Universidad de Oviedo

# ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

## GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

### ÁREA DE ENERGÍA

### RESUMEN DEL TRABAJO FIN DE GRADO

### SITUACIÓN DEL BIOGÁS EN CATALUÑA Y LA COMUNIDAD VALENCIANA, ESPAÑA

**D. SARRALDE ALZORRIZ, Blanca**
**TUTOR: D. LINDVISK, Emma**

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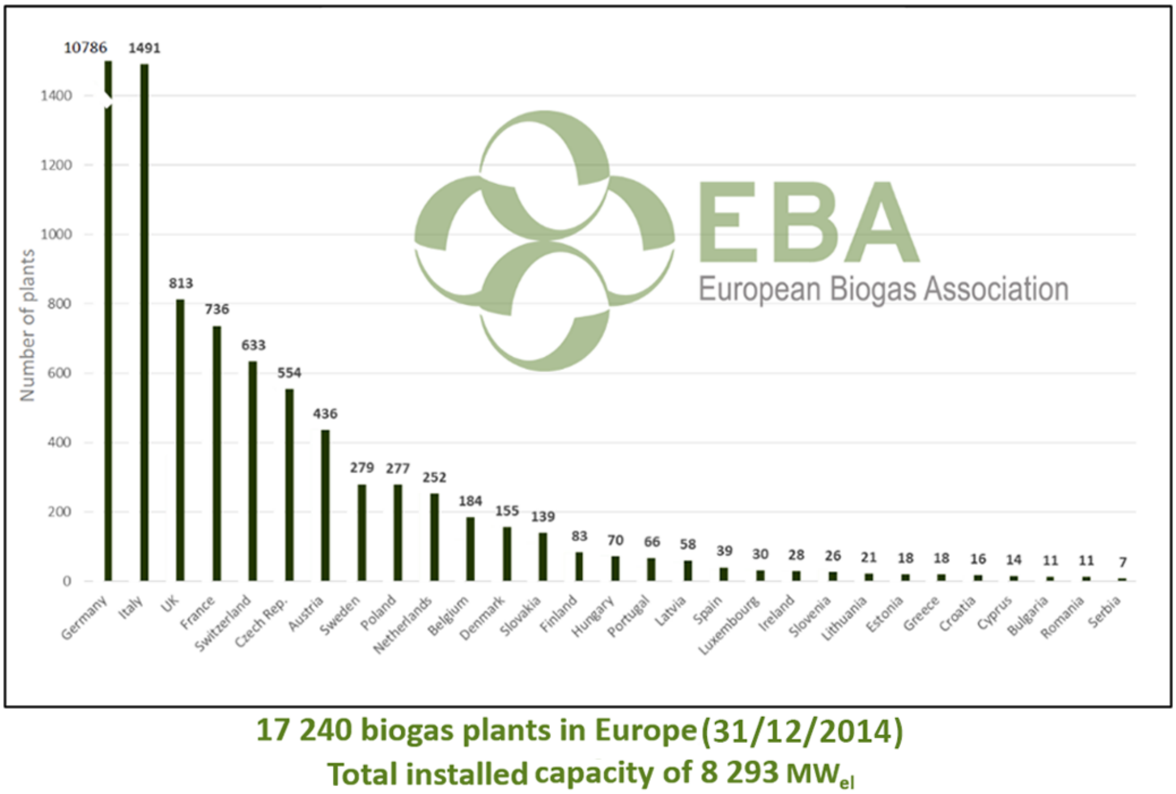
# 1. Introducción

La producción de biogás agroindustrial en España se encuentra en las últimas del ranking europeo. En España se encuentran el 0,22% de las plantas de biogás de Europa. Inmediatamente detrás de España se encuentra Luxemburgo, cuya extensión es 200 veces menor y con una menor densidad de producción de purines. Esta situación es debida a que el gobierno español promociona energías como la eólica y la biomasa,




olvidándose del biogás.

Figura 1. Plantas de biogás en Europa

Como se puede observar en la figura 1 obtenida de las estadísticas de la European Biogas Association, EBA, en 2014, España ocupa la posición 18 con 39 plantas agroindustriales. Este número de plantas se encuentra increíblemente lejos de los primeros puestos, liderando Alemania con 10.786 plantas.

De acuerdo con el último informe de la EBA, la Unión Europea tuvo 17.240 plantas en 2014, 2.677 más que el año anterior. Esto mantiene un ritmo de crecimiento de 20% anual. España pasó de tener 22 plantas en 2012 a 39 plantas en 2014, cumpliendo con el mencionado ritmo de crecimiento. A pesar de esto se seguía sin superar las 50 instalaciones como hacen países más pequeños como Letonia (59) y Portugal (66).

La industria del biogás en Europa tiene un gran potencial por desarrollar. La industria se enfrenta a grandes desafíos por lo que necesita una atención especial y un apoyo político estable.

## 1.1. Objetivo

El objetivo de este proyecto es obtener toda la información disponible de las plantas de biogás de Cataluña y La Comunidad Valenciana que están actualmente activas. Hoy en día hay 20 plantas de biogás agroindustrial en funcionamiento entre Cataluña y La Comunidad Valenciana.

Esta información incluye cómo trabajan y organizar los datos y resultados en tablas para facilitar una visión general.

Con la información obtenida se busca crear un marco de categorización que permita comparar las similitudes y diferencias entre las plantas.

Además también se presentará la legislación nacional y regional que afecta a la producción del biogás. Esta legislación se tratará de presentar en orden cronológico de forma que nos permita entender cómo se ha ido desarrollando el biogás en función de esta.

El estudio concluirá con una evaluación de los resultados.

## 1.2. Método

Las herramientas empleadas para llevar a cabo este estudio han sido:

- Contactar con asociaciones como AEBIG( Asociación Española del Biogás) APPA (Asociación de productores de energías renovables) y EBA (European Biogas Association)
- Investigación por internet: artículos, páginas web de las empresas constructoras de las plantas, de las empresas que dirigen las plantas o de las empresas propietarias...
- Correos y llamadas telefónicas a estas compañías y a los gerentes de las plantas.

Como ya se ha mencionado, también se investigará la legislación española relacionada con el entorno energético para averiguar por qué está sin desarrollar el biogás en España.

El primer caso es conseguir una buena red de contactos en los sitios de interés. Es esencial para el nivel de investigación que se quiere realizar.

Una vez se ha conseguido, se procederá a reunir toda la información necesaria y a clasificarla metódicamente. Para clasificar la información se tiene un marco de categorización predeterminado con la información más relevante clasificada en categorías. Esto permitirá conocer qué categorías son más comunes y permitirá hacer comparaciones con otros países.

# 2. Biogás en España, historia y legislación

En esta sección, para entender como ha sido el desarrollo del biogás en España, se analizará la legislación que ha impulsado o frenado el desarrollo de esta energía.

## 2.1. Legislación nacional

El inicio de las plantas de biogás fue el Real Decreto 661/2007. Este decreto aportaba unas primas muy justas para la rentabilidad y tan solo las plantas óptimas que gestionasen residuos en ciertas zonas o purines de explotaciones muy grandes podían ser rentables. La falta de experiencia en el sector y la sociedad sobre esta tecnología y la larga tramitación requerida hizo que las plantas de biogás se construyeran a un ritmo lento comparado con otras energías de renovables que crecieron mucho en este periodo.

Previamente había sido aprobado el Real decreto 616/2007 el día 11 de Mayo que promovía la cogeneración.

Cuándo se aprobó el Decreto Ley 1/2012 se acabaron las primas para todas las renovables con "carácter temporal" lo que hizo que muchas plantas de biogás en construcción se quedaran colgadas sin rentabilidad. Desde entonces hasta ahora lo único que ha permitido el gobierno en cuánto a energías renovables por el Real Decreto 947/2015, han sido nuevas instalaciones de eólica y biomasa, pero no de biogás.

Luego llegó el Real Decreto ley 9/2013, conocido como de rentabilidad razonable, que básicamente recorta las primas a todas las instalaciones existentes de energías renovables incluyendo al biogás. Esto llevó a muchas plantas existentes a una situación financiera límite y a refinanciar sus préstamos. También generó una gran desconfianza en la inversión en renovables por la inseguridad jurídica.

Finalmente el gobierno aprobó el Real Decreto 900/2015, conocido como 'impuesto al sol'. Se trata de la norma más restrictiva del mundo y a la práctica impide que se realicen plantas de biogás para autoconsumo.

Tampoco existe en España una norma ni una ley de promoción del biometano o inyección de biogás depurado a la red de gas.

En España, a diferencia de la mayoría de países Europeos, si se generase biogás para vehículos el gobierno cobraría los impuestos especiales de carburantes igual que con la energía fósil. Además, se cobra un impuesto por generar el biogás y otro por la venta de energía eléctrica.

### 2.2. Planes que definen las líneas a seguir

Básicamente, los Planes que marcan las líneas a seguir en la producción del biogás son los siguientes:

- Plan de Energías Renovables (PER) 2005-201099

- Plan Nacional Integrado de Residuos (PNIR) 2008-2015100

- Plan de Biodigestión de Purines101

-Planificación Sectorial de Gas y Electricidad 2008-2016102 Además, a nivel andaluz encontramos los siguientes planes:

# 3. Proceso de producción

El biogás es el producto gaseoso de la descomposición microbiológica de materia orgánica biodegradable en condiciones anaerobias (ausencia de oxígeno). Su composición, que depende del sustrato digerido y del tipo de tecnología utilizada, puede ser la siguiente:

– 50-70% de metano ($CH_4$).

– 30-40% de anhídrido carbónico ($CO_2$).

– ≤ 5% de hidrógeno ($H_2$), ácido sulfhídrico ($H_2S$), y otros gases.

El metano, principal componente del biogás, es el que le confiere su característica combustible. El valor energético del biogás, por lo tanto, estará determinado por la concentración de metano – alrededor de 20 ó 25 MJ/m3, comparado con 33 a 38 MJ/m3 del gas natural.

Una planta de biogás transforma los sustratos biodegradables en energía eléctrica y térmica. Los equipos principales de una planta son los siguientes:

- Sistema de homogeneización y alimentación de sustratos
- Digestores
- Sistema de desulfuración
- Unidad de cogeneración

La alimentación y homogenización de los sustratos de entrada varía según las características propias de los mismos, habiendo diferentes métodos de pretratamiento de los residuos para mejorar el proceso.

Los digestores son unos depósitos cilíndricos (de hormigón o acero) provistos de equipos de agitación y calefacción que aseguran unas condiciones óptimas del proceso de la biometanización.

El biogás generado se acumula en un gasómetro. Una vez eliminado el ácido sulfhídrico (H2S) mediante un sistema de desulfuración y deshumidificado mediante condensación, el biogás se conduce a una unidad de cogeneración donde es transformado en electricidad y calor. La electricidad generada puede venderse a la Red o ser autoconsumida, el calor cubre la propia demanda de la planta y el excedente puede utilizarse para calefacciones o sistemas industriales externos. Estos son los usos que se le dan comúnmente al biogás en España, pese a que como se explicará en las posteriores secciones se puede emplear para otras aplicaciones.

Además de biogás, los sustratos una vez procesados en la planta, (el “digestato“) pueden ser utilizados como fertilizantes. Dicho digestato es una materia orgánica metabolizada, rico en nutrientes inorgánicos, por tanto muy idóneo para su aplicación agrícola.

## 3.1. Tipos de plantas según residuo empleado

Las plantas de biogás pueden agruparse en 3 tipos según el residuo que emplean.

- Agroindustrial

Este tipo de plantas trabaja con estiércol animal procedente del Ganado, restos animales procedentes de mataderos, residuos de la agricultura y residuos con origen en la industria alimentaria.

- Vertedero

En los vertederos se deposita y almacenan residuos que no se pueden reconvertir ni reutilizar.

Dentro de los vertederos se producen reacciones anaeróbicas, por lo tanto la fracción de residuo orgánico se degrada produciendo gas de vertedero conocido como “LFG”. Este gas se recoge y almacena para su uso energético.

- Plantas de tratamiento de aguas residuales

Las plantas de tratamiento de aguas residuales se consideran Fuentes de recuperación de energía. La tecnología más implementada es la de combustión en calderas, y en la actualidad en España se están desarrollando las microtubinas en este tipo de plantas para aprovechar la energía del biogás.

## 3.2. USO DE LOS PRODUCTOS

De la digestión anaeróbica de los residuos orgánicos se obtienen los siguientes productos:

### 3.3.1. BIOGÁS

El biogás es el principal producto de la digestión anaeróbica y se le dan los siguientes usos:

- En una caldera para generar calor.

- En motores o turbinas para generar electricidad y calor.

- En pilas de combustible tras eliminar el $H_2S$

- Se puede añadir a la red de gas natural tras purificarlo y añadir aditivos.

- Fuel para automóviles.

### 3.3.2. BIOFERTILIZANTE

El digestato es un subproducto de la digestión anaeróbica. El digestato es un excelente fertilizante ya que contiene muchos nutrientes como nitrógeno fósforo y potasio. Se ha probado que el digestato es un fertilizante más seguro que la materia orgánica sin tratar. Reduce la contaminación de agua y el suelo debido a su alta concentración en minerales.

Al reemplazar una tonelada de fertilizante artificial por digestato se ahorra 1 tonelada de aceite, 108 toneladas de agua y 7 toneladas de emisiones de CO2.

# 4.PLANTAS DE BIOGÁS AGROINDUSTRIAL

## 4.1. PLANTAS DE BIOGÁS AGROINDUSTRIAL EN CATALUÑA


Figura 8. Zoom de las plantas estudiadas en Cataluña. [18]

A Gimenells  B Castelló de Farfanya  C Torregrossa I &II  D Torres de Segre

E Balaguer(&Torre Santamaría)  F Montargull  G Miralcamp  H Juneda  I Almenar

J Cassà de la Selva  K Mas bes  L Sant Esteve de Guialbes(Sant Mer)  S Vila-sana

## 4.2. PLANTAS DE BIOGÁS AGROINDUSTRIAL EN LA COMUNIDAD VALENCIANA

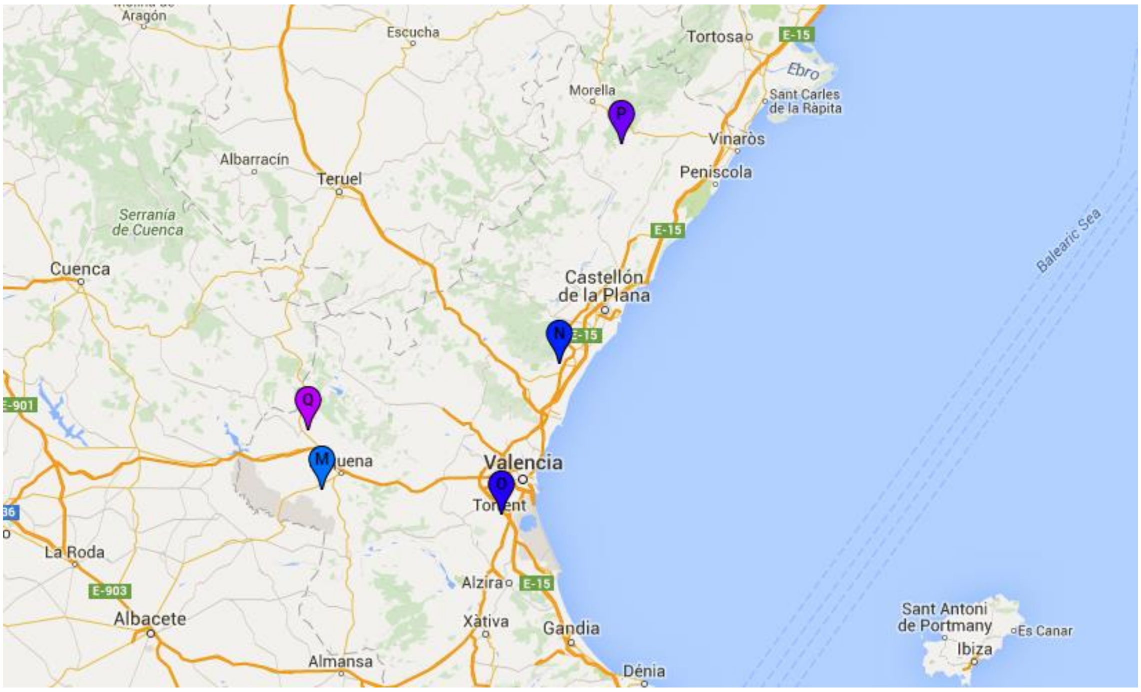



Figura 9. Zoom de las plantas estudiadas en La Comunidad Valenciana. [18]

M Requena(San Ramón) N La Vall d'Uixó O Picassent P Catí Q Utiel

## 4.3. PLANTAS DE BIOGÁS PROCEDENTES DE VERTEDEROS Y DEPURADORAS

En Cataluña hay 6 plantas de tratamientos de aguas residuales con aprovechamiento del biogás, en Rubí, Tarragona, El Prat de Llobregat, Reus, Vilanova i la Geltrú y Granollers. También cuenta con algún vertedero en el que se aprovecha el biogás.

En Valencia hay EDAR en Ontoniente, Aldoros-Elche, Alcoy, Gandía, Pinedo, Quart, Paterna, Castellón, Carraixet-Bétera, Pobla de Farnals y Ontinyent.

## 4.4. MARCO DE CATEGORIZACIÓN

En este marco de categorización las plantas son clasificadas en las siguientes categorías: Substrato, organización, uso del biogás, tecnología de digestión y capacidad.

**①Gimenells ②Castelló de Faranya ③Torregrosa I ④Torregrosa II ⑤Torres de Segre ⑥Balaguer ⑦Cassa de la Selva ⑧Montargull ⑨Vila Sana ⑩Miralcamp ⑪ Mas Bes ⑫Juneda-Tracjusa ⑬Torre Santamaría ⑭Almenar ⑮Sant Mer ⑯Granja San Ramón ⑰Vall Duixo ⑱Tramavé/Picassent ⑲Catí ⑳Utiel**

| Substrato | Organización | Uso del Biogás | Tecnología de Digestión | Capacidad* (Suma de todos los digestores) |
|---|---|---|---|---|
| Estiércol ① ② ③ ④ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰ ⑲ | Municipalidad ⑰ | Electricidad para su venta ② ③ ④ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰ ⑱ ⑲ ⑳ | Mesofílica (15-45 °C) ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰ ⑱ ⑲ ⑳ | Pequeña (< 2,000 $m^3$) ③ ⑦ |
| Residuos Industriales ⑰ | Comercial ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑱ ⑲ ⑳ | Calor para uso interno ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑱ | Termofílica (40-65 °C) | Media (2,000-5,000 $m^3$) ① ② ⑥ ⑧ ⑨ ⑪ ⑬ ⑯ ⑱ |
| Cultivos ⑤ ⑯ ⑰ ⑳ | El propietario del sustrato ⑯ | Electricidad para uso interno ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰ ⑱ ⑲ ⑳ | | Grande (> 5,000 $m^3$) ④ ⑤ ⑩ ⑫ ⑮ ⑰ |
| Residuos de matadero ③ ⑤ | Propiedad compartida | Calor para su venta ⑰ | | |
| Desechos domésticos ⑤ ⑥ ⑦ ⑧ | | | | |

Tabla 1. Marco de categorización  con las plantas de biogás estudiadas.

*No hay acceso a la información de la capacidad de las plantas ⑭ ⑲ ⑳

Estudiando esta clasificación se puede obtener algunos resultados y conclusiones, así como conocer qué aspectos tienen estas plantas en común. Como se puede apreciar, la mayoría de las plantas usan estiércol animal en bruto para la producción de biogás.

En España la mayoría de las plantas de biogas actualmente son privadas. El gobierno no apoya económicamente este tipo de energía. Esto debería cambiar ya que se necesita una alta inversión inicial para desarrollar este tipo de plantas y tienen una baja rentabilidad, por ello el gobierno debería proporcionar ayudas. En el único caso en el que se la planta es municipal, Vall Duixo, emplean la energía eléctrica generada para el suministro de casas y la térmica se distribuye gratuitamente a los establecimentos locales.

El uso que se le da al biogás es solo para la producción de energía eléctrica o térmica.

La mayoría de las plantas tienen una capacidad media.

# 5.CONCLUSIÓN

Se ha conseguido obtener una visión de conjunto de la situación actual del biogás en las provincias de Barcelona y La Comunidad Valenciana. A pesar de que no se ha conseguido toda la información que se hubiera deseado, lo obtenido es suficiente para hacerse una idea de cómo las plantas de biogás están trabajando, su tamaño, los sustratos que se están utilizando y el uso que se le da a los productos en cada planta.

El capítulo de la historia y legislación en España permite comprender cómo se ha ido desarrollando el biogás en estas zonas y porqué su desarrollo ha sido tan lento. También ofrece un pronóstico hacia el futuro con una nueva perspectiva de los cambios que sería necesario hacer.

# BIOGAS SITUATION IN CATALUÑA AND VALENCIA, SPAIN


Blanca Sarralde

Department of Energy Systems

Linköping University, Institute of Technology


Tutor, Emma Lindkvist

Examinator, Magnus Karlsson

LINKÖPING UNIVERSITY

Linköping 2016

# ABSTRACT

This bachelor thesis is focused on studying the biogas production in Spain. This includes structure, prerequisites and the necessary documents and licenses. Several questions are answered in this study, such as which raw materials are used for the production of biogas, what uses are given to the biogas, or which ratio of treated material and biogas is obtained.

This study is framed in a larger one related to the situation in other European countries. It is extremely useful for the assessment of the biogas situation in each country and the comparison with neighboring countries.

Once obtained the necessary information the common pattern of the biogas plants in Spain was found. This enables an overview of the different types of plants that can be built and which are most effective and appropriate in each case.

Previous projects have been carried out in countries such as England, Denmark, Germany or Sweden, coinciding in the difficulties to compare different plants, even though there might be similarities between them. Therefore, a deeper review is implemented in order to obtain a clarifying conclusion.

Additionally, the study pursues the following issues: The situation and history of biogas in Spain within the European context and a brief introduction to the production of biogas to understand the categories used in the classification of plants and in the framework. Subsequently, the characteristics of each plant are presented separately.

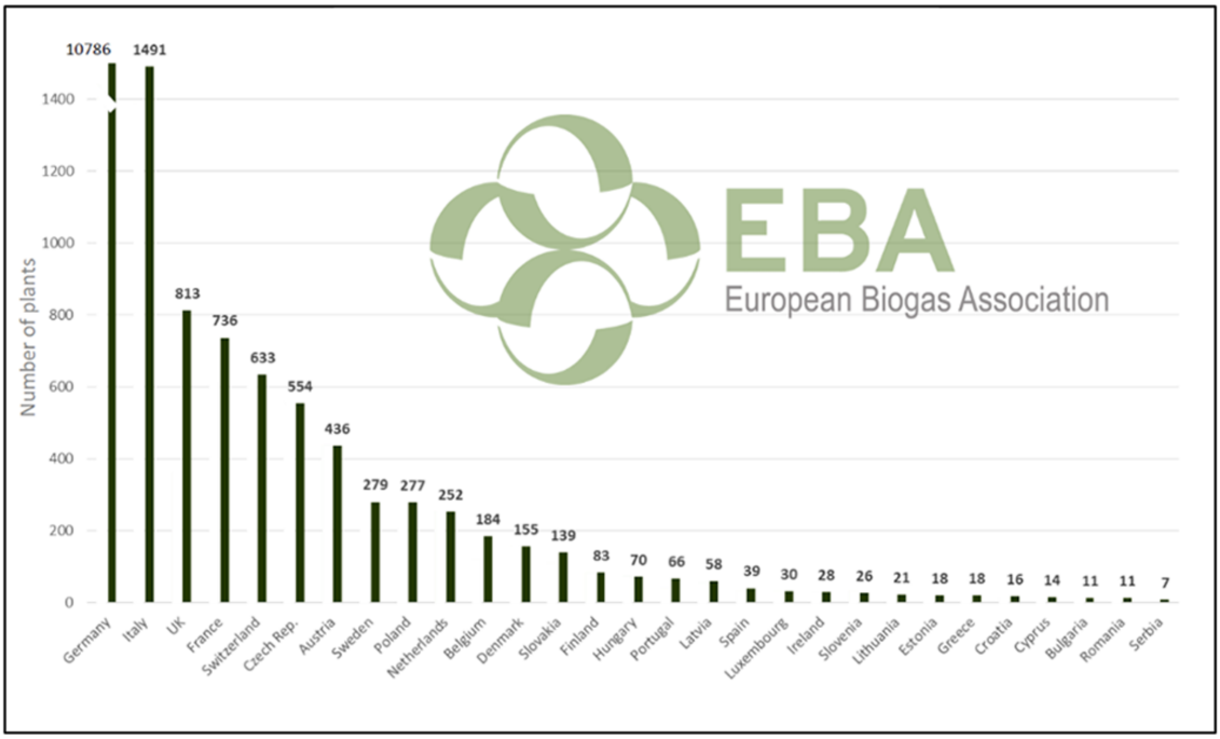
The study concludes with the evaluation of the results and a few plans and schemes.

# TABLE OF CONTENTS

# 1 INTRODUCTION: BIOGAS IN SPAIN, EUROPE

Spanish Agro-industrial biogas production is located at the very end of the European Ranking. Meaning of "Agroindustrial biogas" as biogas from agro-industrial substrates such as e.g. cattle manure, sludge from food processing industries, crop residues, energy crops, etc. [53]

In Spain there are located the 0.22% of biogas plants in Europe. Immediately after goes Luxembourg, with a 200 times smaller territory and a minor density of production of purines, which is rather contradictory. This is due to the Spanish Government promotion of wind and biomass energies, leaving the biogas energy in the background. [1]




**17 240 biogas plants in Europe (31/12/2014)**
**Total installed capacity of 8 293 $MW_{el}$**

Figure 1. Biogas plants in Europe [2] [65]

At the annual published statistics by the European Biogas Association, EBA, in 2014, which we can see in the Figure1, Spain occupied the 18th position with 39 Agroindustrial biogas plants. However, that number of plants still stratospherically away from the first countries, led by Germany with 10,786 plants. The next place is occupied by Italy with 1,491 plants, followed by the 813 plants in the UK, 736 in France and 633 in Switzerland.

Spain advances slightly in positions (the 22nd to 18th) and plants (22 to 39) from 2012 to 2014, but does not exceeds the fifty installations, such as Latvia (59) and Portugal (66).

According to the latest statistical report of the EBA, the European Union had 17,240 plants (8,339 MW) in 2014, 2,677 more than the 14,569 (7,857 MW) of 2013, which maintains a growth rate of almost 20% annually. Among the most notable case is UK passing from 360 plants in 2013 to 813 plants in 2014, more than double plants they had in the previous year.

In the report of the European agro-biogas we can find that the production of electricity from this biofuel reaches 63.3 TWh which corresponds to the annual consumption of 14.6 million European homes. [3] The EBA said that biogas in Europe has acquired enough development to resist in times of lower profitability while new development opportunities are been researched.

The EBA has encourages the development of the implementation of new policies for renewable energies, such as the Paris agreement of the last summit of climate change. The EBA wants the Member States to mark their objectives in renewable energy in heating for 2020-2030.

Another point to consider is to standardize the European biomethane to flow through the network of natural gas continent. In that way in relation with biogas, the European Commission, EC, should encourage the member states to maximize the overall efficiency of their plants by using heat recovery for use directly in the plant itself, in nearby buildings or heating networks. The EC has also mentioned the importance of replacing the consumption of gas by biomethane.

To achieve effective marketing and injection of biomethane into the gas networks, EBA thinks that a common European market should be encouraged. For the actual replacement it is necessary to assimilate the special properties of biomethane for injection into the network. [1]

The European biogas industry has tremendous potential for further development. The industry is facing major challenges so it needs special attention and targeted, stable political support. [54][4]

## 1.1 AIM

The aim of the project is to obtain all the information available on the current situation of biogas in Spain and the biogas plants that are currently active. There are now 20 biogas plants in operation in Cataluña and Valencia.

The information includes how they work; data and results in tables in order to have an overview of the biogas in Spain.

A framework is created from the information gathered from several plants. This framework is useful to compare the similarities and differences of the plants.

In addition it is also presented the national and regional legislation related to biogas environment.

# 2 METHOD

The tools used to undertake this project are:

- Direct contact with associations such as AEBIG (Spanish Association of biogas), APPA (Association of Renewable Energy Producers) and EBA (European Biogas Association)
- Research on the net: articles, website of plant constructions, operation and structure of several companies...
- Emails and phone calls to those companies and plant managers.

As it has been mentioned, I will search the current Spanish legislation related to energy environment to explore why biogas is underdeveloped in Spain.

The first step is get good contacts at locations of interest. A large network of contacts is essential to investigate in depth about their work. By contact network I mean, to establish contact and send emails to websites that lead the biogas plants and other websites of interest.

Once this is achieved, the plan will be based on going to collect all the necessary information, classify it later to make comparisons of methodology and conclusions.

In order to classify the information obtained, there is a predetermined framework with the relevant information classified into categories. Through this framework will be known which categories are most common and thus be able to make a comparison in the future with other countries.

# 3 HISTORY

The existence of biogas was met several centuries ago, as this occurs naturally in swamps, is called swamp gas. Natural gas, which in its composition is mostly methane, was used by the Chinese and Persian peoples thousands of years ago as a heat generator. Many years later it was realized that methane is not only found in the fossil natural gas, but constantly produced.

In 1776 the Italian scientist Volta discovered that the main compound of natural gas was methane. Later in 1808 the British chemist Humpry Dhabi produces methane gas in a laboratory. This event is taken as the beginning of the research into biogas. Only 100 years after the microbiological origin of methane was found. In 1887, Hoppe-Seyler scientist could check the formation of methane from acetate.

In 1888 Gayon obtained biogas by mixing manure and water, at a temperature of 35 ° C. Soehngen discovered in 1906 methane formation from hydrogen and carbon dioxide. He described the first two agents involved in the formation of methane. Later in 1920 the engineer Karl Imhoff implemented the first digester in Germany. [5]

India experienced since 1939 with various systems for application in cold or hot weather. In Europe and the United States complex chemical phenomena that occur during the digestion process were investigated.

In China, India and South Africa, due to the lack of funds co digestion methods were spreading and developing. Today these countries have more than 30 million digestors functioning properly, and they are developing techniques of biogas generation in small and large scale. China is the country that has implemented the use of biogas in larger scale. There are more than seven million rural digesters in operation. [6]

Figure 2. Rural digester [63] [64]

In Sweden, biogas has been produced in wastewater treatment plants in the country since the early 1960. The original reason was to reduce sludge volumes, and because the oil crisis of 1970 people began to stimulate research and the development of biogas processes. Now, the goal was to reduce oil dependency and environmental problems.

During the 1980s, extraction from landfills began in many places in Sweden. Since the mid-1990s, several new biogas plants treating various organic materials were built. Waste such as food industry, slaughterhouses and food waste from households, commercial kitchens and restaurants are digested. [7]

## 3.1 The biogas in Spain, history and legislation

After discussing the general history of biogas we can move forward and learn how the development of biogas in Spain was. For this purpose we will discuss the legislation that either propelled the progress of this energy or prevented its development.

### 3.1.1 National legislation

In Spain there are only 39 biogas plants, 0.22% of biogas plants in Europe.

The beginning of biogas plants was the **Royal Decree 661/2007** which was launched in the State official newsletter [9] .This decree was launched the 25 May, it regulates the activity of production of electricity in the special regime. This decree brought very fair premiums for profitability. Only the best plants that manage waste or slurry in certain areas with very large farms could be profitable. Besides, the lack of experience in the sector, the lack of knowledge on this technology and the long processing allowed very few biogas plants to be built. They were built at a slow pace in comparison with other renewable technologies that developed greatly during this period.

Previously was approved the **Royal Decree 616/2007**[9] of 11 May on promoting cogeneration.

The Ministry of Industry and Tourism resolution of 7 April 2010, the Secretary of State of energy, published the values of the cost of the raw material and the base cost of the raw material of natural gas for the first quarter of 2010. For the purposes of calculating efficiency complement and the compensation values of the cogeneration facilities.

When the **Decree Law 1/2012** [9] was approved the premiums for all renewable with "temporary nature" ended and that many biogas plants under construction remain hanging without profitability. It's been four years and the government has only allowed build new biomass and wind facilities by **Royal Decree 947/2015**[9], but no biogas plants.

Then came the **Royal Decree Law 9/2013** [9], known as reasonable profitability, which basically cuts bonuses to all existing renewable energy facilities including biogas. Despite the few biogas plants in Spain it meant a cut between 15 and 30% of the premium received, especially preying on small plants. This caused that many existing plants were in an extreme financial situation and they had to refinance their loans. It also generated a great distrust in investment in renewable energies and biogas. [8]

Finally the government approved **Royal Decree 900/2015**[9], known as 'tax on sun'. This is the most restrictive rule in the world and prevents the construction of biogas plants. This decree makes the legalization process more expensive and more complex in a bureaucratic level. To begin the procedure for dealing is necessary to request a connection point to the power company. Even if you are not going to pour any surplus production to the electricity grid. All own consumption facilities must pay the revolutionary tax for the energy generated and self-consumed without this pass at any time by the electricity distribution network. [55]

Also, does not exist in Spain a law to promote biomethane or refined biogas injection to the gas network.

In Spain, unlike most European countries, if it were generated biogas for vehicles the government would collect fuel excise as with fossil energy. In addition, they charge a tax for generating biogas and another for the sale of electricity. [8]

### 3.1.2 Plans and policies that define the guidelines to follow

In this section are reported the plans that have guided how should be the behavior in Spain regarding the renewable energies, in particular biogas.

-Renewable Energy Plan (PER) 2005-201099

-National Integrated Waste Plan (PNIR) 2008-2015100

-Slurry Biodigestion Plan 101

-Sectorial -planning Gas and Electricity 2008-2016102

This plans can be find in [11]

Below proceed to individually analyze each of these plans:

[56]

#### *3.1.2.1 Renewable Energy Plan (PER) 2005-2010*

It is necessary to consider that, from the date of drafting the Plan, the biogas sector has increased dramatically in Europe, so some of the determinations included in the Plan are obsolete. The objectives marked in the previous plan for the year 2010, were widely achieved in 2003, with 7 years in advance, reflecting the jump in the market.

When the Plan came into effect, there were only 30 biogas generation projects in operation in Spain. In the Plan a list of the main barriers to the development of the energy use of biogas is carried out, indicating the following:

-Barriers in the production phase: Alternative of economic interest, especially liquid manure drying using natural gas as fuel.

It was included in the special regime electricity production of thermal drying of slurry with natural gas as fuel. This has driven away potential investors from the use of anaerobic digestion technology for the treatment of this waste, for purely economic reasons. [50] This thermal drying plants were the ones used before the co-digestion to treat slurry, with the residual heat of combustion, electricity is generated and sold into the grid. It is an easier and cheaper way to get rid of the problems they cause, emission of greenhouse gases, soil contamination and odors. Remain the biodigestion the method currently supports by the advantages it offers. [51]

For the use of livestock waste, the development of anaerobic digestion technology is not common in rural areas, farmers perceive it as something alien to their activity. The same happens to biodegradable industrial waste and for the sewage sludge from urban waste water for the production of biogas for energy purposes.

-Barriers in the implementation phase: High investments.

The main interest in developing the energetic use of biogas is for environmental reasons, no energetic. This is because of the high investment per unit of installed capacity. This also causes that projects are viable only for certain amount of waste treatment.

To minimize barriers in the Plan there is a group of measures designed to encourage the establishment of energy for the use of biogas through the promotion of the sector: Dissemination of existing technologies among the institutions concerned, such as municipalities, provincial and others.

#### *3.1.2.2 National Integrated Waste Plan (PNIR) 2008-2015*

The National Integrated Waste Plan, published in BOE of 26 February 2009 [], is the basic document for management strategies of different wastes generated in Spain.

In this Plan is presented the Spanish strategy to reduce the amount of biodegradable waste going to landfills. A series of measures is established to minimize the input volume of biodegradable waste in landfills. Among these measures, we can find the following:

-Promoting waste separation at source level house.

-Increase separation activities in management plants.

-Increasing demands from landfills for accept waste.

- Valuation activities: Composting, biogas, energy recovery (incineration)

- Adaptation of the biomethanisation processes to the treatment of the organic fraction of municipal solid waste. In the plan the following are designated as priority actions:

  -Conducting pilot projects to promote selective collection and recycling.

  -Actions to promote home composting

  - Collection and use of biogas in landfills RSU

  - Recovery of contaminated soils

  - Actions to eradicate illegal dumping

#### 3.1.2.3 *Slurry Biodigestion Plan*

The Government of Spain has designed a plan to reduce GHG emissions by treating 9.5 million tons of manure per year, reducing $CO_2$ emissions in a volume of 1.78 million tons per year.

In the Plan is discussed, among other issues, the agricultural valorization of the digestate generated during anaerobic digestion processes. The document highlights the problems arising from the use of untreated manure as agricultural fertilizer, which creates inconveniences due to the excessive presence of nitrates in the soil.

Is discussed the feasibility of using covers rafts slurry indicated, using the biogas generated in an inexpensive way. This is increases the chances of developing regions with limited resources, and minimize their energy dependence. This Plan provides the basis for subsidies to install mechanisms using biogas.

#### 3.1.2.4 *Sectoral Planning Gas and Electricity 2008-2016*

The planning includes the production of renewable energy. On biogas are set the targets for 2011 and 2016. Electricity generation using biomass, biogas and waste should double by the year 2011 compared to 2006 and triple by 2016.

# 4 PRODUCTION PROCESS

Biogas is the gaseous product of the microbiological decomposition of biodegradable organic matter under anaerobic conditions (absence of oxygen). Its composition, which depends on the digested substrate and the type of technology used, can be as follows:

- 50-70% methane ($CH_4$).

- 30-40% carbon dioxide ($CO_2$).

- ≤ 5% hydrogen ($H_2$), hydrogen sulfide ($H_2S$) and other gases.

Methane, the main component of biogas is the fuel provides its characteristic. Therefore, the energy value of biogas is determined by the concentration of methane - about 20 or 25 MJ / m3, compared to 33-38 MJ / m3 of natural gas. That is, except for the H2S content is an ideal fuel, with equivalents shown in the Figure 3. below. [12]

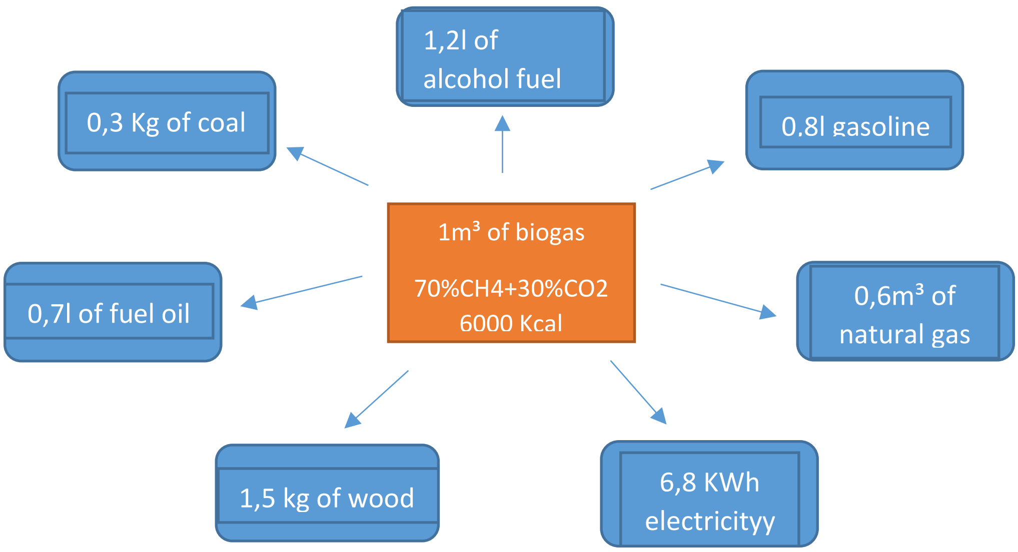



Figure 3. Fuel equivalents [12]

A biogas plant transforms biodegradable substrates into biogas and digestate. The main plant equipment are as follows:

• System of homogenization and feeding substrates

• Digesters

• Desulfurization system

• Cogeneration Unit

Feeding and homogenizing substrates varies according to their own characteristics. There are different methods of pretreatment of waste to improve the process. There are different pretreatment types: Thermal, mechanical, biological, chemical, thermochemical and ultrasounds.

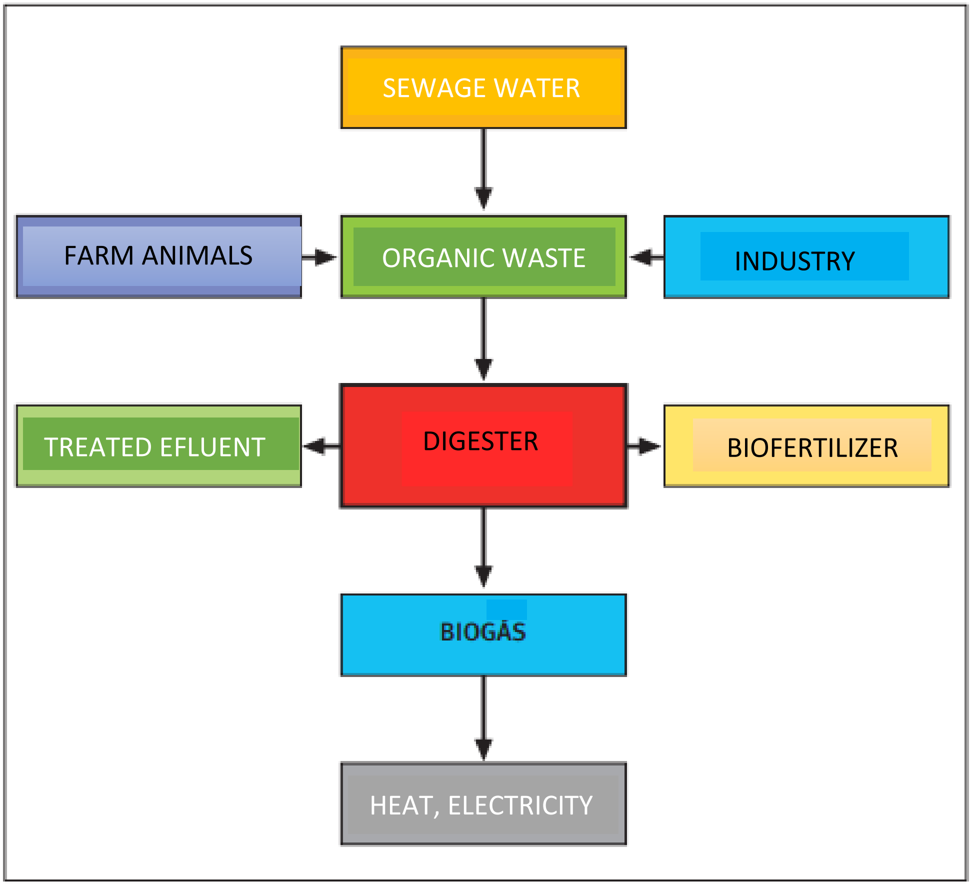



Figure 4. Process Overview [12]

Digesters are cylindrical tanks (concrete or steel) provided with agitation and heating equipment to ensure optimal process conditions of biomethanization.

In the installation occurs rapidly the natural decomposition cycle. Organic materials that are received are mixed and are led to the digesters, as it is shown in Figure 4. Inside these large closed containers without outside air and optimum temperature conditions, is where bacteria acts. From here biogas is obtained. The biogas produced is collected in a gasometer (which can be installed directly on top of the digesters or as a separate unit). Once hydrogen sulfide (H2S) is removed by a desulfurization system and dehumidified by condensation, biogas is fed to a cogeneration unit where it is transformed into electricity and heat. The biogas is fed to a cogeneration unit where it is transformed into electricity and heat. The electricity generated can be sold to the international electricity grid or be self-consumed. The heat covers own plant demand and the surplus can be used for heating. [13]

This are the uses given to the biogas actually in Spain. However, as is explained in one of the following sections, it can also be given other uses to the biogas produced in the plants.

Besides biogas, the byproduct after processing in the plant, the "digestate", can be used as fertilizer. This digestate is rich in inorganic nutrients, therefore very suitable for agricultural application.

## 4.1 Exploitable waste for biogas production

There is a wide variety of recoverable waste through anaerobic digestion, but not all have the same properties regarding the use. There are a number of variables of the different types of waste to be considered to enable the development of the procedure:

• Volume of waste available

• Contaminant potential

• Biogas production potential

• Methane content of the biogas generated

• Alkalinity

• Byproducts generated in the reaction: Methods of inhibition of the reaction.

• Number of volatile solids residue

• The need for pretreatment

• Etc. [56]

The most commonly used residues for the production of biogas are:

- <u>Waste from livestock farms:</u>

  Liquid pig manure and cow manure, chicken manure. In general, the potential for biogas production is not too high, because of its high nitrogen content and excessive liquidity to the process. However, because of its pollution to soil and abundance of the resource, these kind of residues are the first choice for generating biogas through anaerobic digestion.

- Agricultural waste:

Agricultural residues from energy crops, or food crops generating raw materials for the food industry are a suitable substrate, generally for anaerobic digestion. The problem is the seasonality of the resource.

- Waste from the food industry:

The processing of animal and vegetable raw materials for food manufacturing generates abundant waste that can be utilized for the production of biogas. Dairy, breweries, canneries, sugar refineries and similar industries produce waste with a high load of organic matter. Prior pretreatment may be necessary to maximize the potential for biogas generation.

- Fishing Waste:

The remains of fishing and processing of food products of the canning industry and similar happen to be a very good substrate for anaerobic digestion.

- Slaughterhouse waste:

This waste constitute one of the greatest potential for biogas generation. The remains of stomach contents, intestines, etc., as well as the remains of purification of effluents of this type of waste, are a very suitable substrate for biogas production, but generally, this use is carried out in co-digestion with other waste.

- Sewage sludge:

Wastewater treatment generates sludge of difficult treatment but very suitable for the generation of biogas. In fact, there are numerous sewage treatment plants that supply themselves with heat using biogas. [56]

- Municipal Solid Waste:

Provides a source of substrates for biogas production, assuming this operation as a way of recovery and reduce them. However, there is great variability in the potential of biogas production from these residues, based on previous separation operations. [14]

- Biogas from landfill:

Landfills use the biogas systems by placing a network of pipes and chimneys that lead back the biogas generated to the engines for power generation. Thus passively exploits the gaseous emission from the fermentation of waste disposal for the generation of biogas low in methane. [56]

## 4.2 Types of plant according residues that are used

Biogas plants can be grouped in three main types depending on the residue used as is shown in Figure 5.

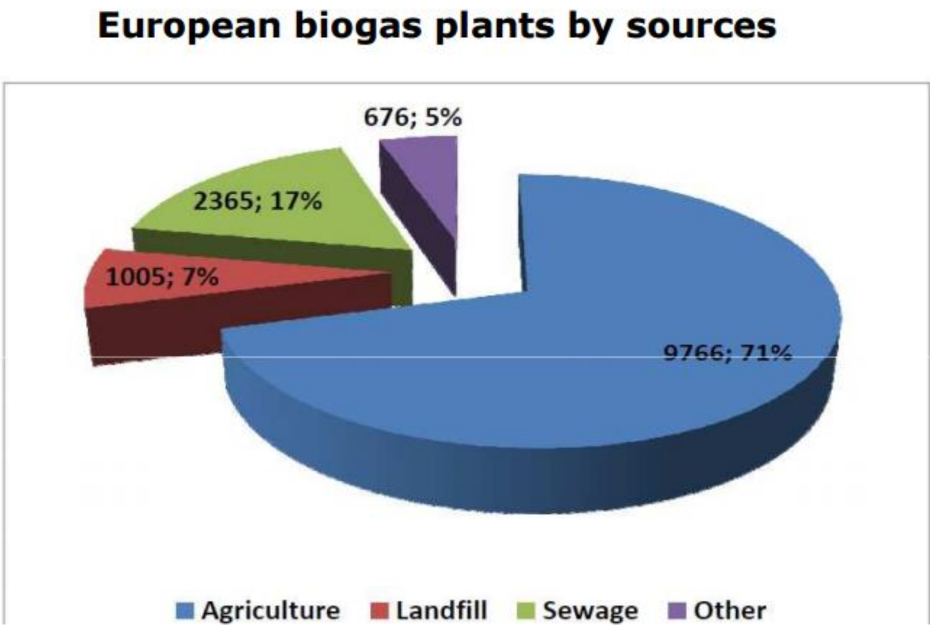



Figure 5. EBA Biogas Report 2014 [54] [65]

- Agriculture and Livestock

In Spain this plants are called agroindustrial biogas plants. As it was explained previously this type of farms work with substrates that came from livestock farms, agricultural waste, waste from the food industry and waste from slaughterhouses.

- Landfill

Landfills are those places where occur the deposit and storage of waste lacking of recovery or because there is no installation of screening compounds that minimizes the amounts sent to it.

Inside anaerobic reactions are produced, so that the organic fraction of the waste degrades generating what is known as "LFG" or landfill gas , which must be collected and stored for later energetic use.

- Sewage

There is a growing tendency to consider the Waste Water Treatment Plants (WWTP) as resource recovery systems, rather than only facilities to prevent release of pollutants to the environment. The recovery of energy and added value products maximizes the economic and environmental potential of the facilities, thereby allowing the reduction of operating costs.

Among the technologies for the use of biogas in WWTPs the combustion in boilers is the most implemented, generating the heat necessary to maintain the temperature of the digesters, cogeneration plants, producing heat and electricity, and more recently, microturbines.

The microturbines by integrating an innovative turbine engine, magnetic generator, advanced power electronics, and patented air bearing technology, continue to define the standard for clean and reliable energy solutions. The main difference of a microturbine in comparison with a normal turbine is in the fact of having a recovery cycle to improve the electrical performance. [52]

## 4.3 Use of products

First it is defined the different parties involved in the production process:

**- Production process**: an activity whose main objective is to obtain a product with specific characteristics, as in industrial production and agricultural and livestock production.

**- Product**: any material deliberately obtained in a production process. In many cases it is possible to identify a "primary" (or more) product, which is the principal material produced.

**- Waste from production processes**: material that is produced in a production process unintentionally.

**- Byproduct**: substance or object, resulting from a production process whose purpose is not the production of that substance or object that meets the four conditions set out in paragraph 1 of Article 4 of Law 22/2011, of July 28 [62], and is declared as such by the relevant decree.

**- Producer of the byproduct**: person who produces the by-product in a production process.

**- Receiver of the byproduct**: person in whose production process is used the by-product instead of a raw material. [15]

From the anaerobic digestion of organic waste the following products are obtained:

1. Biogas
2. Biofertiliser or compost

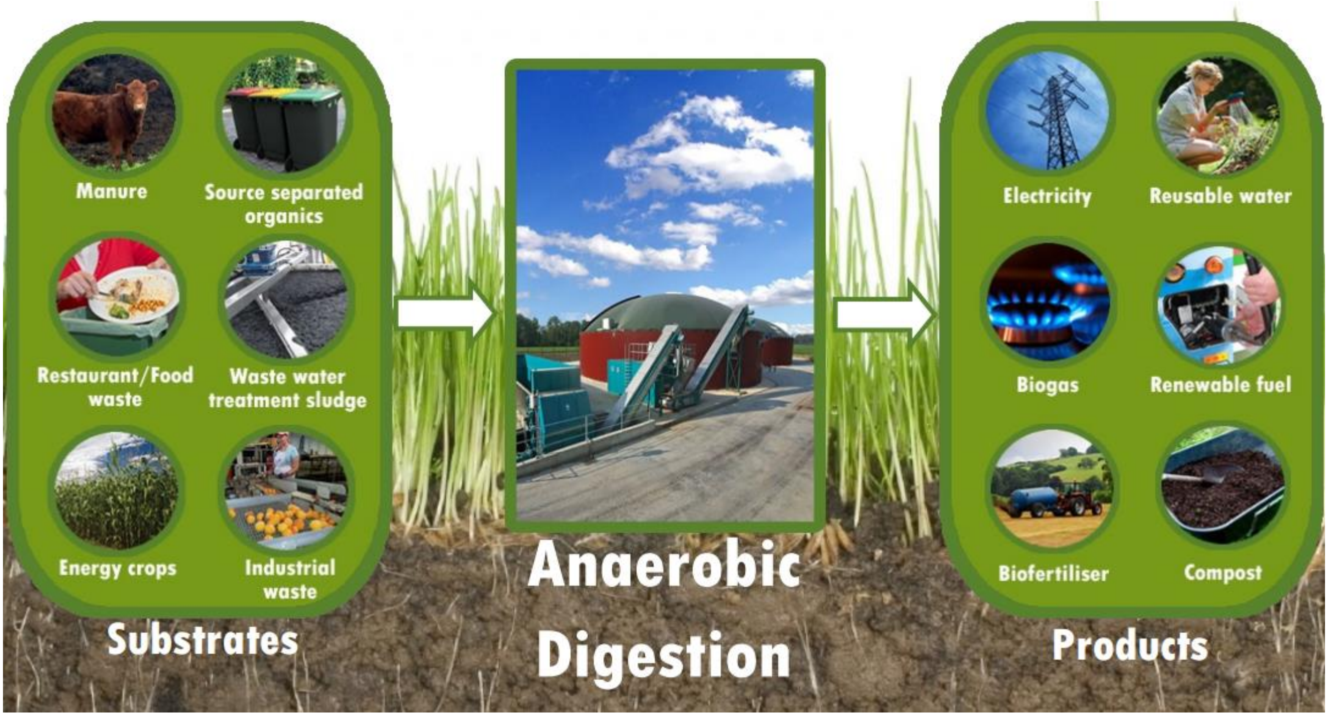


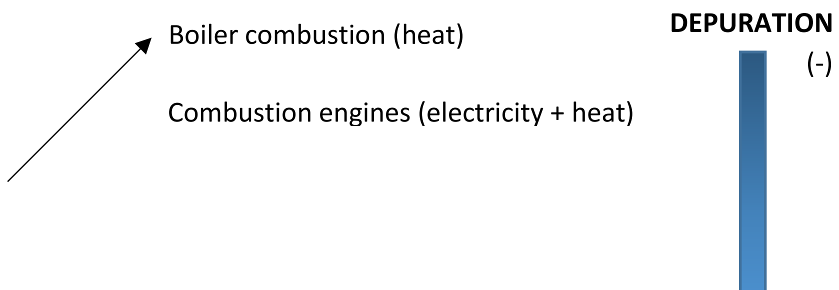
Figure 6. Anaerobic digestion products [16] [65]

### 4.3.1 Biogas

The biogas is the main product of the anaerobic digestion and it has the following uses:

- In a boiler to generate heat or electricity.
- In engines or turbines to generate also electricity and heat
- In fuel cells, after performing a cleaning H2S and other contaminants.
- Purify and add additives for insertion into a network of natural gas.
- Automotive fuel.

[12]



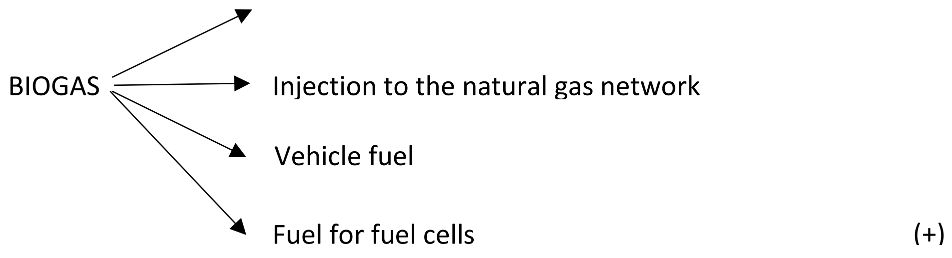



Figure 7. Applications of biogas according to its purity [57]

### 4.3.2 Biofertiliser

Digestate is a by-product of the anaerobic operation. Digestate is an excellent fertiliser containing all nutrients and micronutrients necessary for modern farming, including nitrogen, phosphorus and potassium. Digestate has proven to be a much safer fertilizer than nutrients from raw organic material. It is safer because its use reduces the risk of water and soil pollution resulting from high concentrations of minerals in a reduced space.

One ton of artificial fertilizer replaced with digestate saves 1 ton of oil, 108 tons of water and 7 tons of $CO_2$ emissions. [16]

# 5 BIOGAS PLANTS IN SPAIN (CATALUÑA&VALENCIA)

Currently there are 15 agroindustrial biogas plants operating in Cataluña and 5 operating in Valencia. Its location is shown in Figure 7. The study made below will focus on these 20 plants.

There are also sewage and landfill biogas plants but as I have no information of them all, and they won´t be included in the framework I have not located them on the map.


Figure 7. Studied agroindustrial plants in Cataluña and Valencia [18]

## 5.1 AGRICULTURE & LIVESTOCK PLANTS IN CATALUÑA

Cataluñ is currently, of the 17 autonomous communities in Spain, the one with the largest number of biogas plants. As it is shown in Figure 8, it has 15 plants and most of them are located in the province of Lleida.


Figure 8. Zoom of the studied plants in Cataluña. [18]

A Gimenells B Castelló de Farfanya C Torregrossa I &II D Torres de Segre

E Balaguer(&Torre Santamaría) F Montargull G Miralcamp H Juneda I Almenar

J Cassà de la Selva K Mas bes L Sant Esteve de Guialbes(Sant Mer) S Vila-sana

### 5.1.1 GIMENELLS (A)

Plant 100% for their own consumption. It is located in the town of Alcarrás near the village of Gimenells, province of Lleida. The plant was built by the INDEREN group was put into operation in 2014. The plant belongs to Ecobiogas company. [20]

It is located in a farm and deals mainly with excrements from the farm with the possibility of mix it with other products.

The biogas cogeneration engine is capable of generating 100KW covering electrical power consumption of the farm and 121 kW thermal power destined for animals heating. Furthermore, in this installation has been introduced a 200KW biogas boiler to adjust-heating demand which is much higher than electricity in the cold months.

Thus manages to reduce to almost zero spending power supplies and heating oil. [19]

<u>TECHNICAL DATA OF PLANT:</u>

• Capacity: 1 digester of 2,490m³

• Digester type: mesophilic operation

• Annual heat production: 1,200,000 kWh / year

• Annual power production: 480,000 kWh / year

• Electric motor power: 100 kW

• Thermal motor power: 121 kW

[21]

In this, as in the following plants, when it is written “thermal and electrical motor power” It is referring to the same engine.

### 5.1.2 CASTELLÓ DE FARANYA (B)

Facility built by ecobiogás which is located inside a farm of pigs and near a chicken farm in the province of Lleida. It was launched in 2013. As Gimenells belongs to INDEREN group. [20]

The plant treats only excrements of two farms, a mixture of slurry and manure, and the biogas produced is entirely intended to own energy supply. It has a treatment capacity of 16700 m³ of slurry and 1,800 tons of manure per year. [23]

By engine co-generation of biogas is capable of generating 100kW covering electrical power consumption of the farm and 121 kW thermal heating destined for animals. [22]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Capacity: 2,080m³ the primary digester and 1.300m³ the secondary

• Digester type: mesophilic operation with heat recovery

• Annual heat production: 3,300,000 kW thermal

• Annual power production: 2,900,000 kW electric

• Electric motor power: 100 kW

• Thermal motor power: 121 kW [21]

### 5.1.3 TORREGROSSA I (C)

Plant built by Ecobiogás in collaboration with Krieg & Fischer, the plant was launched in 2008. The organic material used are pig manure, sludge from slaughterhouses, and fats. The use that is given to biogas is to produce electricity and heat. A part is sold to the grid and the other part is used for consumption on the farm. [24]

The solid part of the digestate is separated from the liquid, solid is sent to an operator and the liquid is used as fertilizer.

<u>TECHNICAL DATA OF THE PLANT:</u>

• Capacity: 1,360 m³

• Digestor type: mesophilic operation (36 ° C)

• Annual heat production: 1,700,000 kWh thermal

• Annual power production: 1,500,000 kWh electric

• Electric motor power: 191 kW

• Thermal motor power: 215 kW [21]

### 5.1.4 TORREGROSSA II (C)

Plant in operation since 2014, is located next to a pig farm which supplies slurry to the plant. The plant can treat a total of 27,000 tons / year of liquid manure from the farm and other organic co-substrates supplied by an authorized agent (18,500 m³ of liquid manure and 8,300 m³ of organic waste).

Inderen was responsible for the construction of the heating system of the plant, as well as the entire network of pipes, manifolds and pressure equipment substrates, liquid, slurry and gas.

Of the operation and maintenance of the biogas plant is responsible the company APROFITAMENTS Energetics Agricoles, S.L., with experience in the field of biogas and waste management. [26]

From Som Energia it is done a daily monitoring of plant operation thanks to a remote system monitoritzation and follow-up meetings with operators of the plant. [25]

All energy generated by cogeneration, both electricity and heat will be self-consumed by the farm, selling surplus electricity to the grid at market price energy. It is generated 26,500 tonnes of digestate for agricultural use as fertilizer. [26]

TECHNICAL DATA OF THEPLANT:

• Capacity: 3 digestors of 1.700 m³ each

• Digestor type: mesophilic operation (36ºC)

• Thermal annual production: 4,320 MWh / year

• Annual power production: 3,992 MWh / year

• Electric motor power: 499 kW

• Thermal motor power:540 Kw [26] [21]

### 5.1.5 TORRES DEL SEGRE (D)

This biogas plant is located in the province of Lleida and was built by the German company Krieg & Fischer. The plant was launched in 2012.

Its organic residue derived from slaughterhouse sludge, kitchen waste and silage corn. It is a pioneer in Spain in generating biogas for energy crops such as corn or ryegrass. This plant operated for 8000 hours per year. The biogas obtained is used for the production of electrical and thermal energy. The 2.4 MW generated is equivalent to the consumption of 5,400 families. [27]

[

TECHNICAL DATA OF THE PLANT:

• Digester Capacity: 2 x 4,400 m³

• Digestion type: mesophilic operation [24]

• Electric motor power: 2,400 kW

• Thermal motor power: 2,000 kW [21]

### 5.1.6 OS DE BALAGUER (E)

Biogas plant located in the province of Lleida. As the previous one, it was built by the German company Krieg & Fischer in collaboration with the company Ecobiogas. It is an initiative of the Natura Energisat company that has 6,000 pigs. The construction of the plant was completed in 2009.

Of the biogas produced both electrical and thermal energy is obtained. It works for 8000 hours a year. Its treatment capacity is 10.500$m^3$ of liquid manure and 6.250$m^3$ of organic waste. [24]

TECHNICAL DATA OF THE PLANT:

• Capacity: Three digesters of 1,200 m3 [30]

• Digester type: mesophilic operation

• Annual heat production: 3,300,000 kWh thermal

• Annual power production: 2,900,000 kWh electric

• Electric motor power: 370 kW

• Thermal motor power: 411 kW [21]

### 5.1.7 CASSA DE LA SELVA (J)

The biogas plant is located in Casa de la Selva, Girona. This plant was built by the company Krieg & Fischer and was launched in 2008. It is running 8000 hours per year. It has a capacity of 10,500 m3 treatment of 6,250 m3 of liquid manure and organic waste. Organic wastes are working with pig manure, sludge slaughterhouses and fats.

[24]

TECHNICAL DATA OF THE PLANT:

• Capacity: 1,700 m3 [24]

• Digester type: mesophilic operation. A digester and secondary digester with a gas container

• Annual heat production: 3,300,000 kWh thermal

• Annual power production: 2,900,000 kWh electric

• Electric motor power: 370 kW

• Thermal motor power: 411 kW [21]

### 5.1.8 MONTARGULLL (F)

Agricultural biogas plant in Lleida, Cataluña. All substrates are pumpable input, for example, sludge, manure and fats, and are stored in a receiving tank before processing.

It was built by the company Krieg & Fischer and was launched in 2007. It has a gas container above the primary and secondary digest. Treatment capacity of 16,500 m3 of liquid manure and 7,000 m3 of organic waste.

The uses they give to the electricity are for own consumption of the plant and the farm. The surplus is sold to the grid. The thermal energy is used for consumption of plant and farm. [28]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Capacity: 2,080m$^3$ primary and secondary 1.300m$^3$ [24]

• Digester type: mesophilic operation with heat recovery

• Annual heat production: 3,300,000 kWh thermal

• Annual power production: 2,900,000 kWh electric

• Electric motor power: 365 kW

• Thermal motor power: 411 kW [21]

### 5.1.9 VILA SANA (S)

Vila-Sana is the first Spanish agricultural biogas plant. This plant belongs to the company Ecologic biogas. It was founded in 2007, the company has 9 years of activity. This plant is located in Vila Sana, an agricultural area of fruit and vegetable farming, in Lleida. The plant has been built by the company Krieg & Fischer. [29]

Treatment capacity of 11,000 m3 of liquid manure and 4,500 m3 of organic waste. It digests pig slurry and agro-industrial waste. [12]

The electricity generated is sold on the network and for auxiliary consumption of the engines. The thermal energy for own consumption of farms, greenhouse, and digesters. The weed elimination and mineralization digested slurry has improved qualities as fertilizer.

[24] [29]

<u>TECHNICAL DATA OF THE PLANT</u>:

- Capacity: Two digesters of 1,300 m³ .The third of 1,300 m³ was built in 2011
- Digester type: mesophilic operation
- Annual heat production: 2,500,000 kWh thermal
- Annual power production: 350,000 kWh electric
- Electric motor power: 382 kW
- Thermal motor power: 315 kW

### 5.1.10MIRALCAMP (G)

Plant opened in 2009 by the company Abantia. It is located in the municipality of Miralcamp. The materials are digested pig manure and small quantities of agro-industrial waste.

They use electricity to sell in the network and own consumption, and thermal only for own consumption of the installation.

The byproducts are sold as fertilizer formulation additives. [31]

<u>TECHNICAL DATA OF THE PLANT:</u>

- Capacity: 2 x 3,000 m³
- Digestor type: mesophilic operation (35 ° C)
- Annual heat production
- Annual electricity production [32]

### 5.1.11MAS BES (K)

Agricultural biogas plant located in Mas Bes province of Girona. It was built by the company Apergás . This plant was put into operation in 2010. The organic material used is from cattle manure, 4,320 tons of cattle manure and 1,334 ton of cow dung per year. Annually generates 808,902 cubic meters of biogas (1,320 t).

The thermal energy produced by the engines (approximately the same as the electric), 20% advantage to heat the digesters and over is released.

[34]

TECHNICAL DATA OF THE PLANT:

• Capacity: 2 digesters 1.700m³.

• Digester type: mesophilic regime (30-40 ° C)

• Annual power production: 1.625.000kWh [33]

### 5.1.12JUNEDA-TRACJUSA(VAG) (H)

Biogas plant in Juneda, Lleida. The plant is a project of Abantia in collaboration with SENER that manages the slurry generated on farms in the area. It has a treatment capacity of 110,000 tons / year.

The uses of electricity are the consumption of the slurry treatment plant itself and selling to the network (electric energy generated exported 125 GWh per year) , the thermal energy is also for self-consumption of the plant slurry treatment and production of pellets. As byproduct they also generate 6500t of fertilizer annualy. [30]

TECHNICAL DATA OF THE PLANT:

• Electric motor power: 700 kW

• Capacity: 2 digesters 3.000m³

• Annual electricity production: 16.3 MWh. [35]

### 5.1.13TORRE SANTAMARÍA (E)

Plant located in Lleida, which began operating in 2011. The plant was built by the company Krieg & Fischer. The material that is digested is cow manure.

It generates biogas producing electricity for self-consumption of the plant and sale in the network and also generates thermal energy consumption of the plant. The residue from the biogas plant is composted resulting organic material composted which is intended for sale and consumption

[36]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Electric motor power :190 kW

• Capacity: 2.100m³

• Digester type: mesophilic digester [24]

### 5.1.14 ALMENAR (I)

This plant is located in Almenar, Lleida and started its operation in 2014. The facility treats 450 t / day of farmers and food waste. The plant manages slurry from pig farms in five municipalities Segrià: Almacelles, Algerri, Ivars de Noguera, Alfarràs and Almenar. The company Okoteca was responsible for the construction of the plant currently owned by AMDA energy. [59]

The plant makes a comprehensive treatment of materials that have been digestated to concentrate all the fertilizer in solid form and produce a high quality water, which will be delivered 25,000 t / year of concentrated fertilizer. [58]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Digester type: mesophilic operation

• Annual heat power production: 26,500,000 kWh

• Annual electric power production: 24,000,000 kWh

• Electric motor power: 3MW

### 5.1.15 SANT MER (L)

This plant is located in Sant Esteve Guialbes, Girona. It was built by the company Apergás and as a partner the company BIOVEC. It was launched 2009. The plan uses cow manure to produce the biogas.

Use of biogas for production of electricity for sale to the grid and 10% for own consumption of the plant. Of the thermal energy produced by the engines (about the same as electrical), only used 20% to heat the digesters. The other is released over and through the motor cooling. [38] [39]

<u>TECHNICAL DATA OF THE PLANT:</u>

- Electric motor power: 500 kW
- Capacity: Two digesters 3532m³ total
- Digester type: mesophilic regime (30-40 ° C)
- Annual power production: 3.250.000kWh [37]

## 5.2 AGRICULTURE & LIVESTOCK PLANTS IN VALENCIA

Currently there are 5 biogas plants operating in Valencia. Its location is shown in Figure 9.

It is a small number of plants considering that in Cataluña are three times more biogas plants. It is true that there are 7 million inhabitants in Catalonia while in Valencia there are 5 million and that the area of the Valencian Community is slightly lower. However in comparison Cataluña has a further development of biogas.

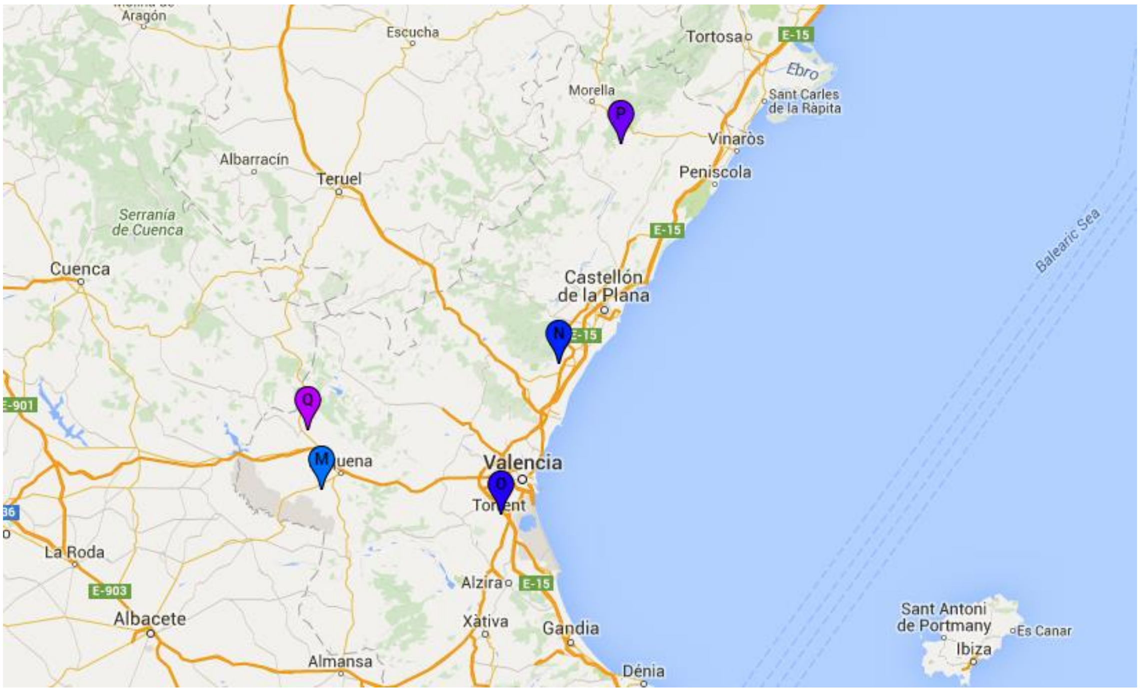



Figure 9. Zoom of the studied plants in Cataluña. [18]

M Requena(San Ramón) N La Vall d'Uixó O Picassent P Catí Q Utiel

### 5.2.1 GRANJA SAN RAMÓN (M)

San Ramon group is a Valencian company founded in 1973 and dedicated to the intensive rearing of cattle for milk production.

In 2001 Granja San Ramon came to Ainia technology center for help to solve an environmental problem associated with manure, main byproduct of their farming activities. So they decided to make a pioneering project in Spain with biogas as a source of renewable energy for electricity and heat production and fertilizer from the digestate from the fermentation products.

Finally in 2009 the company inaugurated a biogas plant in its new facilities in the state La Bonora in Campo Arcís near Requena, built by the company Ainia.

The plant has a capacity of 45,000 tons per year, 35,000 tons from manure from the farm cattle and 10,000 tons of byproduct from cooperatives and production plants orange juice.

Through these wastes are generated 4,000,000 kWh per year equivalent to the electricity consumed by about 307 homes and a reduction in $CO_2$ emissions of 2,808 tons. The thermal output is used to heat the manure at 37ºC. [40]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Capacity: A primary digester of 800 $m^3$ and secondary one of 2200$m^3$.

• Digester type: co-fed anaerobic digestion large digesters continuously under controlled temperature of 38 ° C (mesophilic)

• Annual power production: 4,000,000 KWh [40]

### 5.2.2 VALL D´UIXO (N)

BIOGAS plant in Vall d'Uixo, Castellón, Valencia. INDEREN has made the design and construction of container, pump room and of the biogas plant of the City council of Vall Duixo as land owner in Castellon de la Plana. Vall d'Uixo was the first municipality in Spain with a biogas plant municipal concession.

Inderen also in charge of the construction of the entire pipeline network equipment pressure and liquid distribution, substrates and gasification, as well as the assembly of different elements and control systems.

Thanks to this concession, the City will enter € 40,000 per year, which is the fee paid by the promoter dealership APLITEC S.L. for the transfer of the parcel as well as the recruitment of all staff related municipality.

The electricity generated will be enough to supply more than 1,000 families. A daily output of 5 MW. The thermal energy, produced will be allocated for free to the municipal offices.

Currently, as raw material, citrus residues are used in disrepair and dairy sera from cheese-making, pig or cow manure and sewage sludge. [43]

TECHNICAL DATA OF THE PLANT:

- Capacity: Two digesters 3200m³ each
- Digester type: mesophilic operation (38-40 ° C)
- Electric power: 500 KW [41] [42]

### 5.2.3 TRAMAVÉ/PICASSENT (O)

Plant located in Picassent, Valencia. This plant was launched in 2009. It works with approximately 40,000 tons / year of agro-industrial wastes of various origin. Aczia biogas is the owner company of the plant.

Electricity generated from biogas part is for self-consumption and surplus for sale to the network. The digestate obtained as byproduct separates the liquid and solid part and gives agronomic use. (*)

TECHNICAL DATA OF THE PLANT:

- Capacity: 2500 m³
- Digester type: mesophilic operation, 37ºC
- Annual electric power production: 80.000.000 kWh
- Electric motor power: 2 motors of 500 kW

### 5.2.4 CATÍ (P)

In 2011 the company from Navarra, SPD Biogas, has launched the biogas plant in Catí in the province of Castellon. The facility, with an electrical output of 500 kW, will manage most of the agricultural waste in the area.

The biogas plant Catí has been managed entirely by SPD Biogas S.L., from project design, plant design, procurement of administrative procedure, construction, commissioning and supervision of the it.

Electrical use through the electrical grid connection. Initially thermal use not contemplated but it is possible to use it through the installation of a greenhouse.

As explained by the company, these residues will allow 1.7 million $m^3$de produce biogas, which will involve an electrical power of 4,380,000 kW hour. From the plant it can be extracted more than 25,900 tons of liquid fertilizer and over 11,000 tons of solid fertilizer. [44] [45]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Digester type: Wet Fermentation Technology

• Annual power production: 4,380,000 kWh

• Electric motor power: 500 kW (*)

### 5.2.5 UTIEL (Q)

Gestrevin, located in Utiel-Requena, in addition to the recycling of waste wine from wineries, applies a number of improvements to processes performed to maximize waste and energy generated in its activity.

This cooperative purchase lees from 26 wine cooperatives in Requena-Utiel and transforms them into various products.

Thus, you get alcohol, with which liqueurs are made, but also for industrial use. It is used for the pharmaceutical industry for the manufacture of cosmetics and to make biofuels.

[46]

The biogas plant began operating in 2009. The plant uses the biogas generated at its facilities in the purification of waste waters and to sell it to the grid. (*)

Use given to the digestate after separate solid and liquid composting is used for agronomic application. [46]

<u>TECHNICAL DATA OF THE PLANT:</u>

• Digestor type: mesophilic operation, 37ºC (*)

• Electric motor power: 500 kW

## 5.3 LANDFILL & SEWAGE PLANTS

In Spain this type of plants are under municipal jurisdiction so it is quite difficult to access to the data of most of them. However, most of sewage and landfill plants that produce biogas are shown in the following list:

### 5.3.1 CATALUÑA:

- Sewage plant in Ruby

The Wastewater Treatment Plant (WWTP) of Edar Rubi was Realized by the Barcelona-based company Micropower Europe SL, a joint venture Between the Spanish AESA Group and the Swiss company Verdesis Suisse SA, the exclusive Capstone distributor for the Spanish and the Portuguese markets .The electric power of the installation is 195 kWe.

Since November 2006, the WWTP of Rubi has re-EVALUATED Capstone microturbines ITS using biogas to create heat and power. This micro-cogeneration installation with three CR65 microturbines and an external heat exchanger has become an Important reference site for other wastewater treatment plants of Spain and where have been obtained excellent results.

This is the first sewage plant in Cataluña in which microturbines for biogas energy recovery were installed. [60] [47]

- Sewage plant in Tarragona

Installation electric power of 265 kWe. The technology used is motogenerator. [47]

- Sewage plant in El Prat de Llobregat:

Electrical power of the installation 10,780 kWe. Technology used motogenerators.

It is the largest installation of Cataluña regarding installed capacity.

In the plant of El Prat, biogas available (approximately 4,923,000 m3 / year) is used in a cogeneration installation that provides the heat required for thermal drying of sludge generated in the sewage plant. Two of the four engines are installed dual motors, which can work either biogas or natural gas. [47]

- Sewage plant in Reus

The electrical power of the installation is 240 kWe and the technology used is a motogenerator.

The biogas produced in the plant of Reus is characterized by being very clean and thorough treatment not be necessary prior cleaning (only biogas moisture is removed).The reason is that the process of wastewater treatment plant includes a step of physical-chemical water treatment.

Note that in Reus there are three digesters, two mesophilic, while the third is thermophilic digester, performing the functions of storage and mixing mud.

Reus turnover last year 348,113.33 euros from the sale of electricity produced in the industrial water treatment plant. Most of this energy is produced from the use of biogas resulting from organic waste that previously, and through the debugging process, have been isolated from the dirty water that reaches the treatment plant in through the sewer system .

On the one hand, part of the reclaimed water is used to irrigate fields and on the other, they end up getting two products: biogas (as an energy resource) and compost.

In the case of Reus, biogas obtained is intended, in part, to generate heat in internal processes of self-purification station and elsewhere, it is marketed as electricity produced by cogeneration. [47]

- Sewage plant in Vilanova i la Geltrú:

The electrical power of the installation is 230 kWe and the technology used is a motogenerator.

This is the first sewage plant de Cataluña that has a system for ultrasonic sludge disintegration.

Due to the high cost of constructing a new digester was decided to install a system of ultrasonic disintegration of the sludge reduces the time retention sludge digestion in approximately 8 days.

The experience of the application of this system in the wastewater treatment plant Vilanova translates into increased biogas production around the 56%.

This has contributed to the degree of self-sufficiency of the plant(energy produced / energy consumed) has increased to 59%, when the average for similar facilities stands at 40%.[47]

- Sewage plant in Granollers:

This plan was launched in 2008. It has an electrical power of the installation of 500 kWe .The technology used are motogenerators.

This is one of the first installations of Cataluña which exports all of the electricity generated (all-around).

It is the first sewage plant in Cataluña where the mud is carried co digestion since November 2010. [47]

The results have been very positive, increasing biogas production by approximately 40%

In addition there are these plants from which there is no accessible information:

- Sewage Montores-Barcelona-2006
- Sewage Vilanova i la Geltru-Barcelona-2005
- Landfill Granollers-Barcelona-2007
- Landfill Botarell-Baix Camp-Tarragona-2007
- Landfill Mataró-Barcelona-2010
- Sewage de Rubí- Barcelona
- Sewage de Tarragona
- Sewage de Reus- Tarragona
- Sewage de El Prat de Llobregat-Barcelona [47]

### 5.3.2 VALENCIA

- Sewage Ontoniente-Alicante -1992
- Sewage Aldoros-Elche-Alicante-2001
- Sewage Alcoy-Alicante-2003
- Sewage Gandía-Valencia-2007 :Capacity of 280.000 he
- Sewage Pinedo-Valencia : Capacity of 1.738.000 he
- Sewage Quart-Valencia: Capacity of 412.500 he
- Sewage Paterna-Valencia: Capacity of 235.000 he
- Sewage Castellón: Capacity of 199.500 he
- Sewage Carraixet-Bétera-Valencia: Capacity of 186.600 he
- Sewage Pobla de Farnals: Capaci ty of 150.000 he
- Sewage Ontinyent: Capacity of 140.600 he
- Sewage Utiel: Capacity of 52.840 he [61]

## 5.4 FRAMEWORK

In the framework of categorization the plants are classified into the following categories: Substrate, organization, biogas use, digestion technology and capacity. They have been suppressed the categories of localization and digestate because it has not been possible to obtain the necessary information.

**①Gimenells ②Castelló de Faranya ③Torregrosa I ④Torregrosa II ⑤Torres de Segre ⑥Balaguer ⑦Cassa de la Selva ⑧Montargull ⑨Vila Sana ⑩Miralcamp ⑪ Mas Bes ⑫Juneda-Tracjusa ⑬Torre Santamaría ⑭Almenar ⑮Sant Mer ⑯Granja San Ramón ⑰Vall Duixo ⑱Tramavé/Picassent ⑲Catí ⑳Utiel**

| Substrate | Organization | Biogas Use | Digestion Technology | Capacity* (Sum up of all digesters) |
|---|---|---|---|---|
| Manure ①②③④⑥⑦⑧⑨⑩⑪⑫⑬⑭⑮⑯⑰⑲ | Municipality ⑰ | Electricity to sale ②③④⑧⑨⑩⑪⑫⑬⑭⑮⑯⑰⑱⑲⑳ | Mesophilic[a] (15-45 °C) ①②③④⑤⑥⑦⑧⑨⑩⑪⑫⑬⑭⑮⑯⑰⑱⑲⑳ | Small (< 2,000 $m^3$) ③⑦ |
| Industrial Waste ⑰ | Commercial ①②③④⑤⑥⑦⑧⑨⑩⑪⑫⑬⑭⑮⑱⑲⑳ | Heat to sale ⑰ | Thermophilic[a] (40-65 °C) | Medium (2,000-5,000 $m^3$) ①②⑥⑧⑨⑪⑬⑯⑱ |
| Crops ⑤⑯⑰⑳ | Substrate Owner ⑯ | Electricity for internal use ①②③④⑤⑥⑦⑧⑨⑩⑪⑫⑬⑭⑮⑯⑰⑱⑲⑳ | | Large (> 5,000 $m^3$) ④⑤⑩⑫⑮⑰ |
| Slaughterhouse waste ③⑤ | Shared Ownership | Heat for internal use ①②③④⑤⑥⑦⑧⑨⑩⑪⑫⑬⑭⑮⑯⑱ | | |
| Household waste ⑤⑥⑦⑧ | | | | |

Table 1. The Framework for Categorization with the biogas plants studied inserted into it.

*There is no access to the information of the capacity of the plants ⑭⑲⑳

Studying this framework it is possible to get some results and conclusions as well as knowing the aspects that these plants have in common. As it can be appreciated in this framework, most of the plants use animal manure as raw material for the production of biogas.

In Spain most of the biogas plants are private as it can be seen here. The government does not support this type of energy economically. The high investments needed to develop a biogas plant and its low profitability makes it hard to accomplish. The government should provide aids for their development cycles. In the only case we have municipal plant, Vall Duixo, the electricity generated is used to supply houses, and the thermal energy produced is allocated for free to the local offices.

The use that is given to biogas is only for the production of electrical and thermal energy, being electricity the main target.

Most of the plants have a medium size capacity.

# 6 DISCUSSION

The biogas is much undeveloped in Spain, and more importantly, there is very little information available about it. Almost all agricultural and livestock plants belong to a private entity. Therefore, the information available of them depends on these companies. As typically the construction of the plant, maintenance, financing and control is performed by different companies this complicates the research further.

Despite the poor development of biogas plants in Spain, the two studied, Cataluña and La Comunidad Valenciana communities are the ones that have greater density of biogas plants. The current legislation, little economic support from the state and the lack of knowledge of these technologies are still the main obstacle to overcome for strong implementation of biogas.

However in municipal facilities such as landfills and sewage treatment plants they tend to increase the implement of these systems to reduce waste and save energy. Nevertheless there is few information available of them.

Cataluña is nowadays by far the Spanish community that has invested most heavily in the generation of biogas. There are 15 operational Agricultural and livestock plants today. Although this number remains far below the European average development.

In the near future the government will have to realize that it is worth it investing in biogas, which is not only a solution to waste and $CO_2$ emissions but it is also a reliable source of energy.

Now that we know all the advantages of producing biogas. Biogas production is a good way of elimination of pathogens and malodors while at the same time a potential renewable energy source. This energy can be used in form of electricity, heat and fuel. It is a good alternative to use it as fuel. The production of biogas would allow Spain to reduce its dependence on fossil fuels.

The waste sector obligations and duties to recycle organic waste are increasing in Spain. Biogas is the best instrument for this purpose. Countries like Norway and Sweden are taking advance of this and they are importing waste to its valorization. This is also been done in France, Holland, Germany or Italy, which import products from Spain to make biogas.

In comparison to other renewable energies as solar or wind power, biogas can be produced regardless of adverse factors such as weather conditions or time of day.

The additional benefit is the production of high quality fertilizer, nutrient-rich effluent as nitrogen, phosphorus, potassium or magnesium. This is an advantage to consider in Spain where agriculture is highly developed throughout the country.

In study is appreciated that the main cause of underdevelopment of biogas today, is the legislature, the little promotion and low economic government support.

The government's role is very important. The lack of government financial support is what makes unfeasible biogas development. This is because any company wants to invest in a project with the uncertainty of whether it will be profitable.

## 6.1 CONCLUSSIONS

An overview of the current situation of Spain in the provinces of Cataluña and Valencia has been obtained, although it has not been possible to obtain any information that it would have liked. What obtained is sufficient to get an idea of how biogas plants are working, their size, the substrates they use and the use that is given to products in each plant.

The chapter of the history and legislation in Spain allows to understand how has been the development of biogas in Spain and why it has been so slow. It also gives an outlook for the future in order to know what changes should be made.

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(*) Information obtained through phone calls

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