SURVEY OF SPANISH BIOGAS PLANTS AND THEIR CHARACTERISTICS – THE REGIONS OF ANDALUCÍA, ARAGÓN, ASTURIAS, CASTILLA LA MANCHA, CASTILLA Y LEÓN, GALICIA, MURCIA AND NAVARRA

Bachelor Thesis in Biogas

Department of Management and Engineering

Division of Energy Systems

Linköping University

By

Marieta González Flórez

June 2016

Supervisors: **Emma Lindkvist**

IEI, Linköping University

Examiner: **Magnus Karlsson**

IEI, Linköping University

Upphovsrätt

Detta dokument hålls tillgängligt på Internet – eller dess framtida ersättare – under 25 år från publiceringsdatum under förutsättning att inga extraordinära omständigheter uppstår. Tillgång till dokumentet innebär tillstånd för var och en att läsa, ladda ner, skriva ut enstaka kopior för enskilt bruk och att använda det oförändrat för ickekommersiell forskning och för undervisning. Överföring av upphovsrätten vid en senare tidpunkt kan inte upphäva detta tillstånd. All annan användning av dokumentet kräver upphovsmannens medgivande. För att garantera äktheten, säkerheten och tillgängligheten finns lösningar av teknisk och administrativ art. Upphovsmannens ideella rätt innefattar rätt att bli nämnd som upphovsman i den omfattning som god sed kräver vid användning av dokumentet på ovan beskrivna sätt samt skydd mot att dokumentet ändras eller presenteras i sådan form eller i sådant sammanhang som är kränkande för upphovsmannens litterära eller konstnärliga anseende eller egenart. För ytterligare information om Linköping University Electronic Press se förlagets hemsida http://www.ep.liu.se/.

Copyright

The publishers will keep this document online on the Internet – or its possible replacement – for a period of 25 years starting from the date of publication barring exceptional circumstances. The online availability of the document implies permanent permission for anyone to read, to download, or to print out single copies for his/hers own use and to use it unchanged for non-commercial research and educational purpose. Subsequent transfers of copyright cannot revoke this permission. All other uses of the document are conditional upon the consent of the copyright owner. The publisher has taken technical and administrative measures to assure authenticity, security and accessibility. According to intellectual property law the author has the right to be mentioned when his/her work is accessed as described above and to be protected against infringement. For additional information about the Linköping University Electronic Press and its procedures for publication and for assurance of document integrity, please refer to its www home page: http://www.ep.liu.se/.

© Marieta González Flórez

Abstract

The aim of this bachelor thesis focuses on doing a survey of the biogas production (plants, structure, institutional, prerequisites...) in Spain, specifically in some regions of this country which are Andalucía, Aragón, Asturias, Castilla La Mancha, Castilla y León, Galicia, Murcia and Navarra.

Previous projects have been done in countries such as England, Denmark, Germany or Sweden, reaching the conclusion that, even though there might be similarities between the different biogas plants, it is difficult to compare them. That's why a deeper exploration must be done so as to come to a more clarifying conclusion.

In order to achieve this objective, I have carried out some sort of investigative documentary based not only on the review and analysis of existing general and specific literature on the subject but also made phone calls and sent emails to those companies that run the plants. Besides, the thesis project pursuits to find applicable theories and patrons for the subject through the comparison of the plants.

The theoretical framework is structured into several sections addressing the following topics: a brief introduction of the biogas; an overall view of the biogas situation in Spain and its history; extensive information about each biogas plants which have been evaluated and categorized.

The work finalizes with a set of conclusions about the classifications as well as future prospects.

Key words: Biogas, Spain, legislation, agroindustrial, WWTP, landfill, digester.

RESUMEN TRABAJO DE FIN DE GRADO

Introducción y justificación

Desde hace años, el cambio climático se ha convertido en uno de los temas que más preocupan a la sociedad. Este fenómeno se define como el aumento de la temperatura de la atmósfera terrestre.

Se cree que este calentamiento se debe principalmente al efecto invernadero, fenómeno natural por el cual la radiación sobre la superficie de la Tierra, es absorbida por los gases de la atmósfera y es remitida en todas las direcciones, lo que resulta en un aumento de la temperatura. Estos gases son los conocidos como gases invernadero y se desprenden en procesos como la quema de combustibles fósiles y la deforestación. Entre ellos está el dióxido de carbono.

Es por esto que los científicos están buscando distintas fuentes de energías renovables y menos contaminantes para reducir este problema. Una posible solución es la utilización del biogás con lo que se consigue la disminución de los gases invernadero o el volumen de basura almacenado.

Objetivo y metodología

El objetivo de este proyecto de investigación es llevar a cabo un estudio sobre la producción de biogás y las características de las plantas en las que se genera en España. Concretamente en las regiones de Andalucía, Aragón, Asturias, Castilla La Mancha, Castilla y León, Galicia, Murcia y Navarra.

Este estudio forma parte de un proyecto mayor llevado a cabo por la Universidad de Linköping (Suecia) en el que ya han sido estudiados algunos países europeos como son Alemania, Inglaterra, Dinamarca o mismamente Suecia. Los sustratos que se utilizan, la estructura de la planta, el tipo de digestor o la utilización posterior del biogás generado son algunos de los aspectos estudiados en esta investigación.

Con todo ello se pretende clasificar la producción de biogás en España en un marco teórico que será explicado durante el documento y en el que ya han sido situados los países nombrados previamente. Finalmente, se intentará sacar similitudes con otros países y se establecerán conclusiones sobre la situación actual de este país.

Para realizar este trabajo, será necesario llevar a cabo una investigación a través de artículos y estudios hechos con anterioridad. También se harán llamadas de teléfono y se enviarán correos a las respectivas empresas que dirigen las plantas con el fin de obtener la información que no se encuentre disponible online.

Con el objetivo de ser lo más claro posible sobre este tema, el trabajo se iniciará con una explicación general de lo que es el biogás, su composición, producción e historia. Posteriormente se centrará en la situación en España, cómo comenzó y la legislación que lo rige.

Una vez explicado brevemente el tema, se dará paso al proyecto propiamente dicho. En un primer estudio se clasificarán los principales tipos de plantas en España. En un segundo estudio, se investigarán las plantas existentes en las comunidades en las que se centra el proyecto. Finalmente, se clasificarán las plantas estudiadas en un marco con las categorías más importantes.

Biogás

Desde el inicio de los tiempos, la humanidad ha necesitado de distintos tipos de fuentes de energía con el fin de satisfacer sus necesidades diarias. A medida que ésta ha evolucionado, nuevas alternativas han ido apareciendo entre las cuales destacamos el biogás.

El biogás en una fuente de energía renovable compuesta principalmente de metano y dióxido de carbono. Se produce a partir de la biodegradación de materia orgánica en ausencia de oxígeno. Este proceso consiste en la digestión anaerobia de los substratos orgánicos que son introducidos en el digestor correspondiente, calentados a cierta temperatura y almacenados durante 30-60 días en los que poco a poco se va produciendo la combinación de gases que conocemos como biogás.

La mezcla obtenida incluye un producto gaseoso, el biogás, y un residuo semisólido llamado digestato que tiene un contenido en nutrientes mayor que la biomasa inicial.

El proceso que genera el biogás se puede dividir en tres pasos principalmente:

- El primer paso es la hidrólisis: los microorganismos actúan sobre la materia orgánica, ayudados por enzimas, descomponiendo los compuestos orgánicos complejos en compuestos más simples como el azúcar y los aminoácidos.
- El segundo paso es la fermentación: los monómeros obtenidos son atacados por otros microorganismos, produciendo ácidos orgánicos de cadena corta, principalmente: ácido acético, carbono e hidrógeno (también algunos alcoholes y aldehídos) dióxido.
- Finalmente, los metanógenos: las sustancias producidas en etapas previas son atacadas por microorganismos metanogénicos. Como resultado, se producen metano y dióxido de carbono.

Cada una de estas fases es catalizada por diferentes bacterias. Dependiendo de la temperatura, existen dos regímenes de trabajo diferentes: mesofílicos (bacterias con un metabolismo óptimo de alrededor de 40ºC) o termófilos (bacterias con un metabolismo óptimo de 55ºC).

Las plantas de biogás tienen diseños muy diferentes, pero en términos simplificados consisten en las instalaciones de recepción de la biomasa, digestores de biogás, reactores o tanques donde se produce el proceso anaeróbico, almacenamiento para biogás y digestato y, finalmente, dependiendo del futuro uso que la planta dará a El biogás producido, los equipos para generar energía eléctrica, térmica o combustible de vehículos, por ejemplo.

• Situación actual global

Globalmente, el biogás representa uno de los recursos energéticos más sostenibles y con mayor potencial de crecimiento. Alrededor de 17.000 plantas de biogás en agricultura, industria y tratamiento de aguas residuales están operativas en Europa según la Asociación Europea de Biogás.

La mayoría de ellas se encuentran en Alemania e Italia. Este éxito se debe a las altas tarifas de alimentación y aunque la mayoría de los otros países han intentado copiar este modelo, sus enfoques no han sido tan consistentes como los suyos.

Sin embargo, España sigue estando al final de la lista de biogás agroindustrial europeo (biogás obtenido de la digestión anaerobia de residuos agroalimentarios) a pesar de haber avanzado de la 22º a la 18º y haber aumentado su número de plantas de 22 a 39 desde 2012.

Según los datos del barómetro EurObserv'ER de 2014, la principal contribución proviene de los vertederos (124.000 tep), seguidos del biogás agroindustrial (102.000 tep) y de las depuradoras (30.000 tep). La producción de energía de biogás en España corresponde a sólo el 1,4% (1,2% en el área eléctrica y 0,2% en la térmica de la producción total de energía primaria).

El Plan de Energías Renovables 2011-2020 ofreció una perspectiva muy prometedora para el biogás en España, que al inicio del período acreditaba una producción de 165 MWh y que el 85% de ella provenía de vertederos de desgasificación.

Teniendo en cuenta los datos disponibles, si bien es cierto que Europa tiene perspectivas muy positivas en relación con la producción de biogás, España tiene un crecimiento muy lento a pesar de la gran cantidad de residuos. Está claro cuál es la principal razón por la que esta tecnología aún no ha alcanzado su velocidad potencial de desarrollo es: la legislación.

- ## Biogás en España

El inicio de las plantas de biogás en España fue con el Real Decreto 661/2007 con el que se primaba la producción y venta del exceso de energías renovables. Sin embargo, tan sólo las plantas óptimas o que gestionaban residuos de grandes explotaciones llegaron a ser rentables por la escasa experiencia en el sector y de la sociedad sobre su tecnología.

Unos años después, el gobierno sacó nuevas leyes con las que básicamente recortó las primas a las instalaciones y muchas se vieron obligadas a cerrar. Cabe destacar el Real Decreto 900/2015, conocido como el ‘impuesto del sol’, la norma más restrictiva del mundo que impide que se realicen plantas de biogás para autoconsumo.

Esta situación creó desconfianza en la inversión en renovables y concretamente en biogás dando lugar a la situación actual. Con un marco legal/administrativo adecuado, España debería convertirse en potencia en la materia dada la interesante cantidad de recursos que posee.

El uso de energías renovables es esencial para garantizar un suministro energético eficiente desde el punto de vista medioambiental. Precisamente, la Directiva 28/2009/CE del Parlamento Europeo sobre el fomento del uso de la energía a partir de fuentes renovables establece como objetivo para 2020 que el 20% del consumo final bruto de energía en la Unión Europea sea proveniente de fuentes renovables. Según el último informe de la CE, 9 de los 28 estados miembros de la Unión Europea tienen dificultades para alcanzar este objetivo. Entre ellos está España, donde la cantidad de energía procedente de fuentes renovables está aún lejos de ese objetivo.

Estudios y evaluaciones

• Estudio 1

De acuerdo con el Plan de Energías Renovables 2011-2020, en España hay tres tipos de biogás:

- Biogás agroindustrial: biogás obtenido a partir de la digestión anaerobia de residuos agroalimentarios. El sustrato utilizado puede ser estiércol de ganado, lodos de las industrias de procesamiento de alimentos, residuos de cultivo o cultivos energéticos.
- Biogás de FORSU y de vertedero originado a partir de la de degradación biológica de los residuos orgánicos.
- Biogás a partir de lodos procedentes de una Estación Depuradora de Aguas Residuales (EDAR). En las EDAR, se depuran las aguas industriales y urbanas a través de una serie de procesos físicos, químicos y biológicos que tratan de separar los sólidos en suspensión de los lodos. A partir de dicho lodo se generará el biogás, una vez que pase a través del proceso de digestión anaerobia.

• Estudio 2

Para poder llevar a cabo las valoraciones y evaluaciones siguientes, información sobre las distintas plantas que existen es necesaria.

La mayoría de estudios e información disponible es sobre el biogás agroindustrial. En este momento alrededor de 50 plantas producen biogás agroindustrial en España, todas distribuidas alrededor de la península. Sin embargo, la mitad de ellas se concentran en el noroeste del país. Este proyecto se centrará en el resto del territorio dejando la investigación de Cataluña y Valencia a otro proyecto. Además, algunas plantas que producen otros tipos de biogás también serán estudiadas.

Para este estudio, 24 (de A a X) plantas de biogás fueron seleccionadas para evaluar el marco de categorización que se explicará en detalle más adelante y para analizar la clasificación del Estudio 1. Las plantas fueron elegidas de manera que permitieran obtener una vista tan amplia de la producción de biogás en España como fuera posible. Las plantas estudiadas se diferencian por ejemplo en el sustrato usado, en la técnica de digestión, organización, uso de biogás, uso de digestores y capacidad. La idea inicial fue estudiar al menos una planta de cada tipo en cada región. Sin embargo, como se mencionó anteriormente, no hay información disponible sobre algunas de ellas y es por esto que únicamente se las nombra.

- **<u>Andalucía</u>**

En esta región se han encontrado 18 plantas de biogás en funcionamiento en este momento. Sin embargo, sólo dos de ellas serán analizadas en profundidad:

a. Campillos, Málaga (A)

La organización privada Giesa Agroenergia gestiona la planta agroindustrial de biogás en Campillos desde el año 2016. Procesa la mayor parte del estiércol de la zona (35.000 toneladas), además de otros desechos agroalimentarios (60.000 toneladas) y lodos de depuradora (8.000 toneladas).

Lechada, estiércol de aves, estiércol de cabra... Todos ellos son reciclados para generar electricidad con la que alimentar la planta y el calor para las granjas de cerdos y pavos de la zona. La planta de 1,9 MW de potencia cuenta con 2 digestores mesofílicos de 2.800 m^3 de volumen. Aproximadamente 16.000.000 kWh/año de biogás se produce y el digestato se revaloriza para utilizarlo como fertilizante.

b. Montalbán (B)

Esta planta que utiliza biogás de vertederos de residuos domésticos y municipales en el Complejo Ambiental de Montalbán, inaugurado en junio de 2008, es un ejemplo de la fuerte apuesta de Epremasa a favor de las energías renovables. El uso energético de los gases de vertedero se lleva a cabo mediante la instalación de dos generadores de 2.546 kW y un motor de 2.612 kW. Esta planta consume 1.420 Nm^3/h de biogás y tiene una electricidad anual de 11.076 MWh. El consumo estimado anual de gas es equivalente a un promedio de 3,229 tep/año y la electricidad alimentada a la red pública, neto del consumo propio de la instalación, se estima en 10.700 MWh/año, equivalente al consumo de 2.950 hogares en producción año.

- **Aragón**

En Aragón hay 9 plantas de biogás de entre las cuales, tres han sido seleccionadas:

c. Undúes de Lerda, Zaragoza (C)

En Undués de Lerda, el biogás es producido por la empresa privada Agronsella en la misma finca que manejan. Desde 2014, su planta realiza la digestión anaerobia de 6.000 ton/año de estiércol concentrado obtenido. Para ello, cuentan con un digestor de 700 m^3 y un post digestor de 500 m^3. Además, se necesitan dos calderas de 170 kW para el consumo de calor de la finca y una caldera de 60 kW para las digestiones. El biogás producido es entonces mejorado en la propia planta para ser utilizado como calor para las granjas y el digestato se utiliza para aplicaciones agronómicas. Además, se producen anualmente 765 MWh de biogás que generan 765.000 kWh de energía en el proceso.

d. Remolinos, Zaragoza (D)

La empresa de responsabilidad limitada Urbiliza Renovables puso en marcha la planta de biogás en Remolinos en 2012. El biogás producido por la planta proviene de excreciones bovinas (10.000 toneladas/año) y de residuos agrícolas y alimentarios (10.000 ton/año) tratados en dos digestores de 2500 m^3 que funcionan a 45ºC. Para la generación de energía, la planta cuenta con dos equipos de 250 kWe. Entre 1,7 y 1,9 MNm^3/año de biogás se genera y el digestato se utiliza como fertilizante para el campo. Aproximadamente 4.300 MWh/año de electricidad se produce; Siendo el consumo anual de las instalaciones eléctricas 497.218 kWh/año y el resto se exportará a la red. La energía térmica producida se utilizará para proporcionar calor a los digestores.

e. EDAR Almozara (E)

En Zaragoza, DRACE del Grupo ACS opera la planta convencional de lodos activados. Desde 1989 recoge los vertidos de diferentes barrios, zonas industriales y lugares cercanos. Tiene un digestor primario de 3.850 m^3 que opera a 30-35ºC durante 25 días cada vez (tiempo de retención) para producir biogás y digestato. El biogás se utiliza para la cogeneración de eficiencia energética y el digestado como fertilizante. La planta genera 2.300 MWh de electricidad al año y tiene capacidad para tratar 34.560 m^3 de residuos por día.

- **Asturias**

En Asturias hay dos plantas donde se produce biogás:

f. Tineo (F)

La única planta agroindustrial de biogás en Asturias se encuentra en Tineo y está dirigida por una compañía privada local, Biogas Fuel Cell. Operando desde 2014, la planta procesa 26.000 toneladas/año de aguas residuales, residuos de mataderos, agroindustriales, industria láctea y desechos de ganado generando 1.300.000 Nm^3/año de biogás. El proceso se realiza en dos digestores de 1.000 m^3 a 55ºC (proceso termofílico) y luego en dos post-digestores de 1.000 m^3 a 39ºC (proceso mesofílico). Después de un proceso de reducción de su contenido de H2S y vapor de agua, el biogás se quema en un motor de cogeneración de 250 kW. El calor recuperado es utilizado por la propia instalación y la electricidad se alimenta a la red. Finalmente, el digestato se almacena temporalmente en un tanque para luego ser recogido por los agricultores y utilizado como fertilizante para los campos. Aproximadamente 2.000 MWh/año de energía se extrae en el proceso.

g. COGERSA (G)

En Serín, la empresa pública COGERSA gestiona el centro de tratamiento de residuos de la Zoreda desde 1982. Este vertedero de residuos no peligrosos recibe 390.000 ton/año de RSU y 60.000 ton/año de lodos que son tratados en el vertedero a una temperatura inferior a 50ºC. Después del proceso anaerobio, la captura de la red del biogás se realiza usando los pozos verticales y las líneas aéreas que conducen. El biogás se utiliza para producir energía eléctrica y calor para el quemador. El vertedero tiene una potencia eléctrica de 6,5 MW y logra producir 34 Mm^3/año de biogás.

- **<u>Castilla La Mancha</u>**

En Castilla y La Mancha se han localizado 5 plantas y todas ellas generan biogás agroindustrial. Se expondrán tres:

h. Balsa de Ves (H)

El grupo Sanchíz con la ayuda de Inderen instaló una planta de biogás en Albacete en 2013. El estiércol resultante de la granja Ves se utiliza para alimentar la planta de biogás, ayudando a reducir el nivel de N, CH_4 Y el CO_2 en la atmósfera y evitar el mal olor. El estiércol se digiere en un digestor mesofílico de 3.000 m^3 a 37ºC para obtener 150 m^3 de biogás por hora. Posteriormente, el biogás sirve para alimentar las instalaciones de calefacción y el digestato generado se utiliza como fertilizante organo-mineral en parcelas agrícolas propiedad de la compañía.

i. Bonete (I)

En Bonete, Albacete, Grupo Sanchiz colocó una planta de biogás de cogeneración (producción de dos tipos de energía al mismo tiempo, generalmente calor y electricidad) en la finca de Ingapor en 2013. El biogás se produce a partir del estiércol generado en la finca. Un digestor mesofílico de 3.000 m^3 a 37ºC trata a los substratos. El biogás se utiliza entonces para suministrar calor y electricidad a la propia planta y el exceso se vende a la red. El digestato se utiliza como fertilizante natural. Aproximadamente 150 m^3/hora de biogás se genera en la planta. La potencia eléctrica de la planta es de 350 kW.

j. Chinchilla de Montearagón (J)

Grupo Sanchiz es propietario de la planta de biogás en Chinchilla de Montearagón, Albacete. Desde 2013 esta planta de cogeneración trata el estiércol de la finca para obtener 150 m^3/hora de biogás que se utilizará para calentar la instalación. El digestato se actualiza como fertilizante. La potencia eléctrica de la planta es de 250 kW. Cuenta con un digestor mesofílico de 3.000 m^3 que funciona a 37ºC.

- **Castilla y León**

En Castilla y León se investigarán las 4 plantas encontradas:

k. Juzbago (K)

En Juzbado (Salamanca), el biogás es producido desde 2011 por una empresa llamada Enusa con la colaboración de Biogas Wesser-EMS en una granja. Aunque la cantidad de sustratos varía anualmente, las proporciones son usualmente 80% de estiércol y 20% de polvo de cereal, ambos obtenidos en áreas cercanas. Los substratos se digieren a 40ºC en dos digestores mesofílicos de 2.200 m^3. La planta tiene una potencia de salida de 500 KW (potencia eléctrica) y 550 kW (potencia térmica). El biogás es mejorado en la finca para ser utilizado para la combustión en una unidad de cogeneración para generar energía térmica y eléctrica. La producción anual total de biogás es de 2.117,5 MWh/año según RD413/2015. El digestato se utiliza como fertilizante.

l. Almazán (L)

En Soria, la empresa privada Purines de Almazán S.L. Construyó la planta de 250 kW con una capacidad de aproximadamente 52.000 m^3/año de residuos (variable en función del contenido de sólidos de los residuos tratados). Valoriza los residuos orgánicos como el estiércol de pollo o cerdo producido en una instalación adyacente construida por la empresa durante el año 2015 para el tratamiento de cadáveres de cerdo. El estiércol de los agricultores en la localidad de Almazán se traslada en un tanque desde la fosa séptica hasta la planta. Una vez en la planta, el producto irá a incrementar la digestión anaeróbica para la producción de biogás (1.100.000 Nm^3/año) en un digestor mesofílico de 3.000 m^3 que funciona a 37ºC. El biogás se convertirá en electricidad para la red y el calor para la instalación de la red de autoconsumo. Finalmente, el digestato se almacena temporalmente en balsas y luego es utilizado por los agricultores como fertilizante.

m. Santiener (M)

En Iscar (Valladolid), el biogás se produce en una planta establecida por Santibañez Energía en 2014. La planta produce sólo energía térmica de 5.000 toneladas por año de residuos agroalimentarios de planta. Para ello, utilizan dos digestores de 500 y 700 m^3 de volumen. El biogás producido se actualiza para ser utilizado sólo en una caldera y el digestato se utiliza como fertilizante. Aproximadamente 500.000 Nm^3 de biogás se producen al año con un 58% de CH_4 y 1.2 GWh de energía se extrae del proceso.

n. EDAR Madrona (N)

En Segovia, la EDAR trabaja desde 2003. Esta planta fue diseñada para tratar un flujo de 41.280 m^3 por día, y es capaz de alcanzar hasta 4.400 m^3/hora y satisfacer las necesidades de 147.920 personas. Todos los lodos de aguas residuales (3.775 toneladas por año) provienen de la planta de tratamiento de aguas residuales y se tratan en un digestor de 3.000 m^3 a 36,5-37,5 ºC durante 28-30 días. Parte del biogás producido alimenta dos calderas que proporcionan calor al proceso, otro se deriva para producir electricidad en un motor y el resto vuelve al proceso o se almacena. En total, se generan aproximadamente 740.800 m^3/año de biogás y 1.197 MWh/año de electricidad. El digestato se utiliza como fertilizante. Sin embargo, fue remodelado desde marzo de 2014 hasta marzo de 2016 por lo que en este momento no está funcionando en pleno rendimiento.

- **Galicia**

En Galicia se han encontrado 9 plantas de biogás. Tres de ellas se explicarán en más detalle:

o. Cospeito (O)

En Xustás (Lugo), la empresa privada Norvento colocó una planta de biogás de 50 kW en 2015. En cuanto a estiércol (residuos agrícolas y ganado) de la finca de Xustás gestionada por la empresa SAT Xustás, el sustrato se procesa en un digestor de 350 m^3 y el biogás producido, mejorado a calor para ordeñar el circuito de establos y electricidad para venderlo por cuadrícula. Eventualmente están produciendo 190 m^3/día de biogás y el digestato se utiliza en los campos de la SAT.

p. Mouriscade (P)

En la finca de Mouriscade en Lalín (Pontevedra), el biogás se produce desde 2012. La granja cuenta con 100 vacas lecheras que son el origen de los residuos de ganado que abastecen principalmente a la planta de biogás. También se utilizan como sustrato los residuos de alimentación obtenidos en el laboratorio de la finca. La planta trata 1.500 m^3 de estiércol y 500 m^3 de residuos alimenticios por año en un digestor mesofílico de 258 m^3 de volumen. Se producen alrededor de 80.000 m^3 por año de biogás. Después de ser actualizado, el biogás utilizado para la calefacción y la electricidad y el digestato se utiliza como fertilizante para la granja en sí. Fuera del proceso, se extraen 190.000 kW de energía eléctrica.

q. Carballo (Q)

La planta de Carballo es propiedad conjunta de Calvo (productor de residuos) y JB Ingenieros desde 2009. La planta de biometización utiliza como sustratos los residuos industriales y los trata en un digestor termofílico de 1.000 m^3 de volumen para producir biogás. Aproximadamente 800-1600 m^3/día de biogás se produce y se utiliza para la producción de electricidad para alimentar la red. El digestato se actualiza como fertilizante.

- **Murcia**

En Murcia, las dos plantas encontradas se han analizado:

r. Biometización Cañada Hermosa (R)

En Cañada Hermosa, Estrella Levante maneja la planta de biogás desde el 2014. Los desechos provienen principalmente de la industria alimentaria, aunque el digestor también está autorizado para recibir materiales orgánicos recuperados de los residuos domésticos tratados en la planta de tratamiento del Centro de Tratamiento de Residuos de Cañada Hermosa. Tiene la capacidad de tratar 22.000 t/año de residuos orgánicos en su digestor de 2.300 m^3 y es capaz de generar 2 Nm^3/año de biogás que se utilizará para producir energía para calefacción y electricidad. No hay información disponible sobre el uso del biogás.

s. Los Alcázares (S)

Kernel Export ejecuta una planta de biogás de 370 kW de potencia eléctrica capaz de manejar una capacidad de 60 toneladas por día de residuos agroalimentarios. La construcción de esta instalación fue ejecutada por Ludan Energías Renovables España. El biogás producido se utiliza para generar electricidad para el autoconsumo y el digestato se utiliza como fertilizante. A la empresa no se le ha permitido vender el exceso de electricidad a la red. La temperatura de funcionamiento para el digestor anaeróbico de 3.000 m^3 está dentro del rango óptimo 38-40 °C (mesofílico) y este proceso suele durar 57 días. El consumo medio de energía de la planta de biogás es de 50 kWh.

- **Navarra**

Actualmente hay 8 plantas en funcionamiento en Navarra, 5 de ellas se verán en más detalle:

t. Agralco (T)

En Estella, la cooperativa Agralco S.Coop produjo biogás desde 2006. Con una capacidad de 15 m^3/hora de depuración de vino de las heces, logran digestar en dos equipos mesofílicos hasta 7.000 m^3 de sustratos originados de productos de bodegas de vinificación: orujo de uva y lías de vino para alcohol vinoso, sales tartáricas, aceite de semilla de uva y enocenina. Ellos procesan anualmente 50.000 toneladas de orujo de uva y 18.000 toneladas de lías de vino y obtienen 1.750.000 Nm^3 de biogás al año que se utiliza para la producción de electricidad para los cuatro motores de cogeneración (160 kW) de la propia planta. No lo vende a la red. El digestato se vierte en la depuradora.

u. Mendigorria (U)

En Mendigorria, el biogás es producido por Bioenergía Mendi SL desde el año 2011. Esta planta de cogeneración trata 15.000 m^3 de lechones de cerdos de la finca El Saso y 22.000 toneladas de residuos (agua residual de aseos y alcantarillado entre otros) Con el fin de producir aproximadamente 1.752.000 m^3 de biogás por año. Luego se utiliza para generar electricidad y calor para las instalaciones y el digestado como fertilizante. De este proceso se extraen 500 kW de potencia eléctrica y 600 kW de potencia térmica. La planta tiene dos digestores de 1.500 y 2.100 m^3.

v. HTN (V)

En Caparroso, el biogás se produce a partir de residuos de ganado y estiércol de la sociedad de responsabilidad limitada HTN en una planta de cogeneración. La planta procesa los sustratos que son pasteurizados antes del proceso de digestión. Una vez tratados estos sustratos, la fracción sólida se separa del líquido y ambos se utilizan para fertilizantes agrícolas. El proceso se realiza mediante dos digestores mesofílicos de 8.000 m^3 cada uno. El biogás producido (9.200.000 m^3 por año) se utiliza como combustible para los motores y para la electricidad, que es de aproximadamente 24.000 MWh/año, y se venderá a la red. El digestato se utiliza como fertilizante orgánico en cultivos agrícolas.

w. Cabanillas (W)

La planta de biogás en Cabanillas está a cargo de la empresa privada E-Cogeneración Cabanillas S.L. A partir de 2013. Dos digestores mesofílicos de 2.400 m^3 de volumen tratan 12.000 t/año de estiércol porcino y 8.000 toneladas de desechos (lodos e industriales) para producir 5.450 MWh/año de biogás que luego de ser mejorados serán utilizados para calentar la planta y la electricidad Para venderlo a la red. El digestato se utiliza para aplicaciones agronómicas. Del proceso se extraen 2.900.000 kWh de energía por año. La potencia de la planta es de 370 kW y cuenta con dos tanques receptores de 60 m^3 y 150 m^3 y una balsa para el digestato de 5.000 m^3.

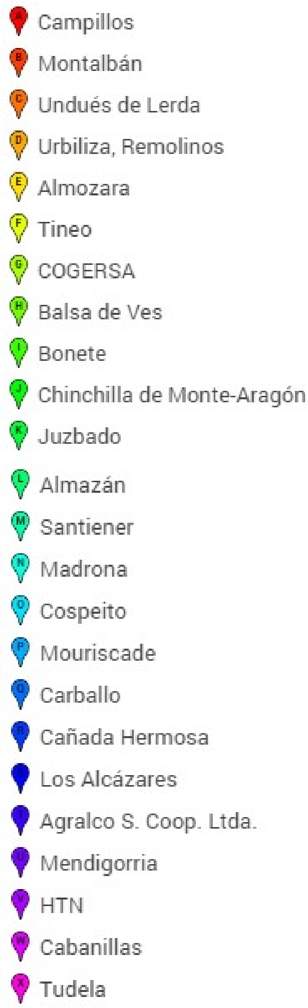
x. Tudela (X)

El vertedero de El Culebrete en Tudela comenzó a funcionar en 2006 por la dirección de la Mancomunidad de la Ribera. La planta de biometización de 1.425 kWe utiliza residuos domésticos en su digestor mesofílico de 5.600 m^3 y los trata durante 14 días para producir 2.216.781 m^3 de biogás por año. El biogás se utilizará para producir electricidad para venderlo a la red y el digestato se compostará mezclado con astillas de madera para usarlo como fertilizante. Alrededor de 3.224.000 kWh de energía se extrae del proceso.

➢ Evaluación 1

En este momento se desconoce con exactitud el número de plantas de biogás que hay España. A causa de la legislación, muchas de ellas se han visto obligadas a cesar su actividad o incluso a cerrar. En el gráfico siguiente se pueden observar la localización de las plantas estudiadas.

Plantas Estudiadas



Después de analizar los tipos de plantas que hay en el Estudio 1 y la búsqueda de información sobre ellas en el Estudio 2, las plantas han sido insertadas en la tabla del Estudio 1. La división se ha hecho a partir de la descripción junto con la información específica encontrada.

Las Plantas Estudiadas en el Estudio 2 introducidas en la Clasificación de Estudio 1

ESPAÑA
Biogás de vertedero y FORSU
(B) (G) (X)
Biogás agroindustrial
(A) (C) (D) (F) (H) (I) (J) (K) (L) (M) (O) (P) (Q) (R) (S) (T) (U) (V) (W)
Biogás de EDAR
(E) (N)

➢ Evaluación 2

Una vez estudiadas las plantas de biogás en el Estudio 2, la información recogida se clasifica por categorías que permitan diferenciar las plantas en el cuadro de categorización siguiente:

Resultados

Las plantas están clasificadas en siete categorías relevantes:

- Substrato: de dónde procede el material usado en el proceso para producir el biogás.
- Organización: propiedad de las plantas.
- Uso posterior del biogás
- Técnica digestiva: mesofílica o termofílica.
- Localización: hace referencia tanto a la localización del substrato (primera columna) como a la localización del gas (segunda columna). También incluye cómo se transportan los substratos a la planta, cómo se trata el gas.
- Digestato: para qué se usa.
- Capacidad: tamaño del digestor.

Cuadro de Categorización con las Plantas Estudiadas en el Estudio 2

Substrato	Organización	Uso Biogás	Técnica de Digestión*[ac]	Localización		Digestato	Capacidad*[b]
Estiércol de cerdo	**Municipal**	**Electricidad**	**Mesofílica (15-45 °C)**	**Substrato principal in situ**	**Valorización**	**Fertilizante**	**Pequeña (< 2 000 m^3)**
(A) (C) (H) (I) (J) (L) (U) (W) (X)	(G) (K) (N) (P) (X)	(A) (B) (E) (G) (K) (L) (N) (O) (Q) (S) (U) (X)	(A) (C) (D) (E) (H) (I) (J) (K) (L) (M) (N) (O) (P) (S) (T) (U) (V) (W)	(C) (H) (I) (J) (N) (P) (Q) (R) (T) (X)	(C) (E) (K) (M) (N) (R) (W)	(A) (C) (D) (E) (F) (H) (I) (J) (K) (L) (M) (N) (O) (P) (Q) (R) (S) (T) (U)(V) (W)	(C) (F) (M) (O) (P) (Q) (U)
Residuos industriales	**Comercial**	**Calor**	**Termofílica (40-65 °C)**	**Substrato bombeado**	**Gas transportado por vehículo**	**Compost mezclado fertilizante de virutas de madera**	**Mediana (2 000-5 000 m^3)**
(U) (W)	(A) (B) (D) (E) (F) (L) (M) (O) (R) (S) (V) (W)	(A) (C) (D) (F) (G) (H) (I) (J) (K) (L) (M) (N) (O)	(F) (Q)	(E) (G)	(F)	(X)	(A) (D) (E) (H) (I) (J) (K) (L) (N) (R) (S) (T) (W)
Lodos de aguas residuales	**Propietario posee el substrato**	**Red nacional de gas**		**Substrato transportado por vehículo**	**Red de gas local**	**Aplicación al cultivo del ensilaje de maíz**	**Grande (> 5 000 m^3)**
(E) (F) (G) (N) (W) (X)	(C) (H) (I) (J) (T)	(A) (B) (O) (Q) (R) (V) (W)		(A) (B) (D) (F) (G) (K) (L) (M) (O) (Q) (S) (U) (V) (W)	(A) (D) (G) (L) (P)	(K)	(V)
Residuos sólidos	**Propiedad**	**Uso interno**			**Conversión de**		

Urbanos	**compartida**				**energía para uso interno [d]**		
(B) (G) (W)	(Q) (U)	(C) (D) (E) (F) (I) (J) (H) (L) (N) (P) (T)			(D) (H) (I) (J) (M) (O) (S) (T) (U)		
Residuos domésticos					**Conversión de energía para uso externo [e]**		
(B) (R)					(B) (D) (K) (Q) (V) (X)		
Cultivos							
(K) (L)							
Residuos agroalimentarios							
(A) (D) (F) (M) (Q) (R) (S) (T)							
Estiércol bovino							
(D) (O) (P) (V) (K)							

* No aplicable para vertederos (B), (G) y (X). [a] La planta de Biometización Cañada Hermosa (R) no se puede colocar en ninguna de estas subcategorías, ya que no se dispone de información al respecto. [b] El tamaño del digestor (es). La fragmentación se basa en los datos de las plantas estudiadas. [c] (Jorgensen, 2009). [d] El uso interno indica que el biogás se utiliza en el sitio de alguna manera, y no necesita ser transportado en ninguna parte. [e] La conversión de energía para uso externo indica que el biogás se convierte en ej: calor y / o electricidad y (parcialmente) utilizado fuera de la planta.

Análisis

En las secciones previas, se ha llevado a cabo la clasificación de la información recogida en el Estudio 2. Para ello, siete categorías fueron consideradas y, a continuación, se incluyen comentarios sobre algunas de ellas.

En las categorías de Técnica de digestión y Capacidad no se pudieron incluir las plantas que producen biogás de vertedero y FORSU pues estas carecen de digestores.

En cuanto a la primera, al origen de los substratos, se ve que pueden proceder de residuos urbanos, agroindustriales, estiércol y lodos. Sin embargo, ninguna destaca por encima de las demás.

Por el contrario, con respecto al uso del biogás, la mayoría de las plantas que lo generan lo utilizan para generar electricidad, calor o ambas. Este hecho se conoce como cogeneración y parece ser muy común en las regiones estudiadas. Además, cabe destacar que parte de la energía del biogás se usa para el autoabastecimiento de las instalaciones, para venderlo a la red o para ambas.

La categoría de Organización se refiere a la propiedad de las plantas de biogás. Muchas pertenecen a empresas privadas que obtienen el substrato de áreas cercanas. Sólo algunas de ellas, como es el caso de la granja de Balsa de Ves o la granja de El Saso, tienen el material en sus propias instalaciones.

La técnica de digestión que predomina es la mesofílica y el digestato se utiliza en casi todos los casos como fertilizante.

Por tanto, a pesar de que en España sólo existen tres tipos de plantas que producen biogás, las diferencias entre ellas son tales que resulta difícil establecer patrones que las relacionen.

Conclusiones

El objetivo de este proyecto era llevar a cabo una investigación sobre las plantas de biogás en algunas regiones de España para poder completar un cuadro dado, que nos permitiera contemplar la situación actual en este país. El trabajo se realizó correctamente y resultó ser un tema muy interesante que permitió conocer en más detalle esta energía renovable con gran potencial.

Tal y como se ha visto, existen tres tipos de plantas de biogás en España: agroindustriales, vertederos y EDAR. De acuerdo con algunos artículos, debería ser en los vertederos donde se debería extraer la mayor parte del biogás. Sin embargo, después de este proyecto, se puede decir que son los residuos de la agricultura y la industria los que más contribuyen a su producción. De hecho, la mayor parte de la información disponible está relacionada con este tipo de biogás, lo que dificultó la investigación de los otros tipos de plantas.

Cabe destacar que al iniciar el proyecto sólo se consideraron las plantas agroindustriales, ya que el presidente de AEBIG no especificó del tipo de planta del que esta organización se ocupa. Las políticas de privacidad de datos que algunas plantas tienen y la falta de información actual también ralentizaron el proyecto y en algunos casos, hizo imposible obtener toda la información necesaria.

Además, el desconocimiento del tipo de plantas de biogás que se dieron desde el principio causó que regiones como Cantabria, La Rioja, Madrid o Extremadura se hayan quedado fuera del proyecto.

Teniendo en cuenta los datos disponibles, si bien es cierto que Europa tiene perspectivas muy positivas en cuanto a la producción de biogás, España sorprende con un crecimiento muy lento a pesar de la gran cantidad de residuos agrícolas disponibles. Hay dos razones por las que esta tecnología todavía no ha alcanzado la velocidad de desarrollo que se esperaba.

La primera se refiere al Real Decreto 1/2012. Esta ley suspendió las primas a nuevas plantas. Ha causado que muchas de las plantas en construcción tuvieran que parar su actividad. La segunda razón implica la necesidad de desarrollar una legislación que establezca normas de calidad para el biogás para permitir su uso mediante la inyección de redes de gas natural, como es el caso de Alemania, Italia y Suecia.

Las asociaciones españolas relacionadas con el biogás defienden diferentes medidas de apoyo sectorial como incentivos a la producción, cogeneración o contabilidad de las emisiones de CO_2 evitadas.

Por lo tanto, como conclusión, para seguir mejorando la producción de biogás, el gobierno debe tomar algunas medidas para promoverlo. De lo contrario, la situación no va a mejorar y eventualmente esta energía será sustituida por otras más rentables.

Contents

1 Introduction

Since some years ago, it has been common to hear that the recent years have been warmer than the previous ones. It is true: the last ten years have been the warmest since records have been kept and scientists announce that in the future, it will be even more. This is the famous global warming, a phenomenon which causes among other things that the sea level will arise.

Scientists attribute these comments to an increasing concentration of greenhouse gases (GHG) in the atmosphere. Greenhouse effect is a natural condition of the atmosphere of the Earth. Some gases such as water vapour, carbon dioxide or methane are called the greenhouses gases because they trap the sun's heat in the lower layers of the atmosphere warming the Earth.

Burning fossil fuels for power generation is the main source of CO2 emissions, and therefore governments and private companies are focusing their efforts on increasing the share of renewable sources in electricity generation, preparing for a low future carbon and this bet is starting to be decided in both developed and emerging countries. The future of renewable energy is promising.

Between the different sources, there is the biogas. Biogas now is developing into a significant alternative energy source. Using biogas to produce electricity satisfies several regulatory concerns at once. Greenhouse gas emissions are reduced because the release of methane is prevented; green and rewenable energy is produced; volumes of waste requiring storage and disposal are reduced.

It seems to be an interesting way of obtaining recovery energy and that is why, a deeper research on the subject would be appeling.

1.1 Aim

The objective of this thesis project is to carry out an investigation about the actual situation of the renewable energy, biogas, in Spain. Specifically, this project will focus in the regions of Andalucía, Aragón, Asturias, Castilla la Mancha, Castilla y León, Galicia, Murcia and Navarra. How the plants work, which substrate they use or which digestion technique is happening during the process are some of the data that will be collected. Information will be gathered to compare the different existing plants.

At the moment, there is no exact number of biogas plants in operation in Spain. The goal is to understand how they work to be part of a larger project and get an overview of the current situation of biogas in Europe.

Legislation will also be studied so as to be able to understand the situation of this country since it seems to be the one to blame for biogas to be underdeveloped.

2 Biogas

2.1 What it is and its production

From the beginning of the times, the mankind has needed some type of energy sources in order to meet a series of daily demands. As civilizations have evolved they have created new energy needs. This situation has led to search for new energy sources that represent viable alternatives to current production methods and, among those alternatives, the use of biogas stands out.

Biogas is a renewable energy source, mainly composed of methane and carbon dioxide as can be seen in Figure 1 and it is generated from the biodegradation of organic matter in the absence of oxygen. (Energías Renovables, 2014)

Table 1: Typical Composition of Biogas (Rouse, 2013)

Typical Composition of Biogas		
Compound	**Molecular Formula**	**Percentage**
Methane	CH_4	50-70
Carbon Dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0-1
Hydrogen Sulphide	H_2S	0-3
Oxygen	O_2	0-0

Biogas plays an important environmental role as it is obtained from treatment and energy recovery of organic waste: energy crops, agricultural by-products, livestock waste, waste agro-industry, organic vegetable and animal residues. It can be generated from most types of organic raw materials except for lignin which is not anaerobically degraded. (Energias Renovables, 2014)

The biochemical process to produce biogas consists of an aerobic digestion of organic substrates which takes place in a biogas plant. Organic material is fed into the digester where it's heated up to a certain temperature and then stirred for 30-60 days, slowly producing the combination of gases known as biogas. The raw material composition will affect the yield of biogas and its content of methane. The mixture obtained includes gaseous products (biogas) and a semi-solid residue (digestate), which has a higher nutrient concentration than the initial biomass.

The biogas process can be divided into three main steps (The Eco Ambassar, 2016):

- First step, hydrolysis: microorganisms act on the organic matter, aided by enzymes, decomposing the complex organic compounds to simpler compounds such as sugar and amino acids.
- Second step, fermentation: the monomers obtained are attacked by other microorganisms, producing short chain organic acids, mainly: acetic acid, carbon and hydrogen (also some alcohols and aldehydes) dioxide.

- Third step, methanogens: substances produced in previous stages are attacked by methanogenic microorganisms. As a result, methane and carbon dioxide are produced.

Each of these phases is catalysed by different bacterias. Depending on the temperature, there are two different working regimes: mesophilic (bacteria with an optimal metabolic around 40ºC) or thermophilic (bacteria with an optimal metabolic of 55ºC). For optimum performance, pH, presence of inhibitors or organic load among other things must also be control. (Bentec Bioenergies, 2016)

Biogas plants have very different designs, but in simplified terms consist of the reception facilities of the biomass, biogas digesters, reactors or tanks where the anaerobic process occurs, storage for biogas and digestate and finally, depending on the future use the plant will give to the biogas produced, equipment for generating electrical, thermal energy or vehicle fuel for example. All these sections can be observed in Figure 1.

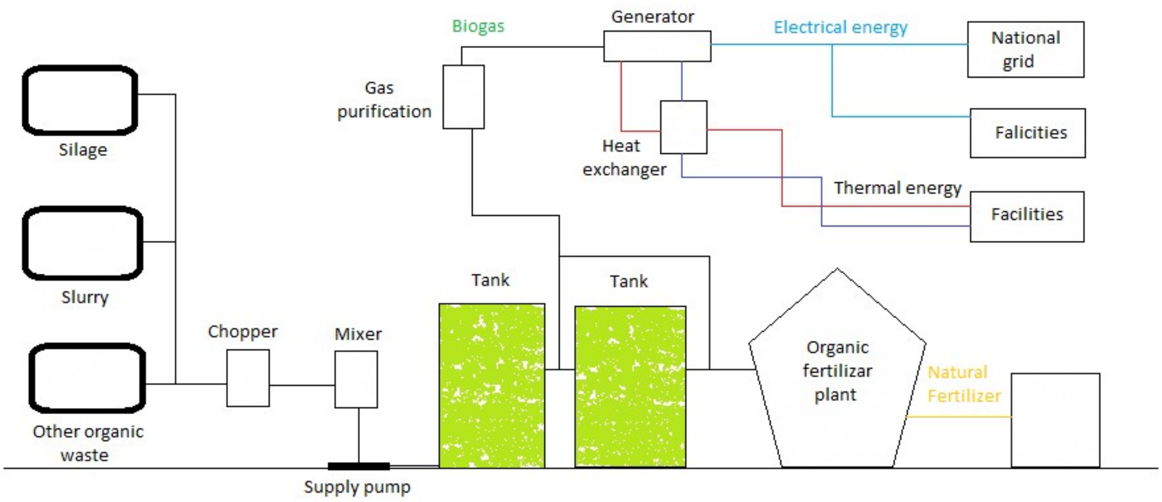


Figure 1: Basic diagram of a biogas plant (Pirecka, 2015)

Biogas can be produced in large scale digesters found in industrial countries for sewage sludge treatment and stabilisation purposes, as well as in small scale digesters on individual farms. Biogas is also produced during anaerobic degradation in landfills and is then referred to as landfill gas.

When it comes to utilisation, biogas has multiple applications but there are three main ones: production of heat and steam, generation of electricity and vehicle fuel. On the other hand, the digestate is used as a natural fertilizer.

Apart from being a renewable source, biogas has many other advantages such as the reduction of the amount of municipal solid waste (Adriana, 2010). It also establishes decentralized centers of energy production and provides high quality fertilizers. Besides, it revaluates residues and decreases the production of bad odour of decaying organic matter. The capture of biogas from landfills and composting plants prevents odours and protects the atmosphere of methane. It is a cheap technology that in addition, creates a large number of jobs (Bagher Askari, 2015).

However, it is a little progress technology and the storage system is complex. Biogas can contain impurities and also be unstable (Grupo AB, 2016)

2.2 History of biogas

It has been known for several centuries that rotting vegetable matter gives off flammable gas. Actually some technologies were documented in China, Persia or India from 1600 B.C. However, it was not until the seventeenth century when records of decaying organic material producing the gas were presented. In 1776, the first scientific substantiation of flammable gas generation in wetland and lake sediments was given by Alexander Volta who found out the presence of methane in marsh gas. (Biogas Fluid, 2016)

After the discovery of the chemical formula of the methane between 1804-1808 by John Dalton and Humphrey Davy, European scientists started making the first investigation in the application of biogas. Several researches added new information about biogas during the following years. That was the case of Bechamp in 1868, who reported that the formation of methane during the decomposition of organic matter was through a microbiological process. Popov in 1875 investigated the effect of the temperature on the quantity of generated gas.

Soon after this in 1881, biogas began to be used for heating premises and street lighting. Lately, in 1890 the first large scale biodigester was built in India. In 1896, England made that all its street lamps in one part of Exeter city were fed by biogas generated from the fermentation of sewage water and collected in closed vessels. (Tasneem Abbasi, S. M. Tauseef, S. A. Abbasi, 2012)

The first large scale biogas plant was built in 1911 in Birmingham (England) and was used for decontamination of sewage water sediments of the city.

In the First World War, biogas plants have stated to be distributed in Europe in connection with fuel deficit. Farms with biogas plants enjoyed favourable conditions. During the Second World War, real energy deficit experienced by all European countries and German and France have put an emphasis on producing biogas from agricultural waste, mainly from manure. However, European biogas plants have lost competition to cheap energy during the afterward years and were dismantled. (Biogas Fluid, 2016)

For the past 20 years, profitable results in terms of discoveries on the functioning of microbiological and biochemical process through laboratory equipment have been made. It allowed the study of microorganisms intervene under anaerobic conditions.

2.3 General view

Globally biogas represents one of the most sustainable energy resources and greater growth potential. Around 17,000 biogas plants in agriculture, industry and wastewater treatment are in operation in Europe according to the European Biogas Association (EBA, 2015). The majority of them are located in Germany and Italy. This success is due to the high feed-in tariffs and although most of the other countries have tried to copy this model, their approaches have not been as consistent as theirs.

However, Spain still remains at the end of European agroindustrial biogas (biogas obtained from anaerobic digestion of agro-food waste) list despite having advanced from the 22º position to the 18º and having increased its number of plant from 22 to 39 since 2012 as shown in Figure 2 and Figure 3.

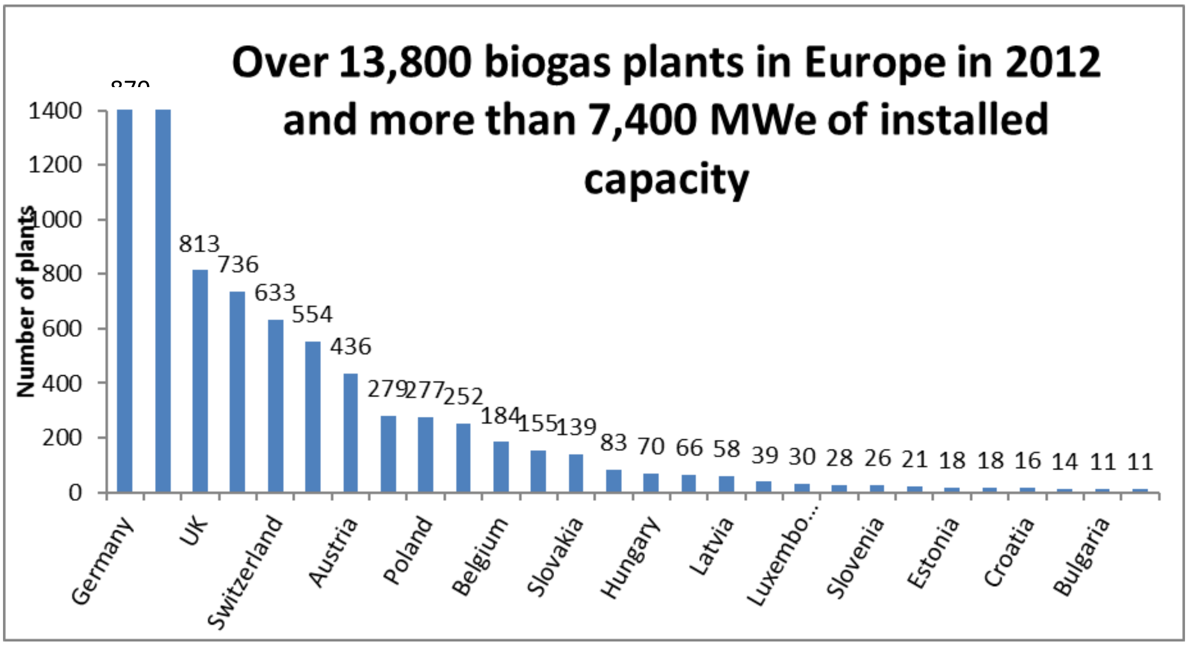


Figure 2: Agroindustrial biogas plants according to EBA in 2012

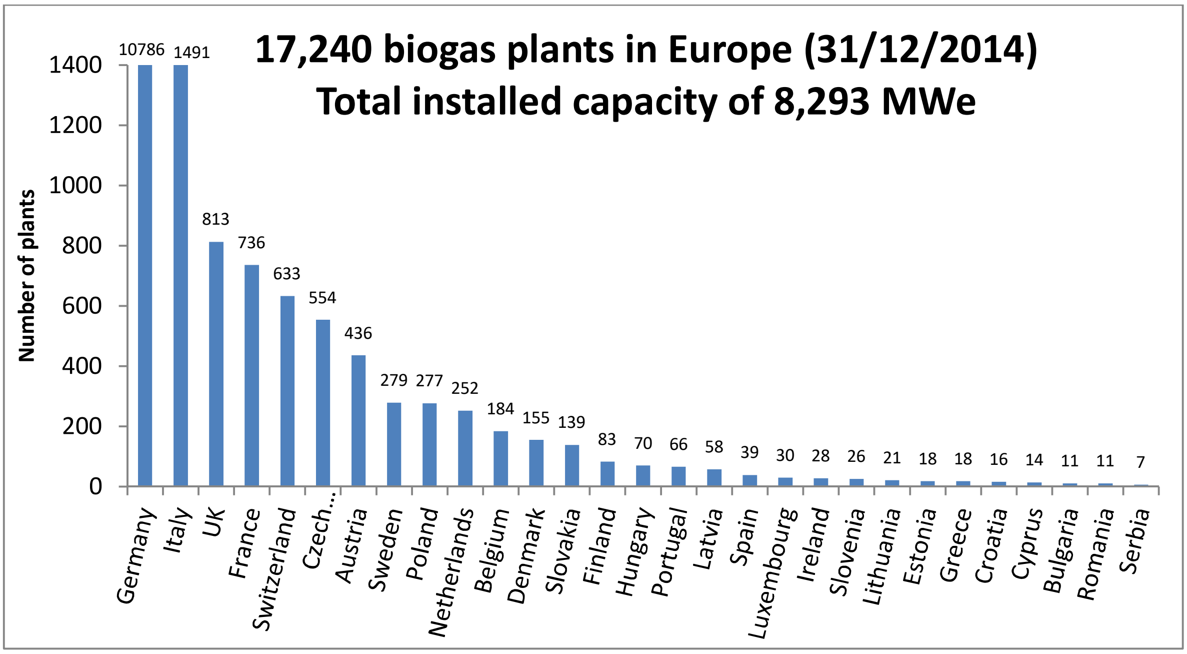


Figure 3: Agroindustrial biogas plants according to EBA in 2014

According to data from 2014 EurObserv'ER barometer (EurObserv’ER, 2014), in Spain, the main contribution comes from landfills (124,000 toe), followed by agroindustrial biogas (102,000 toe) and of sewage treatment plants (30,000 toe). The energy production from biogas in Spain corresponds to only 1.4% (1.2% in the electrical area and 0.2% in the thermal of the total primary energy production) (BioPlat, 2014).

The Renewable Energy Plan (REP) 2011-2020 offered a very promising outlook for the biogas in Spain, which at the beginning of the period credited a production of 165 MWh and that 85% of it came from degassing landfills.

This document mentioned above, defined the biogas generated by the degradation of organic matter under anaerobic conditions and under certain circumstances. According to the REP, biogas production takes place mainly in two types of reactors. On one hand, in landfills (reactors low efficiency) where the gas is collected in them through internal conduits and flaring located on the spot, in order to avoid explosions. On the other hand, there are the anaerobic digesters. They are typical tanks in which wastes are treated with up to 15% total solids (in the most common, complete mixing digesters). Feeding can cover a wide range of organic waste (municipal waste, sewage sludge, cattle manure, agro-industrial waste, energy crops, etc.). Animal by-products not intended for human consumption, SANDACH in Spanish, can even being treated after their sanitization. (REP 2011-2020)

The proportion of biogas which had its origin in landfills has been deeply affected by the Directive 99/31 of the European Commission (EC) on landfills which requires drastically reducing the proportion of biodegradable waste deposited in them, and sets an objective for 2016 its reduction 35%. However, in most of the regions this target has not been accomplished as it is the case of Castilla y León.

Regarding the biogas generated in sewage treatment plants, the objectives of Directive 91/271/EC for treatment of urban waste water have been met: the situation can be considered as fully stabilized.

In view of the available data, although it is true that Europe has very positive prospects (Energías Renovables, 2014) regarding biogas production, Spain has a really slow growth despite the large amount of waste. It is clear what the main reason why this technology has yet not reached its potential speed of development is: legislation.

3 Biogas in Spain

3.1 History of biogas in Spain

The beginning of the biogas plants was with the Real Decree 661 in 2007. This decree brought a very fair bonuses for profitability and only the best plants could be profitable. Besides, the lack of experience both in the industry and society and the long processing, made that relatively few biogas plants were built and at a slow pace compared with other renewable technologies that grew a lot in this period (Biovec, 2016).

Surprisingly in the sector, Decree Law 1 was approved in 2012. This one implied that all the bonuses for all temporary renewable ended and many biogas plants under construction were left without profitability. Four years have gone but still, the only measure taken by the government was the Real Decree 947 set in 2015 which consisted in new wind and biomass installations but no biogas.

However, before this last law was launched, the Real Decree Law 9 of 2013, known as the reasonable profitability, basically cut back the bonuses to all the existent renewable installations including the biogas ones. It meant a reduction between 15 and 30% of the receiving premiums affecting smaller plants in particular. This fact led to many existing plants to a limit financial situation and forced them to refinance their loans. It also generated a great distrust in renewable investment and also in biogas due to legal uncertainty. (Biovec, 2016)

During these years it was possible to make biogas plants for electricity consumption but a set of draft decrees on catastrophic tolls and taxes for self-consumption kept any intention to make a biogas plant for electricity generation. Finally, the government approved Real Decree 900 in 2015, known as tax sun. This is the most restrictive law and it prevents biogas plants for their own consumption to be made.

So far, there is no rule or law to promote the biomethane or refined biogas injection to the gas network and neither there is the intention to work on it. Besides, as opposed to most European countries, if Spain produces biogas for vehicles, the government would collect taxes like with the fossil energy.

3.2 Legislation of biogas in Spain

The use of renewable energy is essential to ensure efficient energy supply from an environmental point of view. Precisely, the Directive 28/2009/EC of the European Parliament on the promotion of energy use from renewable sources sets a target for 2020 that 20 % of gross final consumption of energy in the European Union has to be from renewable sources. According to the latest report by the EC, 9 of the 28 European Union Member States have difficulties to accomplish this target. Among them is Spain, where the amount of energy from renewable sources is still far from that goal. (EBA, 2015)

The main legal aspects regarding the agroindustrial biogas in Spain (REP 2011-2020):

3.2.1 Sanitary legislation

The management of animal by-products (SANDACH) from the time of generation until its final use, recovery or destruction is regulated to ensure that during the time no risks to human health, animal health or the environment are generated and specially to ensure the safety of human and animal food chain.

Royal Decree 1429/2003 SANDACH, of November 21th, laying down the conditions of application of the community rules on animal by-products not intended for human consumption are regulated. It regulates some specific aspects of Regulation nº 1774/2002 but does not change the use of these by-products for biogas production. This Royal Decree establishes the creation of a SANDACH National Commission effectively incorporated in May 2005, and included representatives of all the administrations involved.

Regulation (EC) Nº 1069/2009 of the European Parliament and the Council and Regulation (EU) Nº 142/2011, constitute since March 4th 2011, the legal framework for animal by-products not intended for human consumption and products derived thereof, being repealed from the date Regulation (EC) 1774/2002.

In Spain the Royal Decree 1528/2012 established the conditions of application of the Community rules on animal by-products. Among other measures, defines the distribution of powers between various departments of the General State Administration (AGE) and the autonomous communities (CCAA) in relation to SANDACH, and creates the National Commission on Animal by-products not intended for human consumption as interministerial and multidisciplinary body referee, whose functions include monitoring and coordination of the implementation of the rules on animal by-products.

3.2.2 Environmental legislation

3.2.2.1 Waste Law 10/1998

This law aims to prevent waste production, establishing the legal status of production and management and promote, in this order, reduction, reuse, recycling and other forms of recovery, in order to protect the environment and people's health. The Act applies to all types of waste, with the following exclusions: the emissions, radioactive waste, liquid effluent discharges to inland waters, discharges from land to sea, discharges from ships and aircraft to sea (have specific legislation).

Importantly, this law makes an exclusion of cattle manure from its scope when applied as fertilizer within farms. This cattle manure is not considered waste (or discharges) and it is relieved of the obligation to seek authorization for management. It is considered that there is specific legislation to specifically regulate management, in particular the Regulations and Rules SANDACH Nitrates, which includes a code of good agricultural practices.

3.2.2.2 Law 16/2002 IPPC

Law 16/2002 of July 1, Integrated Prevention and Pollution Control (IPPC), and its subsequent amendments, requires affected facilities to obtain a single permit called Integrated Environmental

Authorisation (AAI) which brings together in a single administrative act granting all environmental permits (environmental impact authorization for waste management, collection and water purification, emissions, etc.).

3.2.3 Climate change

3.2.3.1 Slurry biodigestion plan

Plan for reducing greenhouses gases (GHG) approved by the Cabinet on December 26, 2008. RD 949/2009 of 5 June, by which the regulatory bases are established of the state subsidies to promote the implementation of the technical processes of this plan.

This plan is part of the Urgent Measures Strategy for Climate Change and Energy Plan, and includes the implementation of technological processes of anaerobic digestion of manure to reduce GHG emissions and for vulnerable areas or high livestock concentration. It also includes the possibility of complementing the methanation of slurry with post-treatment reduction or elimination of nitrogen from manure.

Specifically, this plan favours especially biogas plants that take advantage livestock waste (in particular pig manure), and these plants can reach up to 40% of the investment. Priority has been given the treatment of pig manure because national emissions of methane from manure management, comes in around 90% of pigs.

Therefore, the percentage in the mixture of slurry to digest other livestock species of pig manure cannot exceed 30% by volume.

3.2.4 Biogas use

3.2.4.1 RD 661/2007: Royal Decree of special regime electricity production.

Decree RD 661/2007, of 25 May, concerns about the activity of production of electricity in special regime (BOE No. 126, May 26, 2007). It was modified by fixes published in BOE of 25 and 26 July 2007.

It replaces the previous RD 436/2004, providing a new regulation to the activity of electricity production under the special regime, maintaining the basic structure.

3.2.5 Digestate use

3.2.5.1 Royal Decree of Nitrates

RD 261/1996 of 16 February about the protection of waters against pollution caused by nitrates from agricultural sources. Implementation of Directive 91/676/EC on the protection of waters against pollution caused by nitrates from agricultural sources requires Member States to identify waters that are subject affected by nitrate pollution.

It also establishes criteria for designating as vulnerable zones, those territorial whose drainage surfaces leads to nitrate pollution. It indicates the maximum amounts of manure applied to land: in vulnerable areas are set at 170 kg nitrogen/ha and year, although during the first four-year action programs may be allowed to reach the 210 kgN/ha per year.

3.2.5.2 Royal Decree of Fertilizer

RD 824/2005 of 8 July on fertilizer products (and modifications). It establishes the basic rules on fertilizer products. This Royal Decree applies without prejudice to the provisions of Regulation (EC) No 1774/2002 and vice versa, marketing and use of organic fertilizers and soil amendments must comply with the provisions of this Royal Decree. Define "biodegradable organic waste", as that waste or by-product of vegetable or animal origin used as raw material.

There has not yet been established specific criteria required quality of the digestate for consideration as products in this legislation despite its potential agronomic suitability.

4 Methodology

After the previous introduction to biogas, both generally and more specifically in Spain, investigative work had to be done so as to be able to do the corresponding classifications of the biogas plants. Information about location, capacities, production and processess were needed.

There were two main ways of getting the information needed: the first one was going through the available data on the Internet; the second one was emailing the companies that run the plants.

Initially a general search on the subject was done but, as there was no exact data, it was necessary to contact AEBIG (Asociación Española de Biogás, Biogas Spanish Association). Its president Francisco Repullo, facilitated the number of agroindustrial plants which are currently in operation in Spain.

From there deeper exploration about the plants was carried out, firstly on the internet. Several companies published some of their numbers in their webpages. Also, specific studies and reviews contained valid records for the project. However all the information required was not available online. That's why emails were sent to every company not only to get as much missing data as possible but also, to confirmed the information collected before. In fact, most of the data was gathered this way.

Futhermore, a few phone calls were also made when the companies did not supply a contact number.

The project involves two literature studies: Literature study 1 consists of a general investigation about the different types of biogas plants in Spain; Literature tudy 2 is a research about the plants which are currently working in the selected regions.

Once the plants are identified, in Assessment 1 they will be inserted into a classification based on the types of plants characterized in Literature study 1. Later on, according to the specific data of the plants, they will be inserted in the give framework of categorization of Assessment 2.

This framework of categorization is a table which include seven categories that are considered the most essential ones in order to portray a biogas plant.

Finally, some comments about this table will be done.

So as to make the selection of the plants which will be studied, the method was easy: those plants where all the information needed was gathered are included in the categorization. Those ones where there was information missing, were left out of the study.

5 Literature studies and Assessments: Results and Analysis

5.1 Literature studies 1

In Spain, biogas is mainly divided into three plant types according to Renewable Energy Plan (REP, 2011-2020):

- Agroindustrial
- Landfills: organic solid urban waste (FORSU)
- Wastewater Treatment Process (WWTP)

The agroindustrial sector is the principal source of products, organic compounds and residues that will go through an anaerobic digestion in order to produce biogas. The substrates can be cattle manure, sludge from food processing industries, crop residues or energy crops. (Grupo AB, 2016)

Organic waste disposed in a landfill suffers a biological degradation during which landfill gas is generated. Biogas is a fuel obtained as a result of the degassing of the landfill. (Grupo AB, 2016)

The purification of both industrial and urban wastewaters which occurs in sewage treatment plants consists of a series of physical, chemical and biological processes which aims to separate suspended solids and dissolved materials in form of sludge. This sludge will go through a process of anaerobic digestion to produce biogas. (Grupo AB, 2016)

5.2 Literature studies 2

In order to carry out the Assessment 1 and 2, information about the different existing plants was necessary.

By having a quick look on the Internet, it is clear that it is agroindustrial biogas the one that has been more studied so more information is available. At this moment around 50 plants produce agroindustrial biogas in Spain. They are all distributed around the peninsula. However, half of them are concentrated in the northwest of the country. This project will focus on the rest of the territory leaving the research of Cataluña and Valencia to another project. Besides, some plants which produce other types of biogas will be also presented.

For this study, 24 (from A to X) biogas plants were chosen to try to test the framework of categorization that will be explained in further details later on and to analyze the classifications found in Literature study 1. The plants were chosen to get as wide picture of the Spanish biogas production as possible. The studied plants differ e.g. in used substrate, digestion technique, organization, biogas use, digestate use and capacity. The initial idea was to study at least one plant of each type in every region. However, as mentioned before, there is no available information about some of them. That’s why those ones are just listed.

In the sections below, all the biogas plants found are listed. Information about their location, type of plant and power generation of the plant (thermal or electrical) is included in the list. Then those selected for the framework are explained in further details and later on, they will be classified. So as to facilitate the reader the view of the work, the plants chosen incorporate the letter they represent in the following studies.

5.2.1 Andalucía

In this region 18 biogas plants are working at the moment. In Table 2, they are listed and below it, in Figure 4, there is a map in which they are all located. However, only two of them will go through a deeper research so as to have a general view of the biogas in Andalucía. (Informe de infraestructras energéticas de Andalucía, 2012)

Table 2: List of the biogas plants in Andalucía

	Plant	Region	Type	Power (MW)
A	Campillos	Málaga	Agroindustrial	1.9
	Guadalete	Cádiz	WWTP	0.47
	Copero Sur	Sevilla	WWTP	1.90
	Guadalhorce	Málaga	WWTP	1.44
	San Jerónimo Norte	Sevilla	WWTP	0.5
	Ranilla Este	Sevilla	WWTP	0.5
	Churriana Sur	Granada	WWTP	0.6
	Huelva	Huelva	WWTP	0.25
	Tablado Oeste	Sevilla	WWTP	0,5
	Golondrina	Córdoba	WWTP	0.5
	Jerez de la Frontera	Cádiz	Landfill	1.65
B	Montalbán	Córdoba	Landfill	2.55
	Valsequilla	Málaga	Landfill	2.55
	Granada	Granada	MSW[1]	0.62
	Limasa III	Málaga	MSW[1]	3.16
	Cónica Montemarta	Sevilla	MSW[1]	10.41
	Biometización “Sierra Sur”	Jaén		0.8
	BIOLIX	Sevilla		1.42

[1] Municipal Solid Waste (MSW): is a waste type consisting of everyday items that are discarded by the public and ends up in landfills.

Figure 4: Location of the biogas plants in Andalucía

5.2.1.1 Campillos, Málaga (A)

The private organization, Giesa Agroenergia, has been running the agroindustrial biogas plant in Campillos since 2016. It processes most of the manure of the area (35,000 ton), in addition to other agri-food waste (60,000 ton) and sewage sludge (8,000 ton). Slurry, poultry manure, goat manure… They are all recycled to generate electricity with which to feed the plant and the heat for the pig and turkey farms in the area. The plant of 1.9 MW of power counts on 2 mesophilic digesters of 2,800 m^3 of volume. Approximately 16,000,000 kWh/year of biogas is produced and the digestate is upgraded to use it as a fertilizer. (Piñero Grande, 2016)

5.2.1.2 Montalbán (B)

This plant which uses biogas from landfill areas of domestic and municipal waste Montalbán Environmental Complex, inaugurated in June 2008, is one example of the strong bet of Epremasa in favor of renewable energies. The energetic use of landfill gas is carried out by installing two generator of 2,546 kW and one motor of 2,612 kW. This plant consumes 1,420 Nm^3/h of biogas and has an annual electricity of 11,076 MWh. The annual gas estimated consumption is equivalent to an average of 3,229 toe/year and the electricity fed into the public grid, net of own consumption of the installation, is estimated at 10,700 MWh/year, equivalent to the consumption of 2,950 households' production in a year. (Epremasa, 2016)

5.2.2 Aragón

In Aragón 9 biogas plants were found (Bartomeu, 2016) and they are listed in Table 3 and located in Figure 5. From all of them, 3 plants have been selected which will be explained below:

Table 3: List of the biogas plants in Aragón

	Plant	Region	Type	Power (MW)
C	Undúes de Lerda	Zaragoza	Agroindustrial	0.17
D	Urbiliza, Remolinos	Zaragoza	Agroindustrial	0.25
	Pina del Ebro	Zaragoza	Agroindustrial	1.5

E	Almozara	Zaragoza	WWTP	0.24
	Capella	Huesca	Agroindustrial	0.5
	Zaidin	Huesca	Agroindustrial	0.5
	Valderrobres	Teruel	Agroindustrial	0.5
	Peñarroya de Tastavins	Teruel	Agroindustrial	0.5
	Parque Tecnológico de Reciclaje	Zaragoza		5.4

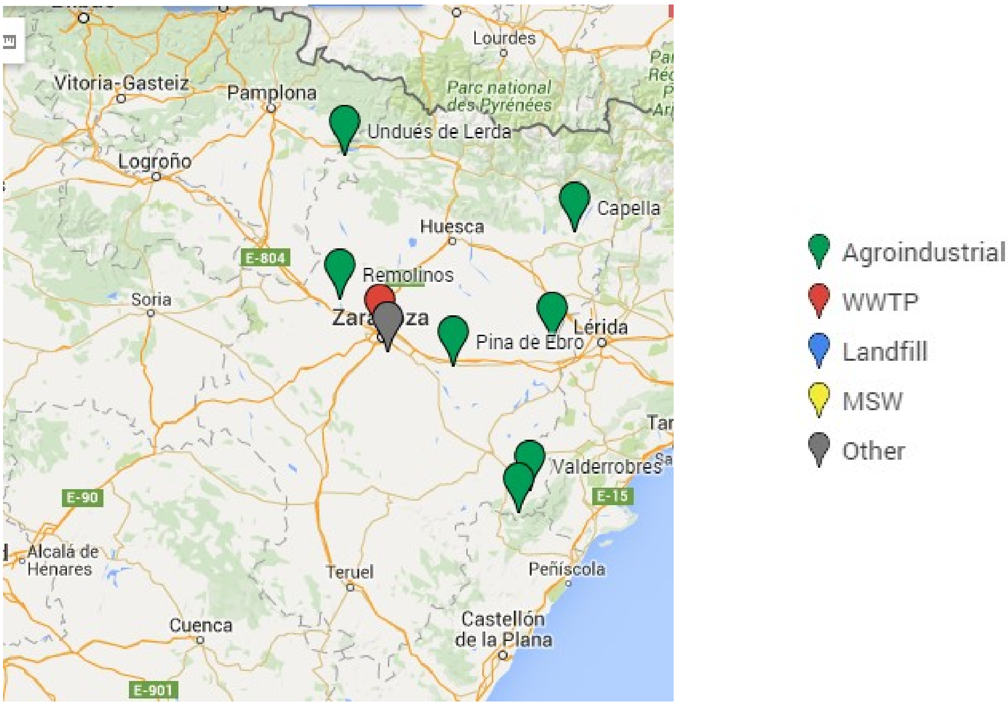


Figure 5: Locations of the biogas plants in Aragón

5.2.2.1 Undués de Lerda, Zaragoza (C)

In Undués de Lerda, biogas is produced by the private company Agronsella in the same farm they run. Since 2014, their plant performs the anaerobic digestion of 6,000 ton/year of concentrated pig manure obtained. In order to do so, they count on one digestor of 700 m^3 and a post digestor of 500 m^3. Besides, two boilers of 170 kW are needed for the farm heat consumption and one boiler of 60 kW for the digests. The biogas produced is then upgraded at the plant itself to be used as heat for farms and the digestate is utilized for agronomic applications. In addition, 765 MWh of biogas is produced each year generating 765,000 kWh of energy along the process. (Biovec, 2014)

5.2.2.2 Remolinos, Zaragoza (D)

The limited liability company Urbiliza Renovables started up the biogas plant in Remolinos in 2012. The biogas produced by the plant comes from bovine excretions (10,000 ton/year) and agricultural and food industry waste (10,000 ton/year) treated in two digestors of 2500 m^3 that operate at 45ºC

(Puente Arcos, 2015). For the power generation, the plant rely on two equipments of 250 kWe. Between 1.7 and 1.9 MNm3/year of biogas is generated and the digestate is used as fertilizer for the field. Approximately 4,300 MWh/year of electricity is produced; being the annual consumption of electric power facilities 497,218 kWh/year and the rest will be exported to the grid. The thermal energy produced will be used to provide heat to the digesters. (Biovec, 2012)

5.2.2.3 WWTP Almozara (E)

In Zaragoza, DRACE from Grupo ACS runs the conventional activated sludge plant. Since 1989 it collects the discharges from different neighborhoods, industrial areas and near locations. It has a primary digester of 3,850 m^3 that operates at 30-35ºC during 25 days each time (retention time) to produce biogas and digestate. Biogas is used for energy efficiency cogeneration and the digestate as a fertilizer. The plant manages to generate 2,300 MWh of electricity per year and has the capacity to treat 34,560 m^3 of waste per day. (Europa Press, 2016)

5.2.3 Asturias

In Asturias, there are two plants where biogas is recovered (Biogas Fuel Cell, 2016). In both Table 4 and Figure 6, they are shown:

Table 4: List of the biogas plants in Asturias

	Plant	Region	Type	Power (MW)
F	Tineo	Asturias	Agroindustrial	0.25
G	Cogersa	Asturias	Landfill	6.5

Figure 6: Location of the biogas plants in Asturias

5.2.3.1 Tineo (F)

The only agroindustrial biogas plant in Asturias is located in Tineo and it is run by a local private company, Biogas Fuel Cell. Operating since 2014, the plant processes 26,000 ton/year of waste water, slaughterhouse waste, agro-industrial, dairy industry and livestock wastes generating out of it 1,300,000 Nm^3/year of biogas. The process is performed in two digesters of 1,000 m^3 at 55ºC (thermophilic process) and then in two post-digesters of 1,000 m^3 at 39ºC (mesophilic process). After a process of reducing its content of H_2S and water vapor, the biogas is burnt in a cogeneration engine of 250 kW. The recovered heat is used by the installation itself and electricity is fed into the grid. Finally the digestate is stored temporally in a tank to be later collected by the farmers and used as a fertilizer for fields. Approximately 2,000 MWh/year of energy is extracted in the process. (Biogas Fuel Cell, 2016)

5.2.3.2 COGERSA (G)

In Serín, the public company COGERSA runs the waste treatment center of la Zoreda since 1982. This non-hazardous waste landfill receives 390,000 ton/year of MSW and 60,000 ton/year of sludge that are treated in the landfill itself at a temperature lower than 50ºC. After de anaerobic process, the biogas network capture is performed using vertical wells and overhead lines driving. Biogas is used to produce electric energy and heat for the burner. The landfill has an electric power of 6.5 MW and manages to produce 34 Mm3/year of biogas. (Gonzalez Fernandez, 2015)

5.2.4 Castilla La Mancha

In Castilla La Mancha only 5 plants were located (Romagera, 2013) and all of them, agroindustrial.
The first three will be exposed right after the list and the map.

Table 5: List of the biogas plants in Castilla La Mancha

	Plant	Region	Type	Power (MW)
H	Balsa de Ves	Albacete	Agroindustrial	0.25
I	Bonete	Albacete	Agroindustrial	0.35
J	Chinchilla de Montearagón	Albacete	Agroindustrial	0.25
	Albarreal del Tajo	Toledo	Agroindustrial	0.499
	Osa de la Vega	Cuenca	Agroindustrial	0.5

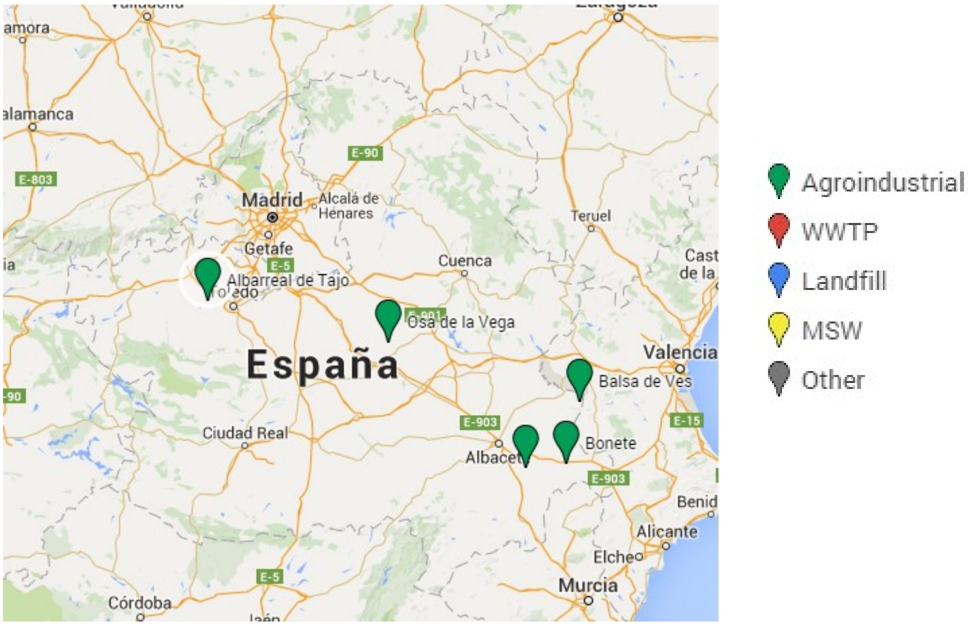


Figure 7: Location of the biogas plants in Castilla La Mancha

5.2.4.1 Balsa de Ves (H)

The Sanchiz Group (De la Cruz Hernández, 2016) with the help of Inderen set up a biogas plant is Albacete in 2013. The manure resulting from the Ves farm is used to fuel the biogas plant , helping to reduce the level of N, CH_4 and CO_2 into the atmospehere and avoiding bad odeur. The manure is digested in a mesophilic digester of 3,000 m^3 at 37ºC to obtain 150 m^3 of biogas per hour. Subsequently, the biogas serves to fuel the heating installations and the digestate generated is used as organo-mineral fertilizer in agricultural plots owned by the company. (Gracia García, 2016)

5.2.4.2 Bonete (I)

In Bonete, Albacete, Grupo Sanchiz placed a cogeneration (production of two types of energy at the same time, usually heat and electricity) biogas plant in the Ingapor farm in 2013. Biogas is produced out of the manure generated in the farm. One mesophilic digester of 3,000 m^3 at 37ºC treats the subtrates. The biogas is then used to supply heating and elecricity to the plant itself and the excess is sold to the grid. The digestate is used as natural fertilizer. Approximately 150 m^3/hour of biogas is generated in the plant. The electric power of the plant is 350 kW. (Gracia García, 2016)

5.2.4.3 Chinchilla de Montearagón (J)

Grupo Sanchiz owns the biogas plant in Chinchilla de Montearagón, Albacete. Since 2013 this cogeneration plant treats manure from the farm to obtain 150 m^3/hour of biogas which will be used to heat the installation. The digestate is upgraded as fertilizer. The electric power of the plant is 250 kW. It counts with a mesophilic digester of 3,000 m^3 that works at 37ºC. (Gracia García, 2016)

5.2.5 Castilla y León

After going through the available information about the biogas in Castilla y León, 4 plants were found. In Table 6 they are listed and in the Figure 8, it can be seen where they are located.

Table 6: List of the biogas plants in Castilla y León

	Plant	Region	Type	Power (MW)
K	Juzbado	Salamanca	Agroindustrial	0.5 (elec+ther)
L	Almazán	Soria	Agroindustrial	0.25
M	Santiener	Valladolid	Agroindustrial	1 (ther)
N	Madrona	Segovia	WWTP	0.71

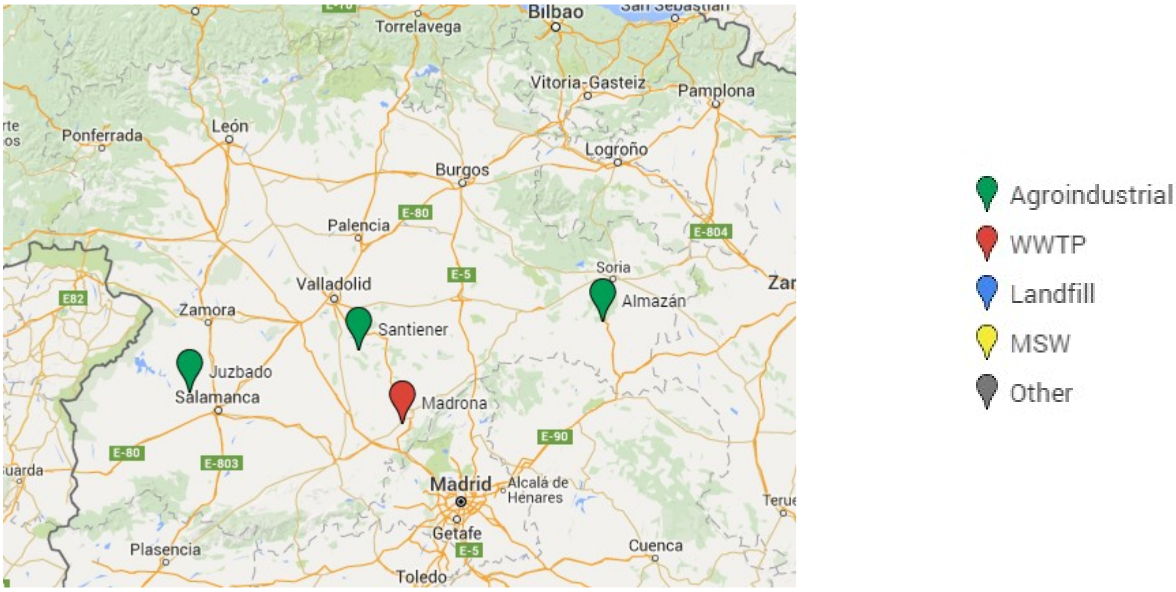


Figure 8: Location of the biogas plants in Castilla y León

5.2.5.1 Juzbado (K)

In Juzbado (Salamanca), biogas is produced since 2011 by a company called Enusa with the collaboration of Biogas Wesser-EMS at a farm. Although the amount of substrates vary annually, the proportions are usually 80% manure and 20% cereal powder, both obtained from close areas. The substrates are digested at 40ºC in two mesophilic digesters of 2,200 m3. The plant has an output power of 500 KW (electric power) and 550 kW (thermal power). The biogas is upgraded at the farm to be used for combustion in a cogeneration unit for generating thermal and electrical energy. The total annual production of biogas is 2,117.5 MWh/year according to RD413/2015. The digestate is used as fertilizer. (Bentec, 2011)

5.2.5.2 Almazán (L)

In Soria, the private company Purines de Almazán S.L. constructed the plant of 250 kW with a capacity of approximately 52,000 m^3/year of waste (variable depending on the solids content of the treated waste). It valorizes organic waste such as chicken or pig manure produced in a facility adjacent built by the company during 2015 for the treatment of pig carcasses. The manure from the farmers in the Almazán location is moved in a tanker from the septic tank to the plant. Once in the plant, the product will go to increase anaerobic digestion for biogas production (1,100,000 Nm^3/year) in a mesophilic digester of 3,000 m^3 which operates at 37ºC. Biogas will be turned into electricity for the grid and heat for self-consumption network installation. Finally, the digestate is stored temporally in rafts and then used by farmers as fertilizer. (Biogas Fuel Cell, 2016)

5.2.5.3 Santiener (M)

In Iscar (Valladolid), biogas is produced at a plant set by Santibañez Energy in 2014. The facility produces only thermal energy from 5,000 tons per year of agrifood residues of plant. In order to do it, they use two digeters of 500 and 700 m^3 of volume. The produced biogas is upgraded to be used only in a boiler and the digestate is utilized as fertilizer. Approximately 500,000 Nm^3 of biogas is produced per year with a 58% of CH4 and 1.2 GWh of energy is extracted from the process. (Santibañez Energy, 2016)

5.2.5.4 WWTP Madrona (N)

In Segovia, the WWTP has been working since 2003. This plant was designed to treat a flow of 41,280 m^3 per day, and is able to reach up to 4,400 m^3/ hour and fulfill the necessities of 147,920 people. All the sewage sludge (3,775 tons per year) comes from the wastewater treatment plant and is treated in a digester of 3,000 m^3 at 36.5-37.5 ºC during 28-30 days. Part of the biogas produced feed two boilers that provide heat to the process, another is derived to produce electricity in an engine and the rest returns to the process or it is stored. In total, approximately 740,800 m^3/year of biogas is generated and 1.197 MWh/year of electricity. The digestate is used as a fertilizer. However, it was refurbished from March 2014 until March 2016 so at the moment it is not working in full performance. (Sanchez Arista, 2016)

5.2.6 Galicia

In Galicia the 9 biogas plants found (Bartomeu, 2016) are presented in Table 7 and situated in Figure 9. Among them, three of them were studied in more details.

Table 7: List of the biogas plants in Galicia

	Plant	Region	Type	Power (MW)
O	Cospeito	Lugo	Agroindustrial	0.5
P	Mouriscade	Pontevedra	Agroindustrial	0.03
Q	Carballo	A Coruña	Agroindustrial	0,191
	As Somozas	A Coruña	Agroindustrial	1.8
	Babcock Kommunal MBH y Técnicas Medioambientales	A Coruña	Landfill	6.275
	Biocerceda	Cerceda	Landfill	2,268
	Urbaser	A Coruña	Landfill	2,5
	Complexo Medioambiental do Barbanza	Lousame	Landfill	0.13
	Albada	A Coruña	MSW	6.2

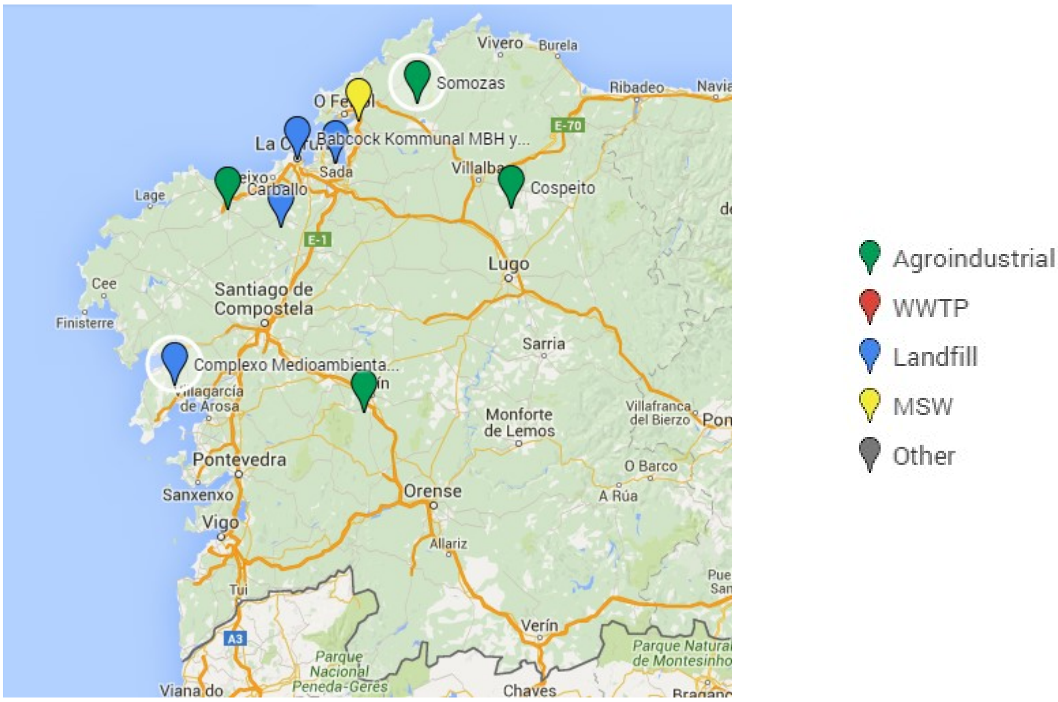


Figure 9: Location of the biogas plants in Galicia

5.2.6.1 Cospeito (O)

In Xustás (Lugo), the private company Norvento placed a biogas plant of 50 kW in 2015 (Bioenergy, 2013). As of manure (agricultural waste and livestock) from the farm in Xustás run by the company SAT Xustás, the substrate is processed in a digester of 350 m^3 and the biogas produced, upgraded to heat for milking circuit stabling and electricity to sell it to the grid. Eventually they are producing 190 m^3/day of biogas and the digestate is used in the fields of the SAT. (Bartomeu, 2016)

5.2.6.2 Mouriscade (P)

In the Mouriscade farm in Lalín (Pontevedra), biogas is produced since 2012 (Nodar Balseiro, 2012). The farm has 100 dairy cows which are the origin of livestock waste that cater mainly to the biogas plant. Also the feed residues obtained in the laboratory of the farm are used as substrate. The plant treats 1,500 m^3 of manure and 500 m^3 of feed residues per year in a mesophilic digester of 258 m^3 of volume. Around 80,000 m^3 per year of biogas is produced. After being upgraded, biogas used for heating and electricity and the digestate is used as a fertilizer for the farm itself. Out of the process, 190,000 kW of electric energy is extracted.

5.2.6.3 Carballo (Q)

The plant in Carballo is jointly owned by Calvo (waste producer) and JB Ingenieros since 2009. The biometization plant uses industrial waste as their substrates and treats them in a thermophilic digester of 1,000 m^3 of volume in order to produce biogas. Approximately 800-1,600 m^3/day of biogas is produced and used for the production of electricity to feed the grid. The digestate is upgraded as a fertilizer. (Bouzada, 2015)

5.2.7 Murcia

In Murcia only two agroindustrial biogas plants were found (see Table 8) which have been located in Figure 10 and right after this, there is the information about them.

Table 8: List of the biogas plants in Murcia

	Plant	Region	Type	Power (MW)
R	Cañada Hermosa	Murcia	Agroindustrial	0.7
S	Los Alcázares	Murcia	Agroindustrial	0.37

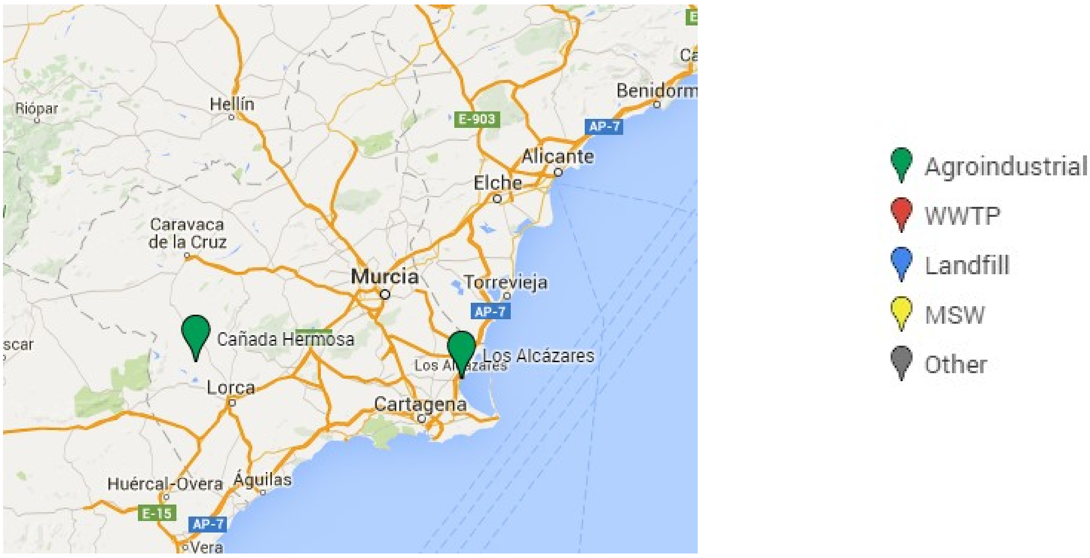


Figure 10: Location of the biogas plants in Murcia

5.2.7.1 Biometización Cañada Hermosa (R)

In Cañada Hermosa, Estrella Levante runs the biogas plant since 2014. Waste mainly comes from the food industry, although the digester is also authorized to receive organic materials recovered from household waste treated at the existing treatment plant at the Waste Treatment Centre of Cañada Hermosa. It has the capacity of treating 22,000 t/year of organic waste in its digester of 2,300 m^3 and it is able to generate 2 Nm^3/year of biogas which will be used to produce energy for heating and electricity. There is no information available about the use of biogas. (Estrella Levante, 2014)

5.2.7.2 Los Alcázares (S)

Kernel Export runs a biogas plant of 370 kW electric power which is able to handle a capacity of 60 tons per day of agrifood waste. The construction of this facility was executed by Ludan renewable Energy Spain. The biogas produced is used to generate electricity for self-consumption and the digestate is used as fertilizer. The company has not been allowed to sell the excess of electricity to the grid. The operating temperature for the anaerobic digester of 3,000 m^3 is within the optimal range 38-40 °C (mesophilic) and this process usually lasts 57 days. The average energy power consumption of the biogas plant is 50 kWh. (Puchades Rufino, 2015)

5.2.8 Navarra

At the moment 8 biogas plants (Gracia García, 2016) are in operation as they are listed in Table 9 and situated in Figure 11. Five of them will be explained in more details below:

Table 9: List of the biogas plants in Navarra

	Plant	Region	Type	Power (MW)
T	Agralco	Navarra	Agroindustrial	0.64
U	Bioenergía Mendi	Mendigorria	Agroindustrial	0.5
V	HTN	Caparroso	Agroindustrial	3.2
W	E-Cogeneración Cabanillas	Cabanillas	Agroindustrial	0.349
	Bioenergía Ultzama	Iraizoz	Agroindustrial	0.5
X	Servicios de la Comarca de Pamplona S.A (Góngora)	Aranguren	Landfill	2.316
	Mancomunidad de Residuos Solidos de la Ribera	Tudela	Landfill	1.426
	Servicios de la Comarca de Pamplona, S.A. (Arazuri)	Arazuri	WWTP	1.1

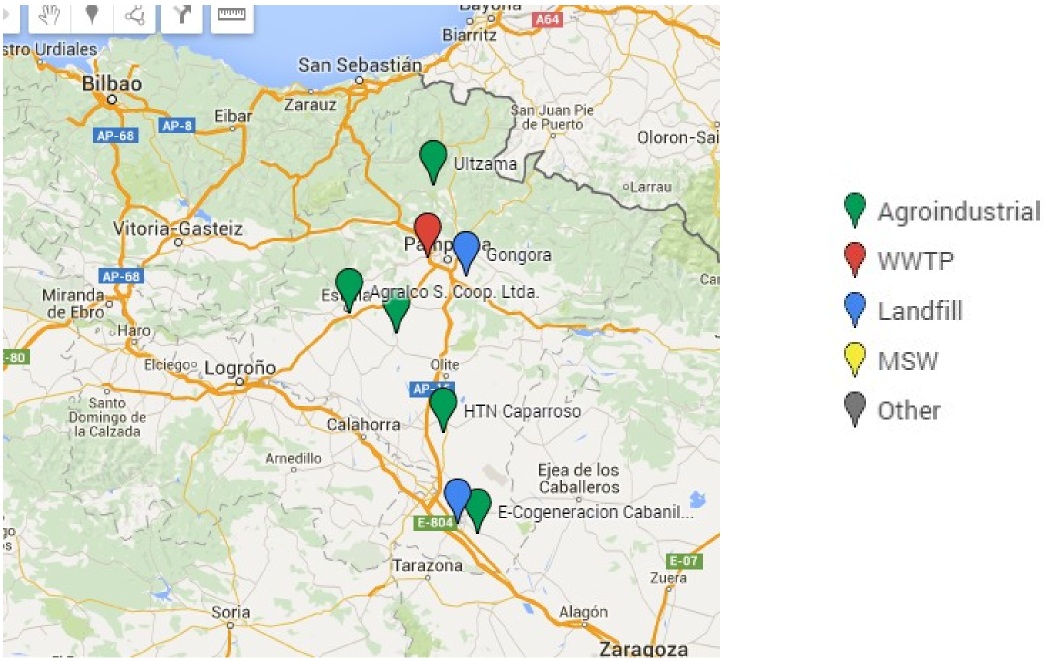


Figure 11: Location of the biogas plants in Navarra

5.2.8.1 Agralco (T)

In Estella, the cooperative Agralco S.Coop produced biogas since 2006. With a capacity of 15 m^3/hour of depuration of wine from the dregs, they manage to digeste in two mesophilic equipment up to 7,000 m^3 of substrates originated from products of vinification wineries: grape marc and wine lees for vinous alcohol, tartaric salts, grape seed oil and oenocyanin. They process annually 50,000 ton of grape marc and 18,000 ton of wine lees and they obtain 1,750,000 Nm^3 of biogas per year which is used for the production of electricity for the four cogeneration engines (160 kW) of the plant itself. It does not sell it to the grid. The digestate is poured into the municipal sewage treatment plant of Estella. (Corella, 2016).

5.2.8.2 Mendigorria (U)

In Mendigorria, biogas is produced by Bioenergía Mendi S.L since 2011. This cogeneration plant treats 15,000 m^3 of pig slurry (breeding mothers) from the farm El Saso and 22,000 tons of waste (water waste from toilets and sewage among others) of the facilitate itself in order to produce approximately 1,752,000 m^3 of biogas per year. Then it is used to generate electricity and heat for the installations and the digestate as a fertilizer. From the process, 500 kW of electrical power and 600 kW of thermal power are extracted. The plant has two digesters of 1,500 m^3 and 2,100 m^3. (Echamendi, 2016)

5.2.8.3 HTN (V)

In Caparroso, biogas is produced from cattle and manure waste by the limited liability company HTN in a cogeneration plant. The plant processes the substrates which are pasteurized before digestion process. Once these substrates are treated, the solid fraction is separated from the liquid and both are used for agricultural fertilizer. The process is performed by two mesophilic digesters of 8,000 m^3 each. The produced biogas (9,200,000 m^3 per year) is used as fuel for the engines and for electricity which approximately is 24,000 MWh/year, and will be sold to the grid. The digestate is used as organic fertilizer in agricultural crops. (Bezdicek, 2016).

5.2.8.4 Cabanillas (W)

The biogas plant in Cabanillas is run by the private company E-Cogeneracion Cabanillas S.L. since 2013. Two mesophilic digesters of 2,400 m^3 of volume treat 12,000 tm/year of pig manure and 8,000 ton of waste (sludge and industrial) to produce 5,450 MWh/year of biogas that after being upgraded will be used for heating the plant and electricity to sell it to the grid. The digestate is utilized for agronomic applications. From the process 2,900,000 kWh of energy per year are extracted. The power of the plant is 370 kW and count on two receiving tanks of 60 m^3 and 150 m^3 and a raft for the digestate of 5,000 m3.

5.2.8.5 Tudela (X)

The landfill of El Culebrete in Tudela started working in 2006 by the direction of Mancomunidad de la Ribera. The biometization plant of 1,425 kWe uses domestic waste in their mesophilic digester of 5,600 m^3 and treats them for 14 days to produce 2,216,781 m^3 of biogas per year. Biogas will be used to produce electricity to sell it to the grid and the digestate is composted mixed with wood chips to use it as fertilizer. Around 3,224,000 kWh of energy is extracted from the process. (Gracia García, 2016)

5.3 Assessment 1

At the moment, there is no certainty of the exact number of biogas plants, all types included in Spain. Due to the actual legislation, many of them have been forced to cease or even close. In Section 4.2 all the plants located have been listed and then some have been selected for further studies. Those can be seen in Figure 12. Deeper information on those plants has been also included.

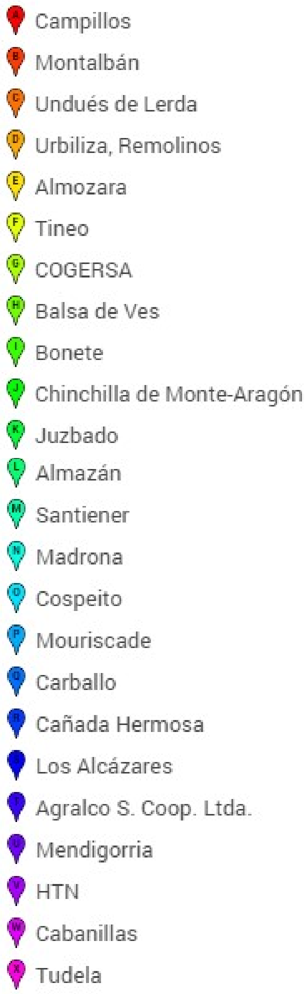


Figure 12: The studied plants.

After analyzing the types of plants in Literature 1 and the research about them in Literature 2, they are inserted into the classification of Literature 1 in Table 10. The classification is based on the description of the classification together with the specific data.

Table 10: The studied plants from Literature Study 2 inserted into the classification found in Literature Study 1

SPAIN
Landfill
(B) (G) (X)
Agroindustrial
(A) (C) (D) (F) (H) (I) (J) (K) (L) (M) (O) (P) (Q) (R) (S) (T) (U) (V) (W)
WWTP
(E) (N)

5.4 Assessment 2 and Complemented framework for categorization

Once the plants have been studied in Literature study 2, the information is organized into several categories to differentiate each biogas production. Hence the Framework for categorization:

5.4.1 Results

In Table 11 there is the Framework of categorization. On it, the plants are classified in seven categories which have been considered as the most suitable ones to characterize a plant:

- Substrate: what the material used in the process come from.
- Organization: it means how the biogas plants are owned.
- Biogas Use
- Digestion Technique: digestion technology which can be mesophilic or thermophilic.
- Localization: both refer to the location from a substrate perspective (the first column) and from a gas perspective (second column). How the substrates are transported to the plant, how the gas is treated.
- Digestate: what the digestate is used for.
- Capacity: the size of the digester.

Table 11: Framework for categorization with the studied plants from Literature study 2 inserted into it

Substrate	Organization	Biogas use	Digestion technique*[ac]	Localization		Digestate	Capacity*[b]
Pig Manure	**Municipality**	**Electricity**	**Mesophilic (15-45 °C)**	**Main substrate on-site**	**Upgrading on-site**	**Fertilizer**	**Small (< 2 000 m^3)**
(A) (C) (H) (I) (J) (L) (U) (W) (X)	(G) (K) (N) (P) (X)	(A) (B) (E) (G) (K) (L) (N) (O) (Q) (S) (U) (X)	(A) (C) (D) (E) (H) (I) (J) (K) (L) (M) (N) (O) (P) (S) (T) (U) (V) (W)	(C) (H) (I) (J) (N) (P) (Q) (R) (T) (X)	(C) (E) (K) (M) (N) (R) (W)	(A) (C) (D) (E) (F) (H) (I) (J) (K) (L) (M) (N) (O) (P) (Q) (R) (S) (T) (U)(V) (W)	(C) (F) (M) (O) (P) (Q) (U)
Industrial waste	**Commercial**	**Heat**	**Thermophilic (40-65 °C)**	**Substrate pumped**	**Gas transported by vehicle**	**Compost mixed with wood chips fertilizer**	**Middle (2 000- 5 000 m^3)**
(U) (W)	(A) (B) (D) (E) (F) (L) (M) (O) (R) (S) (V) (W)	(A) (C) (D) (F) (G) (H) (I) (J) (K) (L) (M) (N) (O)	(F) (Q)	(E) (G)	(F)	(X)	(A) (D) (E) (H) (I) (J) (K) (L) (N) (R) (S) (T) (W)
Waste water sludge	**Substrate owner**	**National gas grid**		**Substrate transported by vehicle**	**Local gas grid**	**Application to cultivate corn silage**	**Large (> 5 000 m^3)**
(E) (F) (G) (N) (W) (X)	(C) (H) (I) (J) (T)	(A) (B) (O) (Q) (R) (V) (W)		(A) (B) (D) (F) (G) (K) (L) (M) (O) (Q) (S) (U) (V) (W)	(A) (D) (G) (L) (P)	(K)	(V)
MSW	**Shared ownership**	**Internal use**			**Energy conversion for**		

					internal use [d]		
(B) (G) (W)	(Q) (U)	(C) (D) (E) (F) (I) (J) (H) (L) (N) (P) (T)			(D) (H) (I) (J) (M) (O) (S) (T) (U)		
Domestic Waste					**Energy conversion for external use** [e]		
(B) (R)					(B) (D) (K) (Q) (V) (X)		
Crops							
(K) (L)							
Agrifood							
(A) (D) (F) (M) (Q) (R) (S) (T)							
Bovine Manure							
(D) (O) (P) (V) (K)							

* Not applicable for landfills (B), (G) and (X). [a] The plant of Biometización Cañada Hermosa (R) cannot be placed in any of this subcategories since there is no available information about it. [b] The size of the digester(s). The fragmentation is based on the data from the studied plants. [c] (Jorgensen, 2009). [d] Internal use indicates that the biogas is used at the site in some way, and does not need to be transported anywhere. [e] Energy conversion for external use indicates that the biogas is converted to e.g. heat and/or electricity and (partly) used outside the plant.

6 Discussion

In the previous section, the classification of the plants from Literature study 2 has been done. There were seven categories considered: Substrate, Organization, Biogas use, Digestion technique, Location, Digestate use and Capacity of the digesters of the plants. Some of them should be commented now.

It should be mentioned that there were two categories, digestion technique and capacity, that could not be applied to one type of biogas plant which is landfill. That is due to the fact that they do not have digesters.

The first one was the origin of the substrates. Pig or bovine manure, sludge, municipal solid waste or crops are some of the possibilities from where the substrate can be obtained. However, there is no one that stands out among the others.

The category Organization means how the biogas plants are owned. Most of them are private companies that obtain the materials from near areas. Only a few, like the farms of Balsa de Ves or El Saso own the substrate they will use to produce the biogas.

When it comes to the utilization of the biogas, most of the plants identified use it to generate electricity, heat of both. That is what it is known as cogeneration which seems to be quite common in the selected regions of Spain. Also, it is necessary to mention that this energy from biogas is used to self-supply the installations, to sell it to grid or both.

Regarding the type of digestion technique, it is clear that the mesophilic technique is the most common one.

Another fact that we can see is that the digestate is always used as a fertilizer.

To sum up, after carrying out these studies, it is clear that even though there are only three types of biogas plants in Spain there are many differences between them and that is why it is quite hard to draw patrons to relate the plants.

7 Conclusions

The aim of this project was to do a research about the biogas plants in some regions of Spain in order to complete the framework of categorization which would give a general view of the biogas situation in this country. The work was completed and it was real interesting to get to know more about this renewable energy that has so much potential.

It is clear that there are three types of biogas plants in Spain: agroindustrial, landfill and WWTP. According to some articles, it should be from landfills where most of the biogas should be extracted. However, after this project, it can be said that it is agriculture and industry waste what contribute the most to the production. Actually most of the information online is related to this type of biogas which made difficult the research of the other types of plants.

It should be mentioned that, when starting the project, only agroindustrial plants were considered since the president of AEBIG did not specify the type of plant this organization takes care of. The data privacy policies that some plants have and the lack of actual information also slowed down the project and in some cases, it made impossible to get all the information needed.

Also, the unknown of the type of biogas plants that were given from the beginning caused that regions like Cantabria, La Rioja, Madrid or Extremadura have been left out of the project.

In view of the available data, although it is true that Europe has very positive prospects as regards to biogas production, Spain surprises with a really slow growth despite the large amount of available agricultural waste. There are two reasons why this technology has yet not reach the speed of development that it was expected.

The first refers to Royal Decree 1/2012. This law suspended the premiums to new plants. It has caused that many of the plants under construction had to stop their activity. The second reason involves the need to develop legislation which set quality standards for biogas to allow its use by injecting natural gas networks, as is the case in Germany, Italy and Sweden.

The Spanish associations related to biogas advocate different sector support measures such as incentives for production, cogeneration, or accounting of CO2 emissions avoided.

So as a conclusion, so as to keep improving the production of biogas, some measures have to be taken by the government in order to promote it. Otherwise, the situation will not get better and eventually this energy will be substituted by others more profitable.

8 References

Bentec Bioenergies SLU-Biogas Weser-Ems GmbH & Co.KG. (2016) Principios del Biogás: Obtenemos energía a partir de la digestión anaeróbica de residuos orgánicos. Retrieved from: http://www.bentec.es/esp/introduccion.htm

Energías Renovables (17/07/2014). Biogás. Retrieved from: http://www.energiasrenovablesinfo.com/biomasa/biogas/

The Eco Ambassador (2016). Biogas and Anaerobic Digestion. Retrieved from: http://www.theecoambassador.com/Biogas.html

Rouse, S. (05/09/2013). Part 2: Biogas Mass Flow Measurement – The Challenge. Sierra. [Table 1]. Retrieved from: http://www.sierrainstruments.com/blog/?biogas-flow-meter-measurementthe-problem

Adriana (15/09/2010). Los beneficios del biogás. Renovables Verdes. Retrieved from: (http://www.renovablesverdes.com/los-beneficios-del-biogas/

Bagher Askari, M. (22/12/2015). Advantages and disadvantages of biogas energy. ResearchGate. Retrieved from: https://www.researchgate.net/publication/287759726_Advantages_and_Disadvantages_of_Biogas_Energy

Grupo AB (2016). Biogas: Aplicaciones. Retrieved from: http://www.gruppoab.it/es/biogas/aplicaciones/introduccion-al-biogas/

Biogas Fluid (2016). History of biogas technologies. Retrieved from: http://www.fluid-biogas.com/?page_id=197&lang=en

Tasneem Abbasi, S. M. Tauseef, S. A. Abbasi (22/09/2012). A Brief History of Anaerobic Digestion and "Biogas" (pag 11-23). Biogas Energy. Springer New York.

Ávila Soler, E. (México D.F. April 2009). Biogás: opción real de seguridad energética para México. Retrived from: http://www.academia.edu/4184340/Tesis_biogas

Biovec (24/02/2016). Breve historia del biogás en Europa y en España. Retrieved from: http://biovec.net/breve-historia-del-biogas-en-europa-y-en-espana/

Javier Rico (15/02/2016). España solo aporta 39 plantas de biogás agroindustrial a las 17.240 europeas. Spain: Energías Renovables. Retrieved from: http://www.energias-renovables.com/articulo/espana-aporta-39-plantas-de-biogas-agroindustrial-20160215

Energías Renovables (28/02/2014). El biogás, la energía renovable con mayor potencial en España y en Europa. Twenergy.com. Retrieved from: http://twenergy.com/a/el-biogas-la-energia-renovable-con-mayor-potencial-en-espana-y-en-europa-1131

European Biogas Association (16/12/2015). EBA Biomethane & Biogas Report 2015 published!. European-biogas.eu. Retrieved from: http://european-biogas.eu/2015/12/16/biogasreport2015/

EurObserv'ER (2014). 'The state of renewable energies in Europe – 2014 edition'. Retrieved from: http://www.energies-renouvelables.org/observ-er/stat_baro/barobilan/barobilan14-gb.pdf

Pirecka, M. (2015). Biogas ang ppt. Slideshare.net. Retrieved from: http://www.slideshare.net/MariaP1234/biogas-ang-ppt

Traco Iberia S.L. (29/06). Primera planta de biogás agroindustrial en Andalucía. Retrieved from: http://www.tracoiberia.com/2015/06/29/primera-planta-de-biog%C3%A1s-agroindustrial-en-andaluc%C3%ADa/

INFORME DE INFRAESTRUCTURAS ENERGÉTICAS ANDALUCÍA ANDALUC. (2012). Prodetur.es. Retrieved 6 June 2016, from http://www.prodetur.es/prodetur/AlfrescoFileTransferServlet?action=download&ref=0032f68b-7056-4eaa-89f8-3a3883525b2c

Epremasa (2016). Complejoj medioambiental de Montalbán. Retrieved from: http://www.epremasa.es/complejo-medioambiental-montalban

Biovec Ingeniería Ambiental (2016). Biogás: Agronsella. Retrieved from: http://biovec.net/portfolio-items/agronsella/

Biovec Ingeniería Ambiental (2016). Biogás: Urbiliza Renovables. Retrieved from: http://biovec.net/portfolio-items/urbiliza-renovables/

Puente Arcos, M. (Zaragoza 22/09/2015). Resolución Expediente 500301_02_2015_02536. MODIFICACION PUNTUAL DE LA AUTORIZACION AMBIENTAL INTEGRADA PLANTA DIGESTION ANAEROBICA Y GENERACION ELECTRICA DE BIOGAS EN REMOLINOS. Retrieved from: https://aplicaciones.aragon.es/inareia/InareiaAction.do;jsessionid=64b008ddbcca44637e0d8584212eae73b8c39d3b7618df464233016502ceb1f9.e3mRchyQbhqMe3uPbh4LaNuLaO1ynknvrkLOlQzNp65In0?opcion=descargar&idUnidad=500301&correlativo=02536&firmaID=0906fca384a6e9c4&norden=1&annoReg=2015&idTipologia=02&documentumID=0906fca384a6d62c&texto=1&codrinaga=40056&anno=2015&tipoReg=2

Alejandro Rivera (30/01/2011). La planta de purines de Valderrobres no estará terminada hasta el mes de junio de 2011. Periódico La Comarca. Retrieved from: http://valderrobresdigitial.blogspot.se/2011/01/la-planta-de-purines-de-valderrobres-no.html

Ecobiogas (2016). En construcción, planta de biogás en Pina de Ebro. Retrieved from: http://www.ecobiogas.es/archivos/es/noticies_pina-ebro.php

Oscar Bartomeu (3/03/2016). Aragón la tercera potencia de biogás en España. Biovec Ingeniería Ambiental. Retrieved from: http://biovec.net/aragon-la-tercera-potencia-de-biogas-en-espana/

Tinas Gálvez, J. (2016). Biogás contra el cambio climático. Jornada nión por la biomasa. Genera. Retrieved from: http://www.unionporlabiomasa.org/pdf/jtinas2015.pdf

J.H.P. (03/03/2016). Aragón es la tercera comunidad con más potencial en biogás. El periódico de Aragón. Retrieved from: http://www.elperiodicodearagon.com/noticias/economia/aragon-es-tercera-comunidad-mas-potencial-biogas_1092461.html

Europa Press (Zaragoza 02/03/2016), Aragón tiene potencial para reemplazar por biogás el 44% de su consumo total de gas natural. Retrieved from: http://www.heraldo.es/noticias/aragon/2016/03/02/aragon-tiene-potencial-para-reemplazar-por-biogas-su-consumo-total-gas-natural-797642-300.html

Oscar Bartomeu (Zaragoza March, 2014). El aprovechamiento del biogás ganadero y agroindustrial: situación actual y potencial en Aragón. Jornada Biogás en Aragón. Biovec Ingeniería Ambiental. Retrieved from: http://www.fundaciongasnaturalfenosa.org/wp-content/uploads/2016/02/4.-Oscar-Bartomeu-16_03_gas-natural-zaragoza_biogas_biovecWEB.pdf

Biogas Fuel Cell (2016). Instalación de referencia en el campo del biogás. Retrieved from: http://biogasfuelcell.com/portfolio/referencias-tineo/

Gonzalez Fernández, I. (November 2015). La situación de la biomasa en Asturias. 2º Congreso Territorial de Noroeste Ibérico. FAEN. Retrieved from: http://www.congresonoroiberico.com/documentos/2_congreso/20151105%20INDALECIO%20GONZALEZ.pdf

Ecología (16/03/2015). La Planta de Biogás en Tineo, de Biogás Fuel Cell, distinguida en ENERAGEN 2015. Retrieved from: http://www.asturiasmundial.com/noticia/71395/planta-de-biogas-en-tineo-fuel-cell-distinguida-eneragen-2015/

Grupo Sanchiz (2016). Granja de Ves S.L. Retrieved from: http://www.gruposanchiz.es/?p=134

Romaguera, R. (25/06/2013). Planta de BIOGAS 250kw en Balsa de Ves (ALBACETE). Inderen Renovables. Retrieved from: http://inderen-renovables.blogspot.se/2013/06/planta-de-biogas-250kw-en-balsa-de-ves.html

Romaguera, R. (25/06/2013). Planta de BIOGAS 350kw en Bonete (ALBACETE). Inderen Renovables. Retrieved from: http://inderen-renovables.blogspot.se/2013/06/planta-de-biogas-350kw-en-bonete.html

Romaguera, R. (25/06/2013). Planta de BIOGAS 350kw en Chinchilla del monte (ALBACETE). Inderen Renovables. Retrieved from: http://inderen-renovables.blogspot.se/2013/06/planta-de-biogas-300kw-en-chinchilla.html

Grupo Sanchiz (2016). Pequechin S.L. Retrieved from: http://www.gruposanchiz.es/?p=279

Resolución de 29/08/2011, de los Servicios Periféricos de Agricultura de Toledo, sobre la evaluación de impacto ambiental del proyecto de: Planta de tratamiento y valorización de residuos no peligrosos para la producción de biogás y energía eléctrica en Albarreal de Tajo (Toledo), recogido en el expediente PRO-TO-11-0719, cuyo promotor es Grupo Azon Ramón y Cajal, S.L. [2011/12671]. Derecho. Com. Retrieved from: http://legislacion.derecho.com/resolucion-29-08-2011-30-noviembre-0002-consejeria-de-agricultura-3711072

Grupo Algon. (2016) Planta BIOGAS Grupo Azon. Albarreal de Tajo (Toledo). Retrieved from: http://www.algonsl.com/index.php/proyectosdestacados/88-proyectos-destacados/92-proyectos-destacados

Bioenergia Internacional (2016). EXPORINSA, una industria alimentaria de primer nivel europeo productora de ganado porcino, ha apostado por el biogás para valorizar los purines. DE Ingenieros. Retrieved from: http://www.deingenieros.com/portfolio-items/exporinsa/

Enusa (2016). Gestión de residuos agroganaderos y agroindustriales. Retrieved from: http://www.enusa.es/areas-de-negocio/medioambiental/gestion-de-residuos-agroganaderos-y-agroindustriales/

Bentec Bioenergies SLU-Biogas Weser-Ems GmbH & Co.KG. (2016). Construcción de la Planta de Biogás de 500kW de ENUSA. Retrieved from: http://www.bentec.es/esp/enusa.htm

Santibañez Energy (2016). Biogás. Retrieved from: http://www.santiener.com/home/biogas

Biovec Ingeniería Ambiental (2016). Biogás: Santibañez. Retrieved from: http://biovec.net/portfolio-items/santibanez-2/

Biovec Ingeniería Ambiental (2014). Biogás de origen vegetal para calor industrial. Retrieved from: http://biovec.net/wp-content/uploads/2014/10/avebiom_biogas_santiba%C3%B1ez.pdf

Biogas Fuel Cell (2016). Planta de tratamiento de purines y subproductos animales. Retrieved from: http://biogasfuelcell.com/portfolio/almazan-b/

Puy Dominguez (October 2008). Biogas plant "Planta de Purines de Almazán (Soria)". Retrieved from: http://www.fedarene.org/wp-content/uploads/2013/09/Spain-Castilla_y_Leon-Planta_de_purines_de_Almazan.pdf

Gobierno de Castilla y León (2016). Planta de generación eléctrica con motor de biogás en la estación depuradora de aguas residuales de Segovia. Retrieved from: http://www.jcyl.es/web/jcyl/Gobierno/es/Plantilla100/1259064235909/_/_/_

Acuaes (2016). Saneamiento de Segovia: ampliación de la EDAR. Retrieved from: http://www.acuaes.com/actuacion/saneamiento-de-segovia-ampliacion-de-la-edar

Ferdarene (2016). Biogas cogeneration in a Waster Treatment Plant Madrona (Segovia) in Spain. Retrieved from: http://www.fedarene.org/best-practices/biogas-cogeneration-in-a-waster-treatment-plant-madrona-segovia-in-spain-council-of-segovia-eren-covenant-eren-and-segovia-council-904

Bioenergy (2013). Planta de biogás de Cospeito. Norvento Enerxía. Retrieved from: http://www.norvento.com/es/project/planta-de-biogas-de-copeito/

Energylab (2016). Planta de biogas finca Mouriscade. Retrieved from: http://www.energylab.es/esp/proyectos_realizados_detalle.asp?var1=Planta+de+biog%E1s+Finca+Mouriscade&var2=Energ%EDas%20alternativas&nar2=13&nar1=59&Page=1

Biovec Ingeniería Ambienal (2016). Biogás: Finca Mouriscade. Retrieved from: http://biovec.net/portfolio-items/finca-mouriscade-2/

Nodar Balseiro, L. (2012). Trabajo de Fin de Master. Planta de biogás: Finca Mouriscade. Retrieved from: https://riunet.upv.es/bitstream/handle/10251/27866/Trabajo%20de%20fin%20de%20M%C3%A1ster.pdf?sequence=1

Sologas (2016). Biogás. Retrieved from: http://sologas.es/

Bouzada Rodriguez, J. (29/01/2015). "Carballo Biometización: experiencia real generando biogás con residuos industriales". Jornada biogás Galicia. JB Ingenieros. Retrieved from: http://www.energylab.es/fotos/150130102816_ziFn.pdf

Javier Rico (26/01/2016). Biogás: Nuevo premio para el biometano de la conservera Calvo. Energías Renovables. Retrieved from: http://www.energias-renovables.com/articulo/nuevo-premio-para-el-biometano-de-la-20160126

Ricardo Romaguera (09/09/2013). Planta de Biogas Estrella de Levante de 500 KW en el Vertedero de Cañada Hermosa (MURCIA). Inderen Renovables. Retrieved from: http://inderen-renovables.blogspot.se/2013/09/planta-de-biogas-de-500-kw-en-el.html

Estrella Levante (05/12/2014). Inaguramos nuestra planta de biometización. Retrieved from: http://www.estrelladelevante.es/inauguramos-nuestra-planta-de-biometizacion/

Levenger (2016). Biogás. Retrieved from: http://www.levenger.es/index.php/es/biogas

Puchades Rufino, L. (2016). Planta de biogás para autoconsumo eléctrico de una gran empresa. Reportaje de planta. Energética XXI Nº 153 (Oct-Nov 2015).

Agralco (2016). Eficiencia energética: Autoabastecimiento de energía térmica y electricidad. Retrieved from: http://www.agralco.es/eficiencia-energetica/

P. Gorría Leire Sevillano (05/02/2016). Dos de cada tres vecinos separan residos en Valdizarbe. Noticias de Navarra. Retrieved from: http://m.noticiasdenavarra.com/2016/02/05/vecinos/zona-media/dos-de-cada-tres-vecinos-separan-los-biorresiduos-en-valdizarbe

Bigadan (2016). HTN Biogas. Retrieved from: http://bigadan.com/c/cases/htn-biogas

Mancomunidad Comarca de Pamplona (2016). A dónde van las aguas residuales: EDAR de Arazuri. Retrieved from: http://www.mcp.es/agua/ciclo-integral/a-donde-van-las-aguas-residuales

Mancomunidad Comarca de Pamplona (2016). Saneamiento y depuración de aguas residuales: Arazuri. Retrieved from: http://www.mcp.es/sites/default/files/documentos/estacion_depuradora_aguas_residuales_arazuri.pdf

Plan de Energias Renovables 2011-2020. Retrieved from: http://www.idae.es/index.php/id.670/relmenu.303/mod.pags/mem.detalle

Fernández, A. President of COGERSA (04/06/2016). Biogas in Asturias

Diez Castilla, S. Head of biomass department. EREN (23/05/2016). Biogas in Castilla y León.

Gracia García, A. Section of Energy and Mines. Dpt. Of Economic Development. Government of Navarra. (23/05/2016). Biogas in Navarra.

Bartomeu, O. Manager of Biovec (03/03/2016). Biogas in Galicia.

Bezdicek, J. Levenger. (11/03/2016). Biogas in Navarra.

Echamendi, L. Mendyra, S.L. (21/03/2016). Biogas in Navarra.

Bartomeu, O. Manager of Biovec. (21/03/2016). Biogas in Aragón.

De la Cruz Hernandez, C. Comercial and Logistic Department of Grupo Sanchiz. (31/03/2016). Biogas in Castilla la Mancha

Corella, F. Director of Mancomunidad de la Ribera (13/05/2016). Biogas in Navarra.

Piñero Grande, D. Technical Director of Giesa Agroenergía. (17/06/2016). Biogas in Andalucía.

Sanchez Arista, M. (23/05/2016). EDAR Madrona. Biogas in Castilla y León.