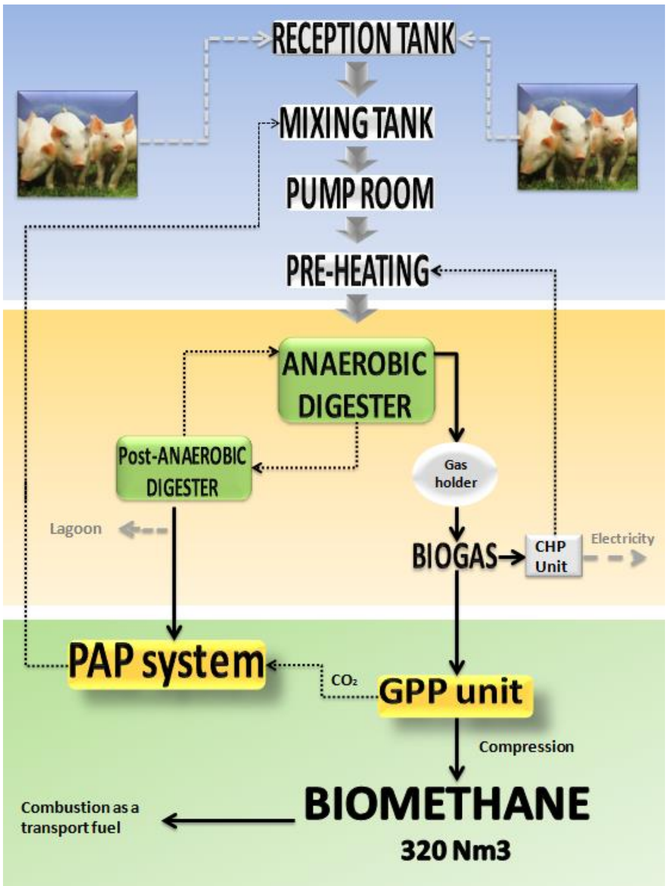


Figure 3- LCA processes of Biomethane

Thus, the inventory has been divided in three modules: pre-treatment of the manure, manure anaerobic digestion and biogas upgrading and use phase.

The biogas plant has mainly pig manure as a primary raw material that is considered a waste on its own. See Table 2.

Table 2: Main characteristics of the pig manure used

| Characteristic | Data | Source |
|---|---|---|
| Pork manure daily flow | 120m3/day | Purines Almazan |
| Manure source | 150 km | Purines Almazan |
| $CO_2$ kg fixed in manure/m³ biogas | 1.9648 | Alvarez et al., 2010 |
| Manure density (kg/m3) | 965 | Almazan website |

In the use phase, the data employed to calculate the 320 Nm³ biomethane consumption and its combustion emissions are based on a technical report made on the emission tests on the CNG lorry used in the LIFE BIOGRID project.

The Global Warming Potential (GWP) achieved is shown for the main stages in Figure 4.

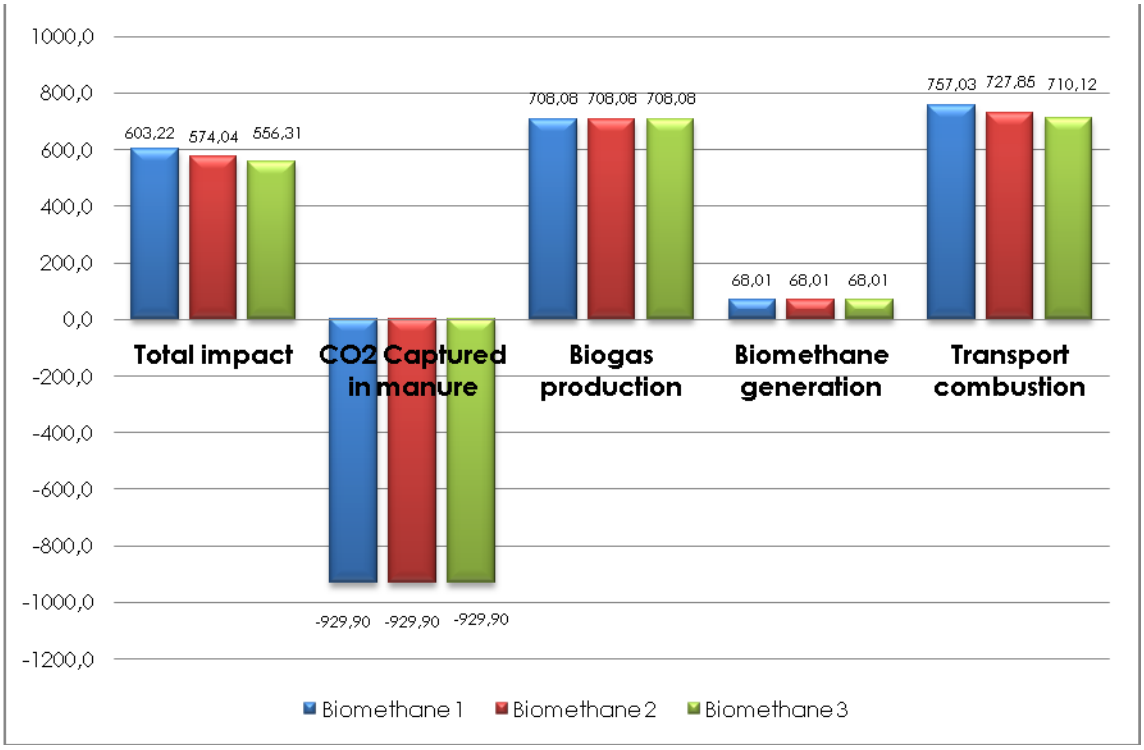


Figure 4- GWP for the different biomethane compositions

Other impact categories were calculated for all the biomethane gases. In the specific case of Biomethane 2, given in Table 3, that fulfills the forthcoming European standards proposal for grid injection, the results are shown for the main stages.

Table 3: Global Warming Potential for Biomethane 2 (kg CO2 eq.)

| Biomethane 2 | Acidification (kg $SO_2$ eq.) | Eutrophication (kg NOx eq.) | Photochemical oxidants (kg ethylene eq.) | Ozone layer depletion (kg CFC-11 eq.) | ReCiPe (PT) |
|---|---|---|---|---|---|
| Total impact | 4.312 | 2.915 | 1.169 | 2.46E-04 | 64.949 |
| 320 Nm³ generation | 3.964 | 2.825 | 0.140 | 2.46E-04 | 35.521 |
| **$CO_2$ fixed** | 0.000 | 0.000 | 0.000 | 0.000 | -42.653 |
| ***Biogas*** | 3.333 | 2.703 | 0.116 | 2.12E-04 | 69.990 |
| **Reception** | 2.620 | 2.413 | 0.088 | 8.64E-05 | 59.550 |
| Motor consumption | 0.036 | 0.007 | 0.001 | 5.95E-08 | 0.357 |
| Pump consumption | 0.009 | 0.002 | 3.37E-04 | 1.49E-08 | 0.089 |
| Manure transport | 2.199 | 0.594 | 0.073 | 8.10E-05 | 55.125 |
| Water | 0.000 | 0.000 | 0.000 | 0.00E+00 | 0.000 |
| Waste water | 0.375 | 1.810 | 0.013 | 5.36E-06 | 3.978 |
| **Mixing tank** | 0.377 | 0.226 | 0.016 | 1.25E-04 | 7.129 |
| Motor consumption | 0.048 | 0.009 | 0.002 | 7.94E-08 | 0.477 |
| Pump consumption | 0.011 | 0.002 | 4.11E-04 | 1.82E-08 | 0.109 |
| Iron chloride | 0.301 | 0.210 | 0.013 | 1.25E-04 | 6.213 |
| Iron chloride transport | 0.017 | 0.005 | 5.33E-04 | 4.47E-07 | 0.330 |
| **Pump room** | 0.133 | 0.026 | 0.005 | 2.17E-07 | 1.305 |
| Grundfos pump | 0.040 | 0.008 | 0.001 | 6.50E-08 | 0.390 |
| Crushing machine | 0.008 | 0.002 | 2.99E-04 | 1.32E-08 | 0.079 |
| Grundfos Landia | 0.042 | 0.008 | 0.002 | 6.95E-08 | 0.417 |
| Compressor | 0.003 | 5.56E-04 | 1.07E-04 | 4.73E-09 | 0.028 |
| Water pump | 0.040 | 0.008 | 0.001 | 6.50E-08 | 0.390 |
| **Digestor** | 0.204 | 0.039 | 0.008 | 3.34E-07 | 2.006 |
| Digester agitator | 0.099 | 0.019 | 0.004 | 1.62E-07 | 0.976 |
| Post digester fan | 0.081 | 0.016 | 0.003 | 1.34E-07 | 0.802 |
| Air fan | 0.010 | 0.002 | 3.68E-04 | 1.62E-08 | 0.098 |
| Biogas fan | 0.013 | 0.003 | 4.90E-04 | 2.17E-08 | 0.130 |
| Air flow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Condensation wells | 3.67E-07 | 7.06E-08 | 1.36E-08 | 6.01E-13 | 0.000 |
| ***Biogas Upgrading*** | 0.631 | 0.121 | 0.023 | 3.41E-05 | 6.223 |
| **GPP** | 0.582 | 0.112 | 0.022 | 3.40E-05 | 5.742 |
| Electricity consumption | 0.581 | 0.112 | 0.022 | 9.52E-07 | 5.718 |
| R23 Refrigerant | 0.001 | 1.61E-04 | 4.66E-05 | 2.17E-05 | 0.011 |
| R404 Refrigerant | 6.35E-04 | 0.000 | 2.81E-05 | 1.14E-05 | 0.013 |
| Air | 0.000 | 0.00E+00 | 0.000 | 0.000 | 0.000 |
| Compressor | 0.016 | 0.003 | 6.05E-04 | 2.67E-08 | 0.161 |
| **PAP** | 0.032 | 0.006 | 0.001 | 5.32E-08 | 0.319 |
| Electricity consumption | 0.032 | 0.006 | 0.001 | 5.32E-08 | 0.319 |
| Water | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Combustion 320 Nm³** | 0.348 | 0.090 | 1.030 | 0.000 | 31.389 |
| **CO** | 0.000 | 0.000 | 1.030 | 0.000 | 1.34E-03 |
| **$CO_2$** | 0.000 | 0.000 | 0.000 | 0.000 | 30.640 |
| **HC** | 0.000 | 0.000 | 0.000 | 0.000 | 0.018 |
| **NOx** | 0.348 | 0.090 | 0.000 | 0.000 | 0.730 |

If all the 320 $Nm^3$ 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. Figure 5 shows the GWP in kg eq. of $CO_2$ per km for biomethane from the LIFE BIOGRID project and petrol.

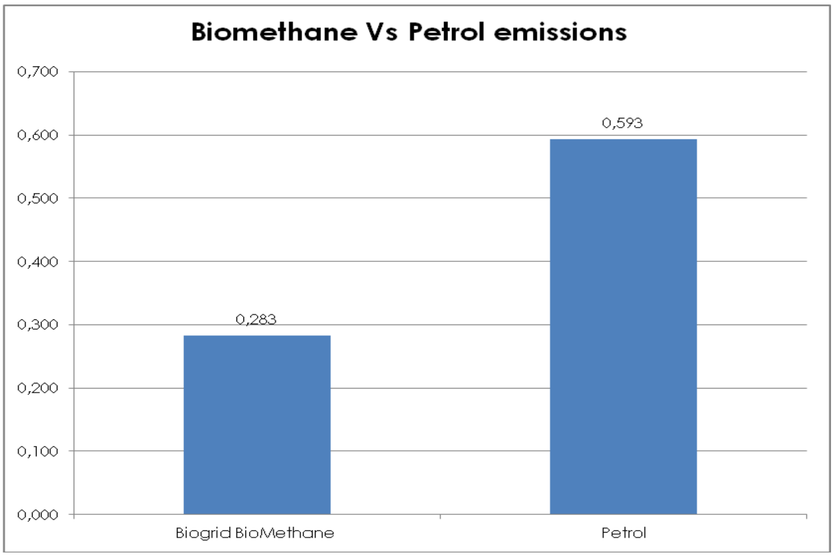


Figure 5- Comparison between biomethane produced from LIFE Biogrid project and Petrol

The results show that the environmental performance of biomethane (kg eq of $CO_2$ per km) under study is better than petrol in 50 %.

Due to the fact that the Technical report on the emission tests on the CNG lorry only shows results for the biomethane and petrol consumption and their associated emissions for a specific distance driven, a comparative analysis has been made using Ecoinvent indicators. Results are shown in Figure 6.

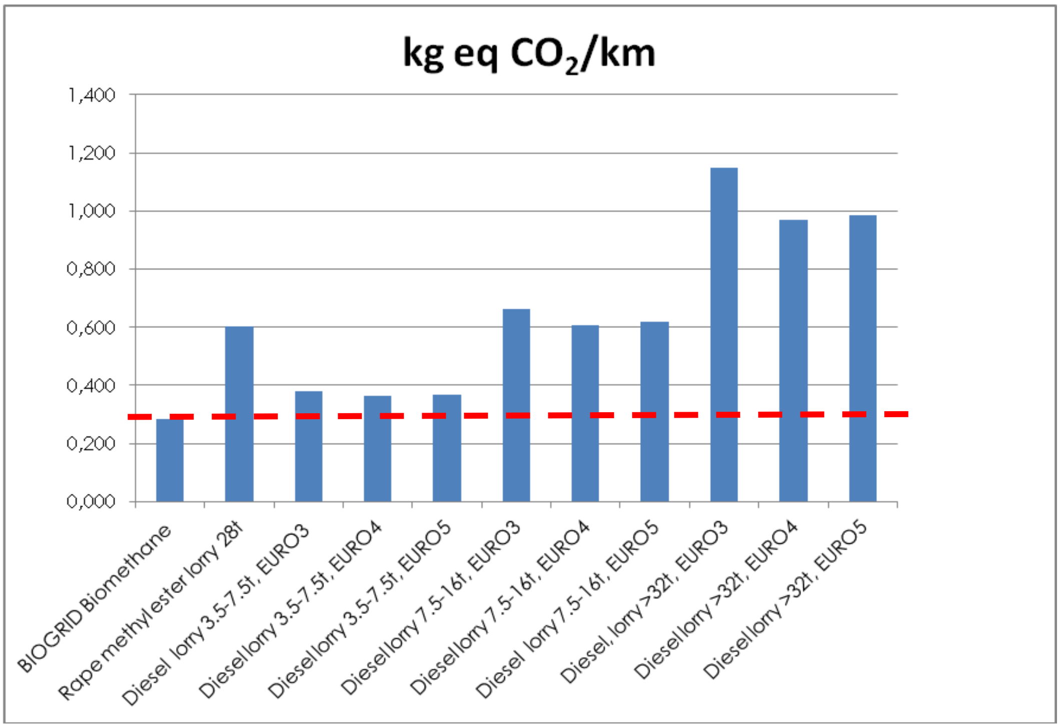


Figure 6- Comparison between Biogrid Biomethane and different type of diesel lorry

For all the cases the kg of $CO_2$ per km was higher than the value reached for the biomethane generated from LIFE Biogrid project.

## Main conclusions

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

1.-• The stage with a major environmental significance throughout the life cycle of the product under study is the biogas production process with about 86% of the total impact (if the $CO_2$ captured is not included). It is mainly due to manure transportation which represents 78.7 % of the biogas production stage.

2.-• The consumption of electricity during the upgrading of biogas generated is the main environmental aspect that affects the environmental impact in this module and it represents about 97 %.

3.-• The use of the biomethane obtained in the process represents 52.2 % of environmental benefit comparing witch fossil natural gas.

4.-• 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.

5.-• Taking into account the capture of $CO_2$ 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 applications such as chemical and pharmaceutical industry among others.

6.-• 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 $CO_2$ eq. The LCA has verified the carbon-negative-bio-energy concept of the project.

7. - **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

- LIFE BIOGRID Project Website: www.lifebiogrid.eu
- Project diffusion: http://teknopolis.elhuyar.org/reportajes/biogas-de-la-granjala-red/?lang=es