



# ***Biogas and Biomethane. Healthy, efficient and sustainable energies***

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**REGIONAL ONLINE TEACHING & TRAINING ON RENEWABLE ENERGY  
TECHNOLOGIES FOR PROFESSIONALS, PRACTITIONERS AND UNIVERSITIES  
IN ECOWAS MEMBER STATES**

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## Challenges of our society



### **WE WANT grow-up and develop our economy**

A growing population wants to live better, with better services and infrastructures, so our economy must grow in a sustainable way

*For a sustainable development of our society, we must carry out a holistic analysis of all our challenges, not only on energy aspects, therefore:*

### **WE NEED to fight against climate change, decarbonizing our society**

It's a worldwide challenge cutting greenhouse gas (GHG) emissions to avoid de global warming

### **WE NEED to take care of our health and the environment**

We have to reduce our polluting emissions, especially in the water cycle, to avoid the degradation of the environment and the impact on our health

## Challenges of our society. Actions



To achieve these challenges, these actions are necessary:

**WE MUST be efficient in our activities. DO MORE WITH LESS**

Efficiency is the cheapest and least polluting source of energy

**WE MUST use decarbonized and local RENEWABLE energies**

They are a clean form of energy to use and can provide energy independence

**WE MUST ensure the best treatment of our wastes**

Circular economy allows a better use of our resources. **FROM WASTE TO RESOURCE**

**WE MUST guarantee security, reliability and affordability of energy**

Energy must always be available and not expensive to meet demand

***Reduce , Reuse & Recycle***

## Renewable electrical energies solutions. disadvantages



Electrification of all energy consumption and its coverage with renewable generation, especially solar (PV and wind) is the most widespread solution currently proposed

These solutions have a lot of advantages (unlimited energy sources, energetic independence, local and decentralized production, abatement of GHG emission, etc), but also disadvantages:

- ❖ **Don't cover all services (heavy and long-haul transport, industrial and high temperature uses, etc)**
- ❖ **It isn't manageable. Don't follow demand (p.e. PV energy at night)**
- ❖ **It may not be a permanent energy resource (cloudy days, no wind,..)**
- ❖ **It has expensive storage costs**
- ❖ **Large capital costs (CAPEX). It isn't always commercially-viable**

## How can we solve these problems?

Using all available energy sources, fulfilling the following conditions:

- ➔ **ENERGY MIX** without discrimination between resources
- ➔ **LEGAL SECURITY** through stable legislation
- ➔ **PROMOTION** of new technologies during the maturation period

Lines of action currently available are:

- ✓ **Biofuels - Use carbon-neutral fuels in non-electrical uses**
- ✓ **Electrical back-up that makes the electrical system manageable**
- ✓ **Short-medium-long-term energy storage: Energy storage in the gas network and development of affordable batteries**
- ✓ **Optimization of CAPEX on new investments**



**BIOFUELS** are a type of fuel, substitutes of fossil fuel, derived from organic matter (broadly described as biomass) produced by living organisms i.e. plants and animals

Examples of sources include energy crops such as Jatropha and Camelina, short rotation coppice (SRC) willow and timber, waste oils and kitchen/food waste, agricultural and forestry residues, industrial bio-wastes and novel feedstocks such as algae



**Jatropha**



**SRC**



**Waste-water plants**



**Food waste**



**Algae**

# Biofuels. Definition



Biofuels can be categorised into two major types:

- ❖ **1st generation biofuels** biofuels currently on the market today are produced largely from food crops e.g. corn (**problem: energy vs food**)
- ❖ **2nd generation biofuels** They are those fuels produced by utilizing the whole plant rather than just the sugar/oil component of food crops (these are usually referred to as lignocellulosic feedstocks)

BIOFUEL GROUP	SPECIFIC BIOFUEL	PRODUCTION PROCESS
Bioethanol	Celulosic athanol	Advanced enzymatic hyfrolysis and fermentation
Synthetic fuels	Biomass-to-Liquids (BTL) Fischer Tropsch (FT) diesel Biomethanol Heavier alcohols (butanol and mixed) Dimethyl ether (DME)	Gasification and synthesis
Biogases	Bio-synthetic natural gas (SNG) Bio-methane	Gasification and synthesis Anaerobic digestion

**RENEWABLE GASES** are that fuel gases, obtained from renewable sources, which in its use has a neutral or even negative balance of net CO<sub>2</sub> emissions.

They are considered renewable gases:

- ❖ **Biogas**
- ❖ **Biomethane**
- ❖ **Green hydrogen** (obtained from renewable electricity)
- ❖ **Blue hydrogen** (obtained from natural gas, including carbon capture and sequestration)
- ❖ **Synthetic natural gas** ( syngas or SNG):



## Renewable gases. Part of the solution

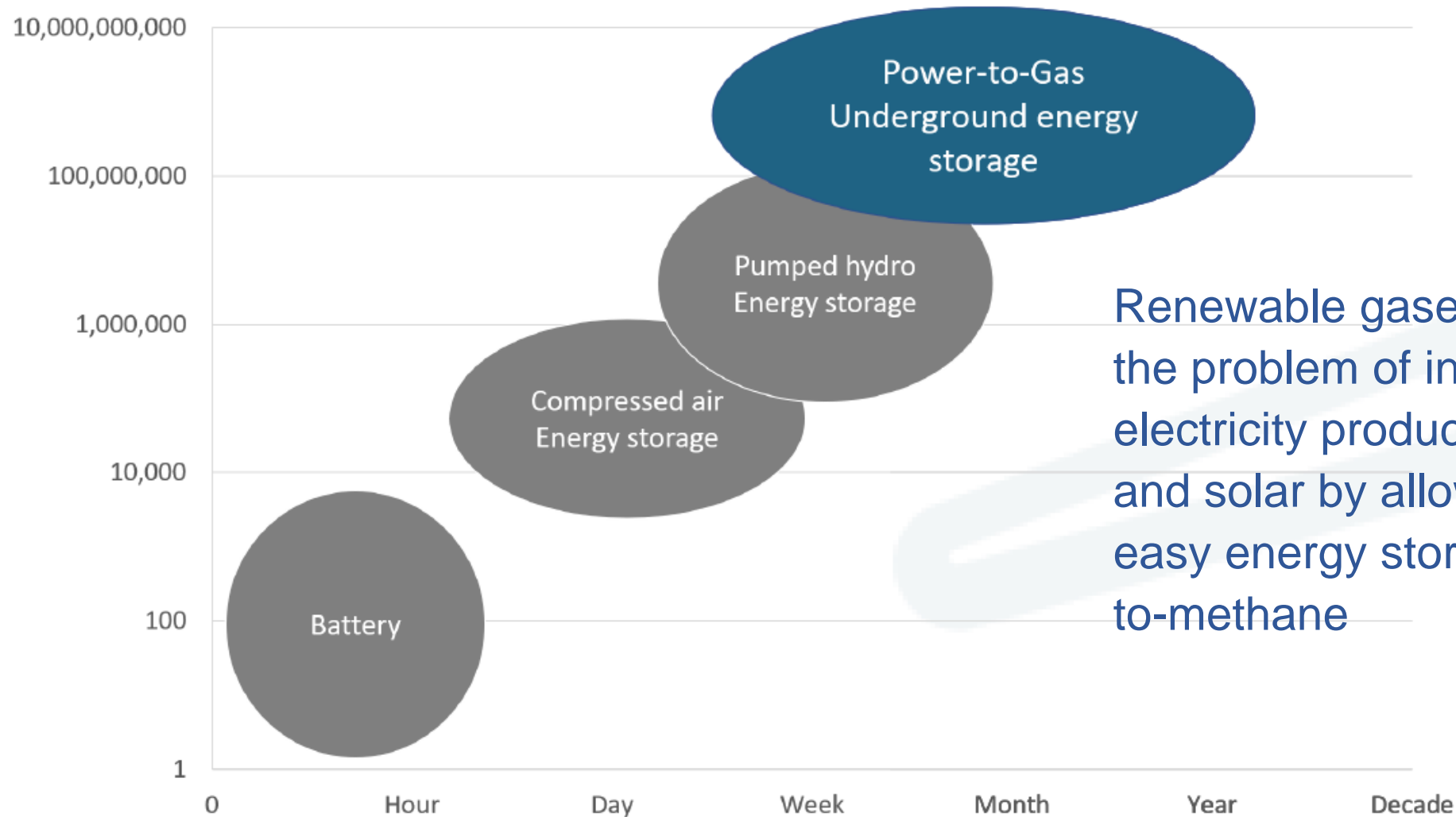


Renewable gas could play a relevant role in decarbonization of all markets, providing the following advantages:

- ❖ **Covers demands as road transport, high temperature applications in industry, buildings thermal demands**
- ❖ **Use local resources (agricultural and population residues)**
- ❖ **Generates local employment through intermediate energy crops**
- ❖ **Generates by-products (organic fertilizers)**
- ❖ **Allows the use of existing natural gas grids for transport and distribution**
- ❖ **Allows energy storage, affordable and for long periods of time (up to annual)**
- ❖ **Allows energy storage of electricity (Power to gas)**
- ❖ **It's a backup for power generation**

# Renewable gases. Part of the solution

## Energy storage on long periods, reliable and affordable

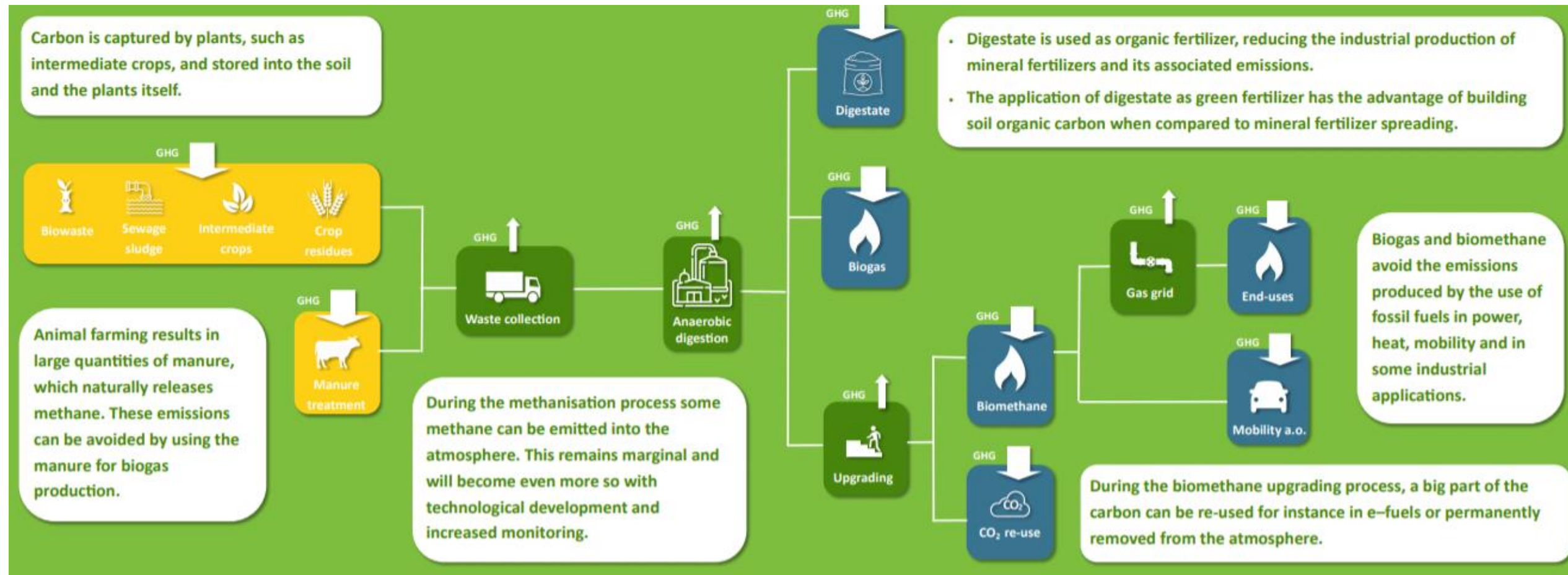


Renewable gases can tackle the problem of intermittent electricity production from wind and solar by allowing cheap and easy energy storage via power-to-methane

# Renewable gases. Part of the solution

## GHG reduction potentials of biogas and biomethane industries

### Process pathway



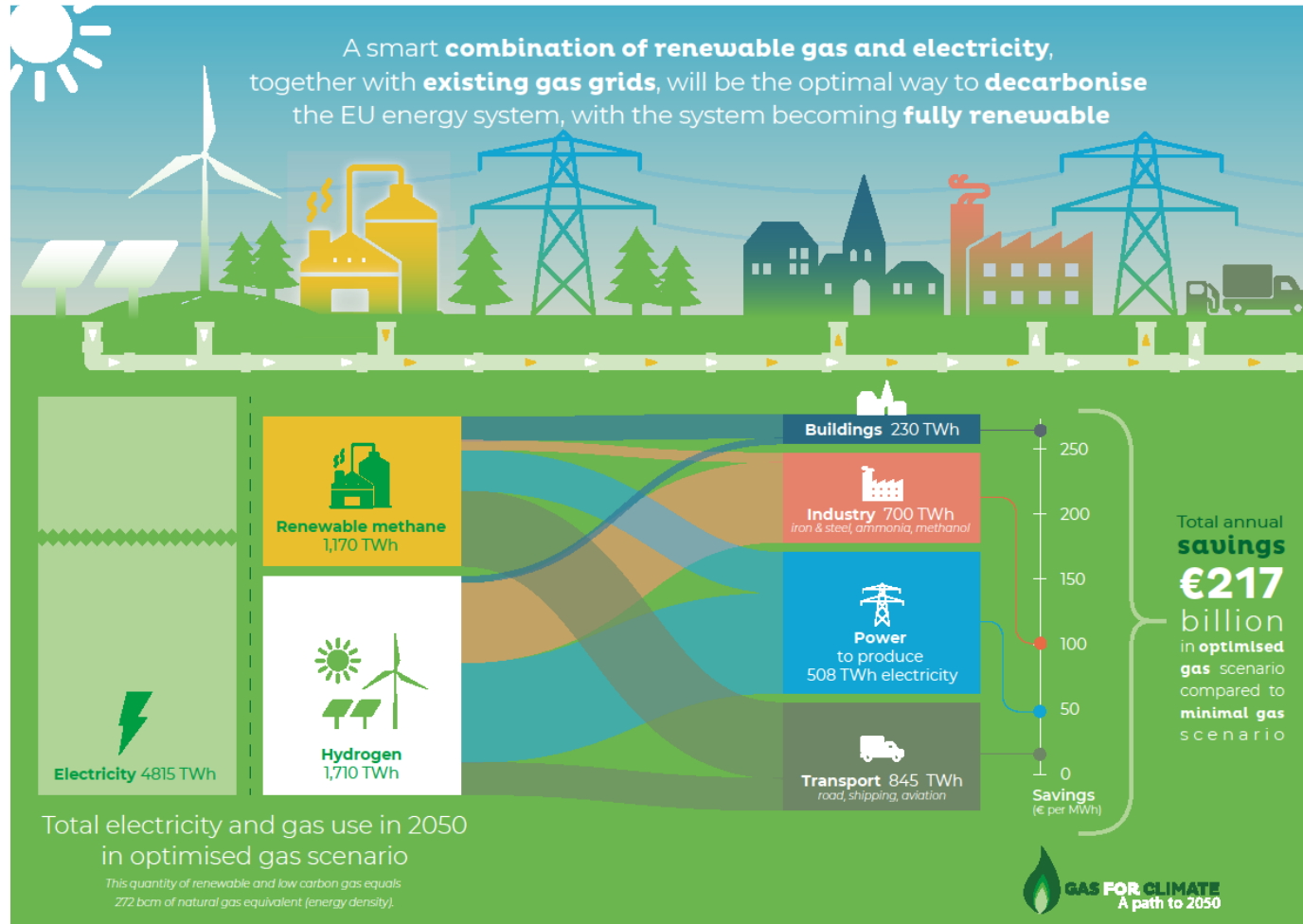
Source: European Biogas Association (EBA). Contribution of the biogas and biomethane industries to medium-term GHG targets and climate-neutrality by 2050

# Renewable gases. Part of the solution

## Electricity and renewable gases combined. The smart solution



Full electrification of all energy sectors is neither financially nor technically feasible



For a energy system progresses towards full decarbonization, a **mix of technologies is necessary to keep the energy system sustainable**, secure, reliable, affordable, socially acceptable and environmentally friendly

# Biogas. Definition

**BIOGAS** is a gas mixture composed mainly of methane ( $\text{CH}_4$ ) and carbon dioxide ( $\text{CO}_2$ ), along with water and other trace gases, produced from biomass through a process named **anaerobic digestion**

Anaerobic digestion is a natural form of waste-to-energy that uses the process of fermentation to breakdown organic matter. Animal manure, food scraps, wastewater, and sewage are all examples of organic matter that can produce biogas by anaerobic digestion

Due to the high content of methane in biogas (typically 50-75%) biogas is flammable, and therefore produces a deep blue flame, and can be used as an energy source

Typical composition of the biogas mixture is:

Compound	Chemical formula	%
Methane	$\text{CH}_4$	50 - 85
Carbon dioxide	$\text{CO}_2$	5 – 50
Hydrogen	$\text{H}_2$	0 – 1
Hydrogen sulphide	$\text{H}_2\text{S}$	0 – 3
Nitrogen	$\text{N}_2$	0 – 5
Oxygen	$\text{O}_2$	0 - 2



Yorkshire  
water  
Knostrop  
Energy &  
Recycling  
Facility  
(UK)



## ❖ Land-fill (LF) type

Is produced by allowing natural decay to occur within a land-fill producing a gas that is captured

## ❖ Anaerobic digestion type

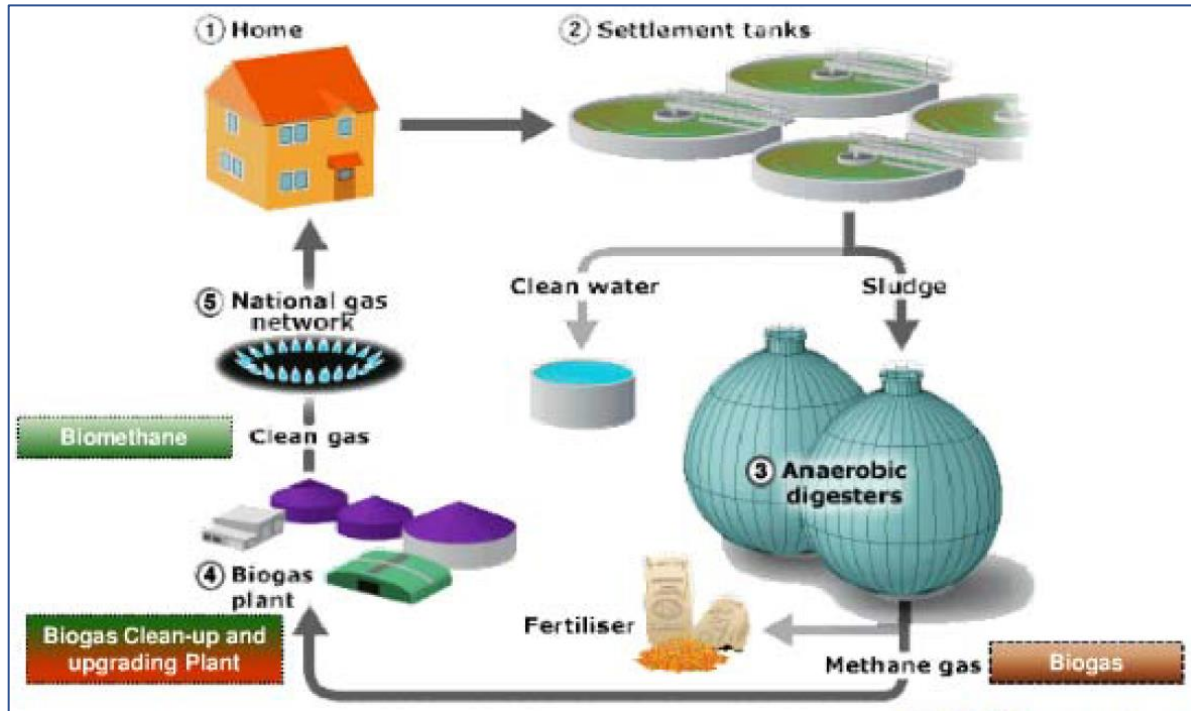
Anaerobic digestion biogas is produced in purpose-designed above-ground plants to optimise the gas producing decay process for greater efficiencies

**Anaerobic digestion is essentially a 3-stage biological process.** The first stage is the breakdown of the complex organic molecules into simpler molecules, volatile fatty acids (VFAs),  $\text{NH}_3$ ,  $\text{CO}_2$  and  $\text{H}_2\text{S}$ . The simpler molecules are then further digested to produce more  $\text{CO}_2$ , hydrogen and acetic acid. The final stage involves further breakdown of the fatty acids into  $\text{CH}_4$ ,  $\text{CO}_2$  and water

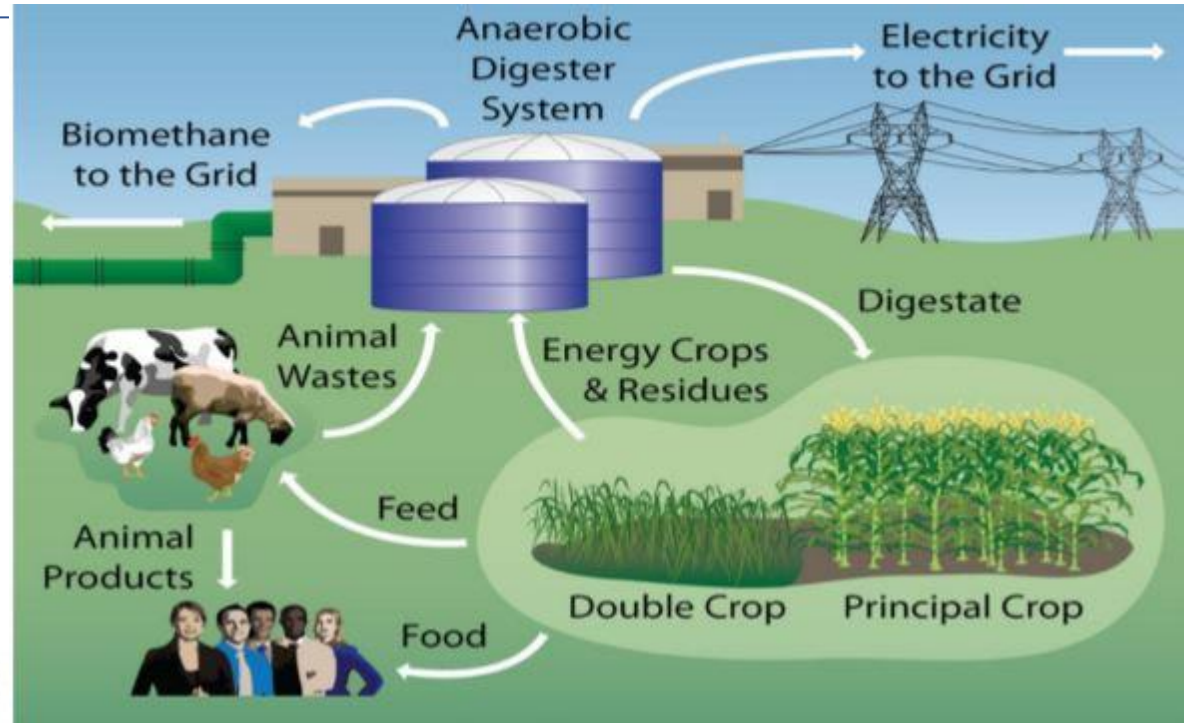


# Biogas. Sources

## Anaerobic digestion type



Generation from wastewater



Generation from livestock and agricultural origin

# How to produce biogas?

## Production of biogas from anaerobic digesters



The anaerobic digestion (AD) process for biogas production can be classified according to the following categories:

- ❖ **The operating temperature of the digester:**

Mesophilic (25-45°C) or Thermophilic (50-60°C)

- ❖ **The state of the organic matter in the digester:**

Wet feed (5-15% dry matter) or dry (over 15% dry matter)

- ❖ **The mode of operation:**

Continuous or batch process

- ❖ **Single or multistage digesters**



# How to produce biogas?

## Production of biogas from anaerobic digesters (AD)



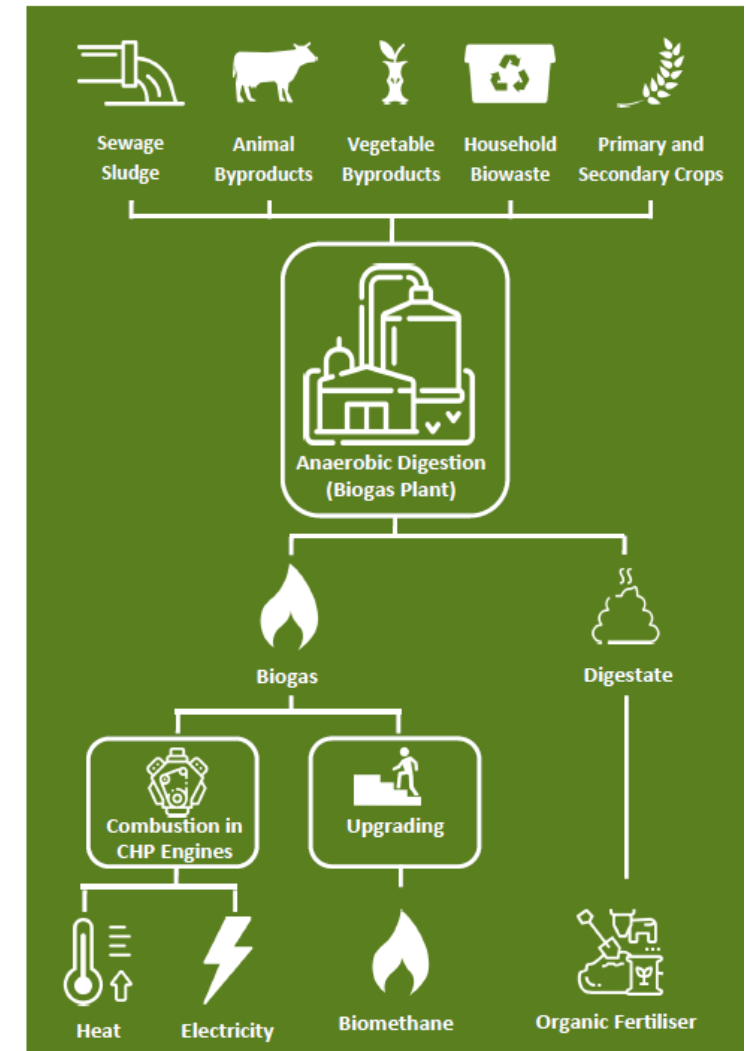
- ❖ **Thermophilic systems** are known to provide much faster biogas production rates per unit of feedstock and cubic metre of digester than mesophilic systems<sup>35</sup>.
- ❖ The **degree of wetness** (or dryness) of the AD system is also a critical operating factor. Dry AD operations tend to be cheaper to run because there is less water to evaporate but have high set-up costs per unit of feedstock. Wet AD processes, on the other hand, have lower set-up costs but higher operating costs than dry AD processes
- ❖ Biogas digesters can also be operated in either **batch or continuous mode**. There are usually technical justifications behind operating the AD in either mode such as the need to overcome peaks or troughs in gas production which can be accomplished by operating multiple batch digesters in parallel. It is also possible to run continuous digesters provided there is a gas holder available on-site big enough to deal with the variations

# Biogas. Why it's interesting?



- ❖ **It's a local energy source**
- ❖ **Biogas turns organic waste and residues into valuable products**, allowing for nutrient recycling and energy production locally
- ❖ **Biogas usually is used on Combined Heat and Power unit (CHP)** to produce **electricity** and **heat**. The electricity is then injected into the existing power grid, while heat is used on site
- ❖ The remaining of the degraded biomass, referred to as **digestate** can be recovered as a by-product and applied as organic fertiliser allowing substitution of conventional fertiliser and nutrient recovery
- ❖ There is a major environmental driver to capture the gas produced from the breakdown of organic matter.

As a result, from a policy point of view, there is a huge amount  $\text{CO}_2$  and  $\text{CH}_4$  reduction produced in landfills and waste degradation





**BIOMETHANE** is methane produced from biomass with properties close to natural gas.

It can be produced by thermochemical conversion (SNG) of woody and lignocellulose biomass or biochemical conversion (from biogas upgrading)

When the biomethane is to be fed into the natural gas grid it has to meet standards imposed by gas quality regulations within a particular region

Typical composition of the biomethane mixture is:  
(Spanish regulation)

Compound	Unit	min	max
Methane (CH <sub>4</sub> )	mol %	90	100
Carbon dioxide (CO <sub>2</sub> )	mol %	-	2,5
Carbon monoxide (CO)	mol %	-	2,0
Hydrogen	mol %	-	5,0
Hydrogen sulphide	mg/Nm <sup>3</sup>	-	15
Ammonium (NH <sub>3</sub> )	mol %	-	3,0
Oxygen	mol %	-	0,01

## Biomethane. Definition

### Processing biogas from anaerobic digesters



- ❖ Biogas from anaerobic digesters can be processed to a gas with higher  $\text{CH}_4$  content referred to as **biomethane or renewable gas**. The amount of unwanted contaminants removed from the produced biogas depends on the final end-use of the gas. Most often water vapour and  $\text{H}_2\text{S}$  removal is required, except when the gas is to be compressed and used as a vehicle fuel then it is recommended that  $\text{CO}_2$  is also substantially removed
- ❖ When the gas is to be fed into the gas grid it has to meet standards imposed by gas quality regulations within a particular region,
- ❖ The need for processing biogas is significant, not least because of the corrosive nature of  $\text{H}_2\text{S}$ , bacteria (via microbially-induced corrosion) and water vapour in the gas.
- ❖ As a result various methods are deployed to purify biogas, which include processes whereby the raw biogas stream is absorbed or scrubbed to remove the contaminants, leaving up to 98% methane per unit volume of the gas stream



## How to produce biomethane?

### Water vapour and H<sub>2</sub>S removal



**Water vapour** must be removed in order to meet pipeline quality standards or CNG vehicle fuel standards. The removal methods may be:

- ❖ **Physical separation:** The simplest way of removing water vapour is through refrigeration. The condensed water droplets are entrapped and separated by either using a demister or cyclone separators
- ❖ **Adsorption drying:** The chemical method of gas drying involves elevating the pressure of the gas and feeding it through a column containing an adsorbent component such as silica. This is a continuous cyclic process and the bed is regenerated thermally to release the water as water vapour every few hours

**H<sub>2</sub>S removal** is required to avoid corrosion issues in piping, engines, compressors. H<sub>2</sub>S is extremely reactive with most metals, and this reactivity is enhanced by the presence of water, elevated temperatures, pressures and concentrations. It reacts with iron oxide or iron hydroxide to form iron sulphide and water, the iron oxide can then be regenerated using oxigene

# How to produce biomethane? CO<sub>2</sub> removal

CO<sub>2</sub> removal is essential for enhancing the energy value of biogas. As the CO<sub>2</sub> is removed, the relative density of the gas is decreased and the calorific value increased, increasing the Wobbe Index.

There are 3 main methods used commercially for the removal of CO<sub>2</sub> from biogas

- Physical separation
- Chemical separation
- Cryogenic separation



Land-fill Valdemingomez (Madrid – Spain)

## How to produce biomethane? CO<sub>2</sub> removal. Physical absorption



One of method of separating CO<sub>2</sub> from CH<sub>4</sub> is by scrubbing the raw gas with water to remove CO<sub>2</sub>, that is more soluble in water than CH<sub>4</sub>

The raw gas is introduced to the bottom of a vertical column at pressure (typically between 1000-2000kPa). Water is then fed to the top of the column which is usually equipped with random packing to provide the surface area needed to facilitate mass transfer between the gas and liquid. As the gas flows up the column the concentration of CO<sub>2</sub> decreases during which the gas becomes richer in CH<sub>4</sub>. The processed biogas then leaves from the top of the column. In order to remove the methane from the water, the water leaving at the bottom of the column is partially depressurised in a flash tank. This releases the CH<sub>4</sub> rich gas which is recycled with the untreated biogas. Water is regenerated using a desorption column, where it is brought in contact with air or steam to strip the CO<sub>2</sub> from it

# How to produce biomethane? CO<sub>2</sub> removal. Chemical absorption

This method uses an amine at slightly elevated pressures to absorb the CO<sub>2</sub> present in biogas. The amine is then regenerated with steam or heat to separate and recover the CO<sub>2</sub>. This is, however, an energy intensive process compared to other methods for absorbing CO<sub>2</sub>



EDAR Butarque (Madrid - Spain) NEDGIA



ECOFUELS (Netherlands) Pentair Haffmans



## How to produce biomethane? CO<sub>2</sub> removal. Cryogenic separation

CH<sub>4</sub> has a boiling point of -161°C while CO<sub>2</sub> boils at -78°C which means that CO<sub>2</sub> can be separated from biogas as a liquid by cooling the gas mixture at elevated pressure CH<sub>4</sub> can be extracted as a liquid or vapour depending on how the system has been designed

This is an energy intensive process



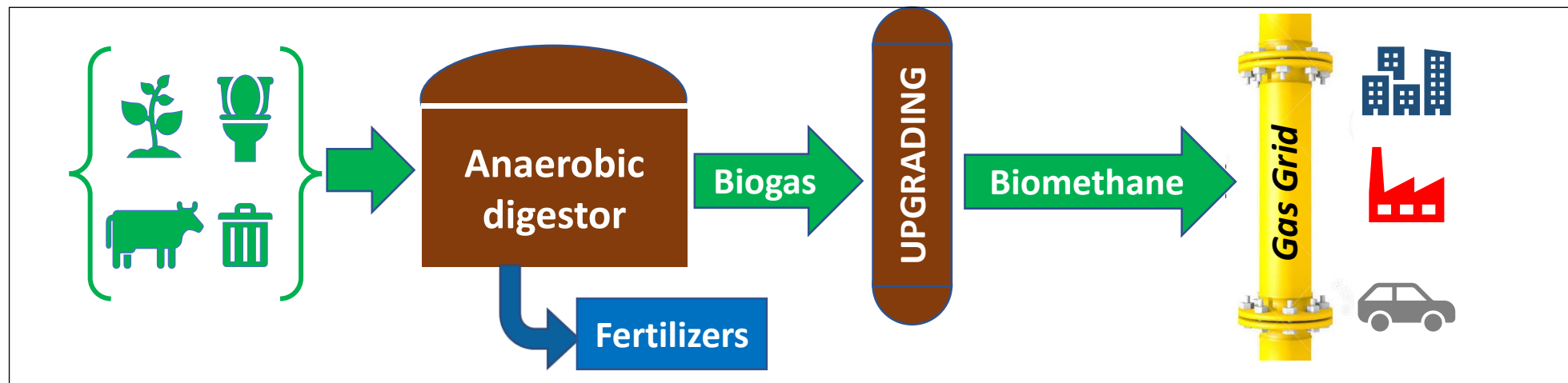
Greenville Energy (Northern Ireland) Cryo Pur unit

## Biomethane, when it's interesting?

Biomethane can be utilized in a variety of ways:

- It can be burnt in boilers to **provide heat**
- It can be used to generate **electricity** in gas turbines or engines.
- It can be compressed for use as a **vehicle fuel**
- It can be **injected to the gas grid** for subsequent use

The most promising method of utilising biomethane would be introducing it into the natural gas distribution network.

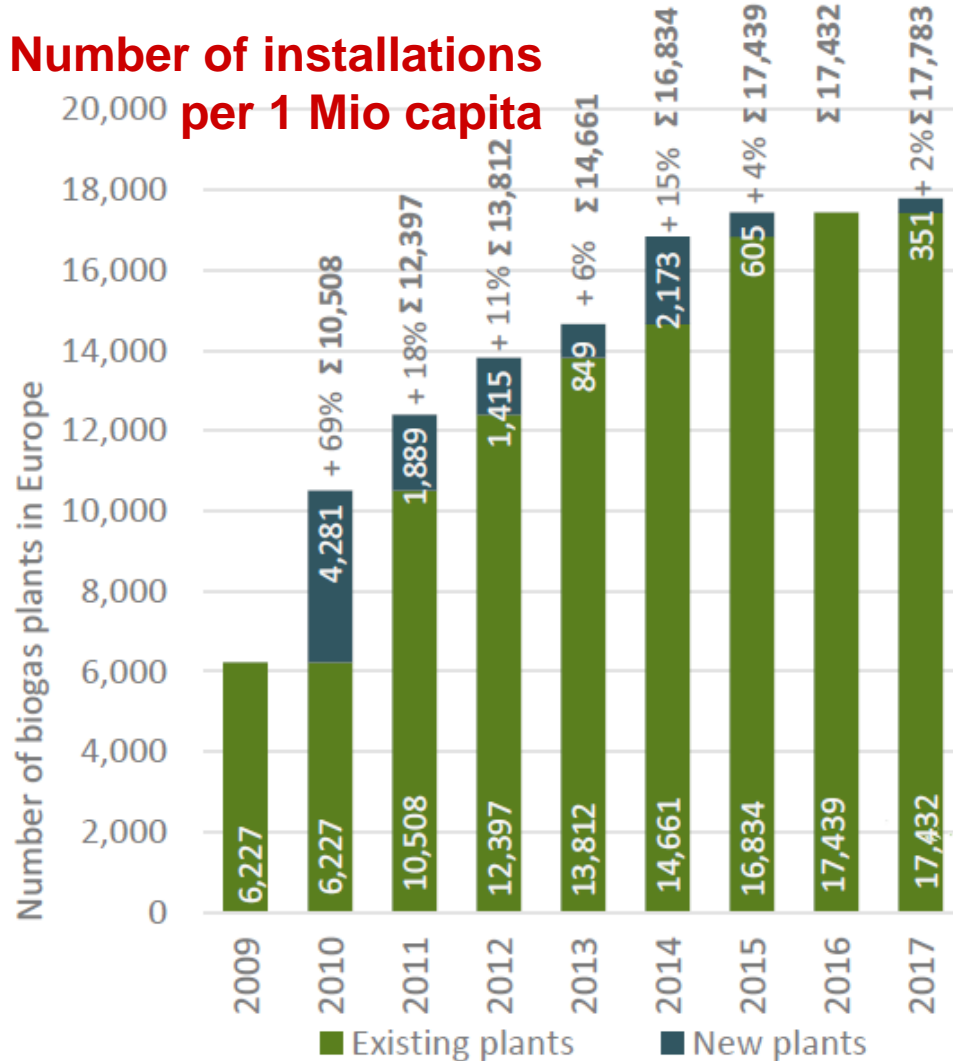




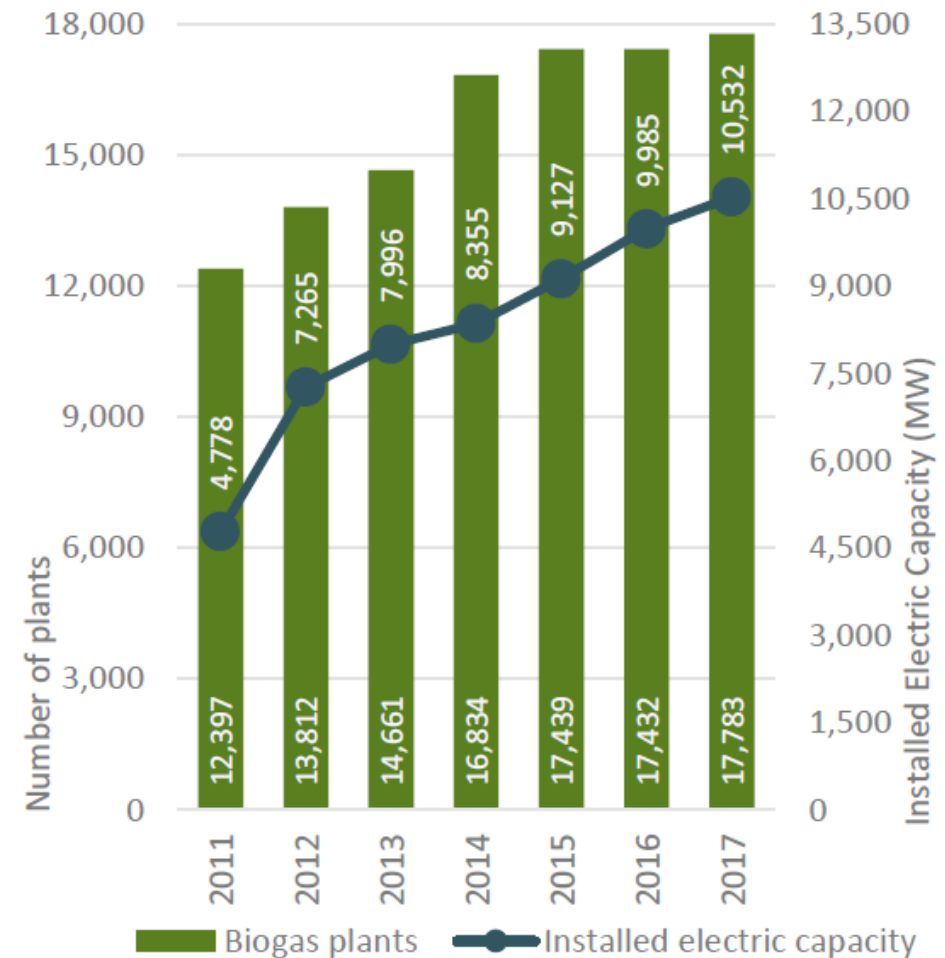
# Current situation in Europe

## Development of European biogas sites

**Number of installations  
per 1 Mio capita**



**Power installed in MW/year**



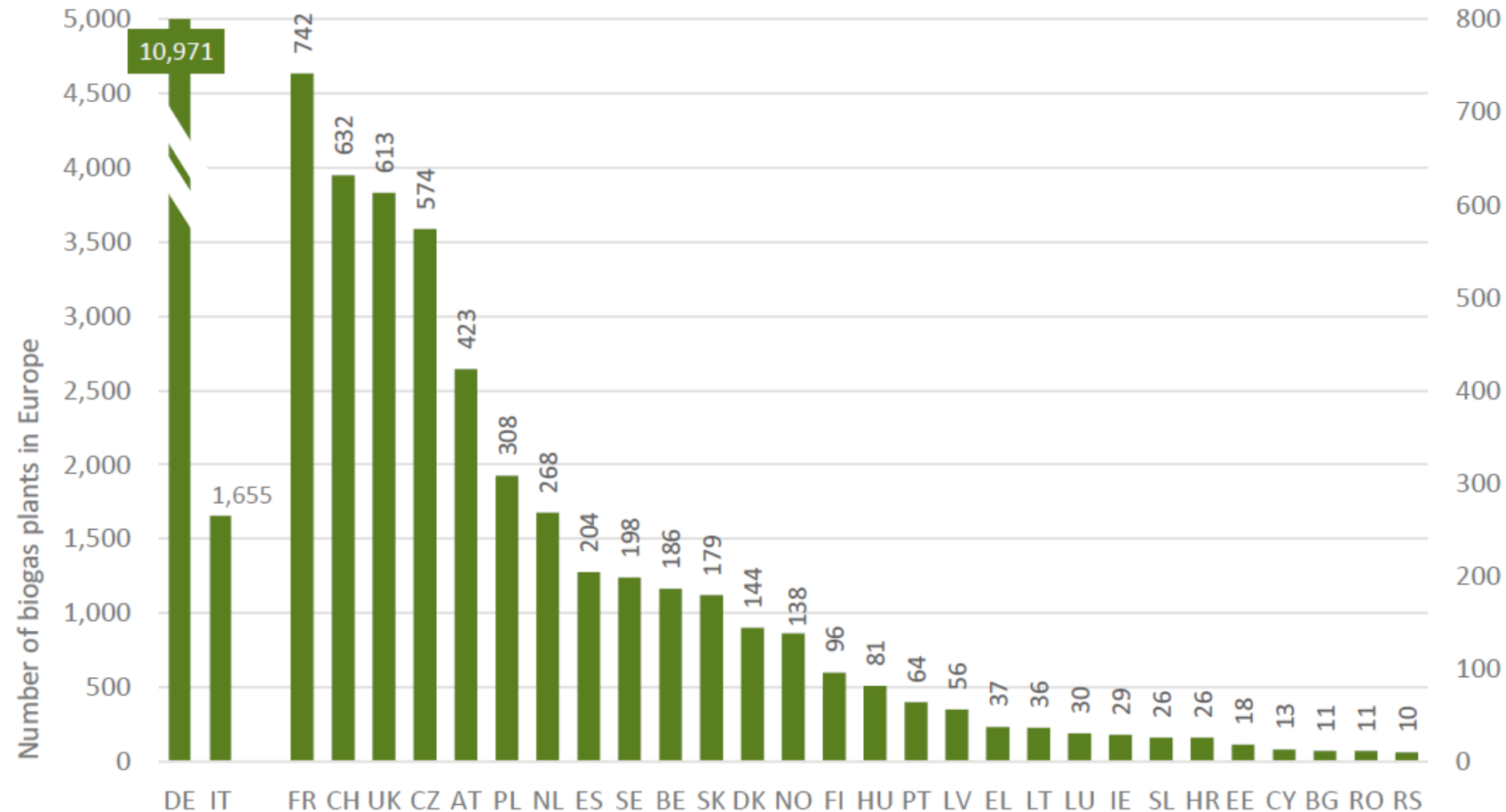
Source: European Biogas Association (EBA). Statistical Report 2018

# Current situation in Europe

## Development of European biogas sites



### Number of installations by country



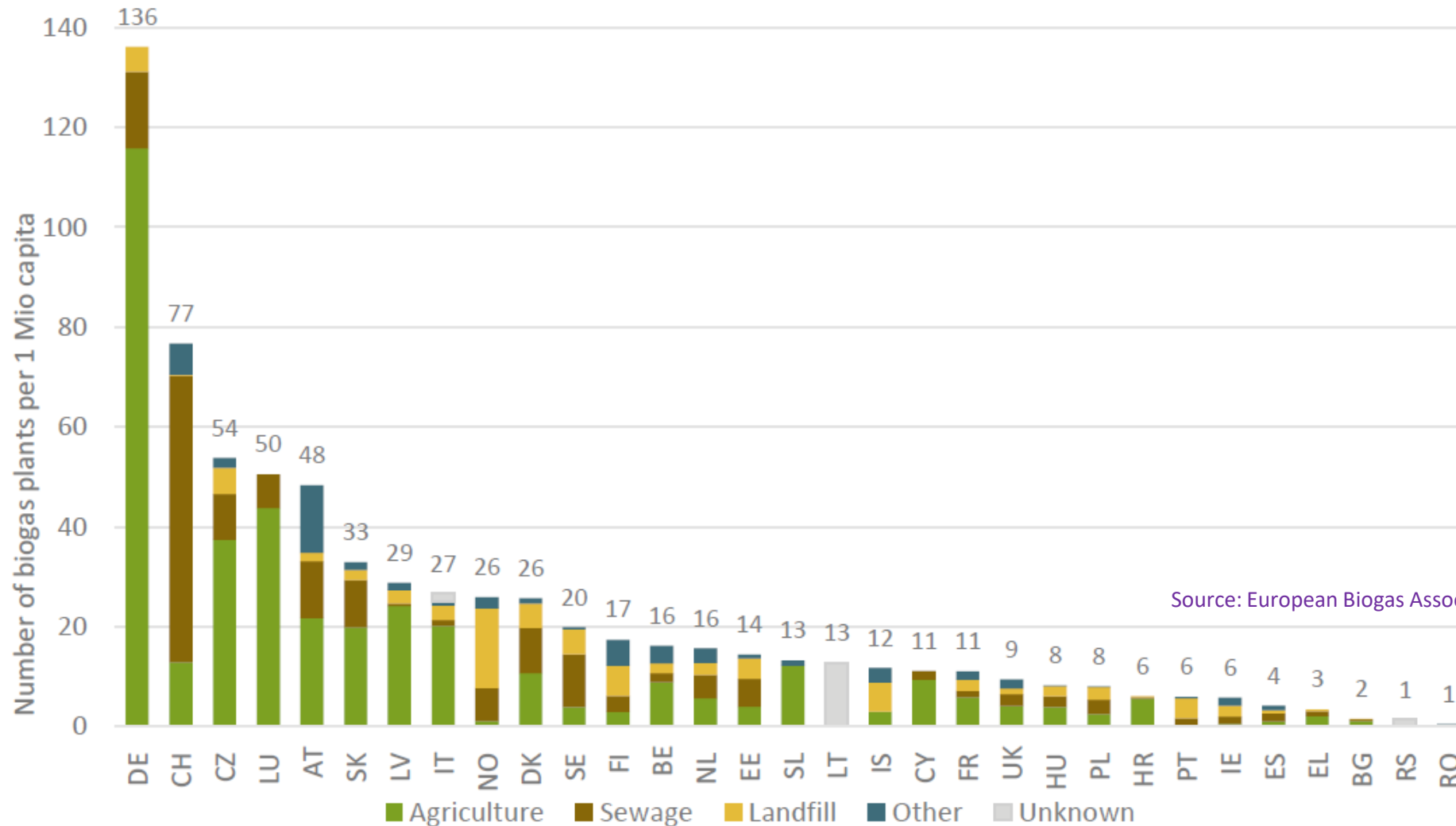
Source: European Biogas Association (EBA). Statistical Report 2018

# Current situation in Europe

## Development of European biogas sites



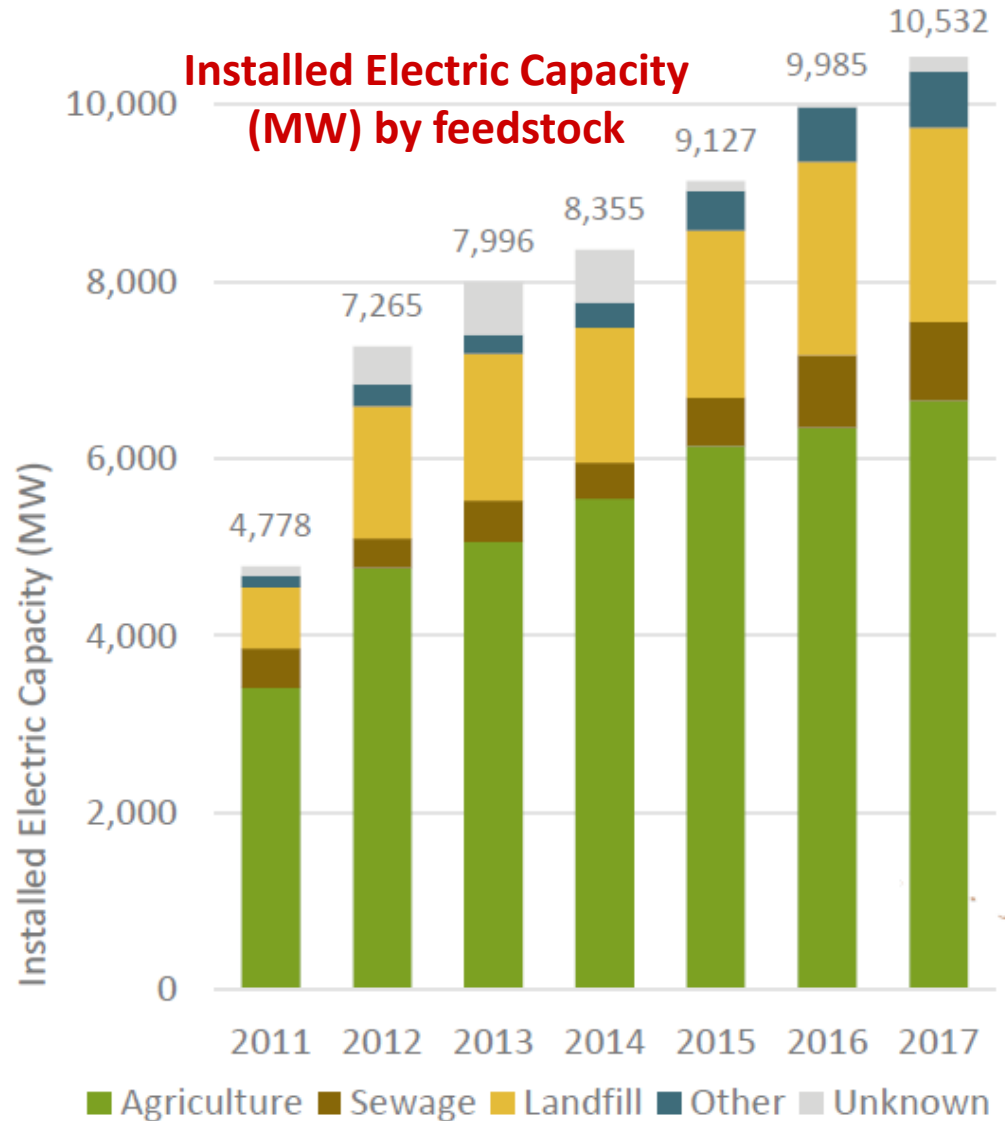
### Number of installations by feedstock



Source: European Biogas Association (EBA). Statistical Report 2018

# Current situation in Europe

## Development of European biogas sites

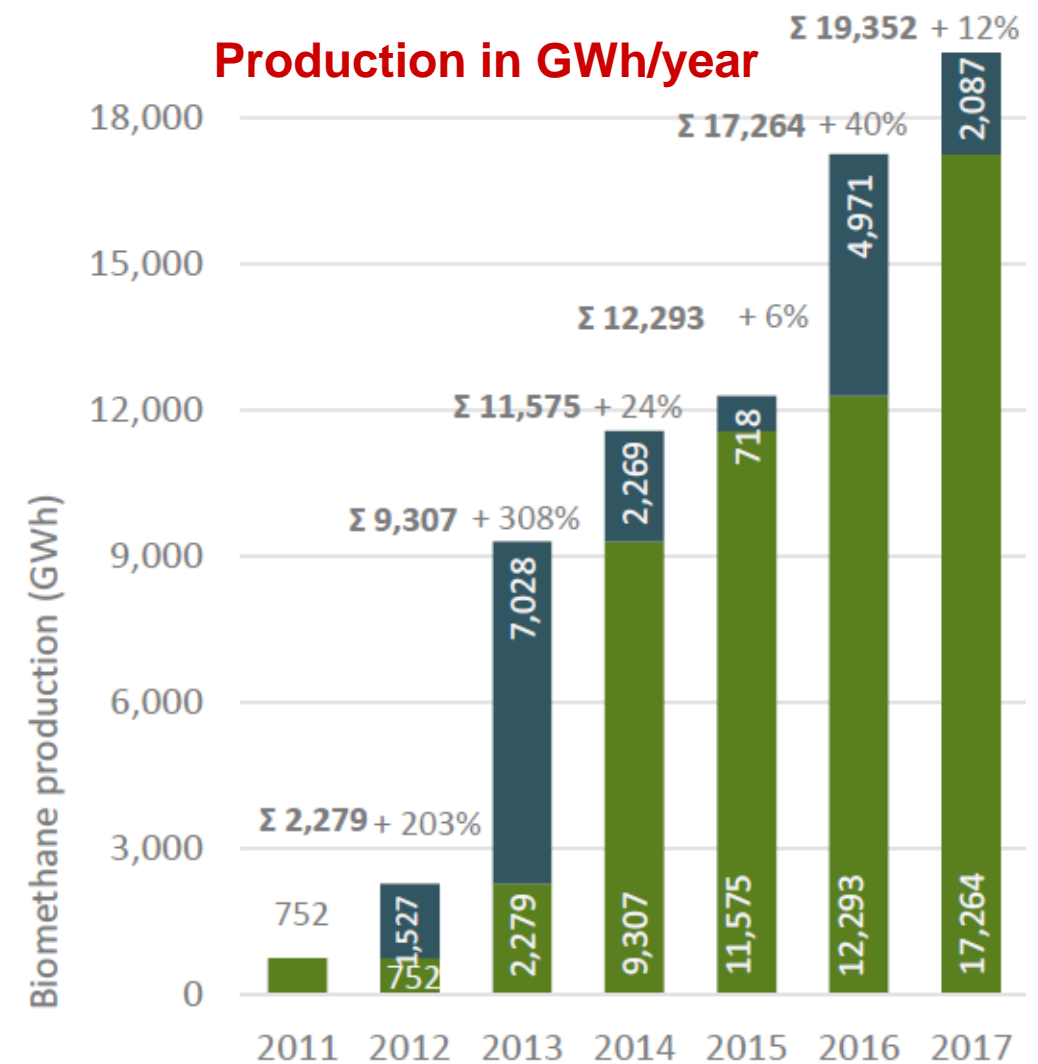
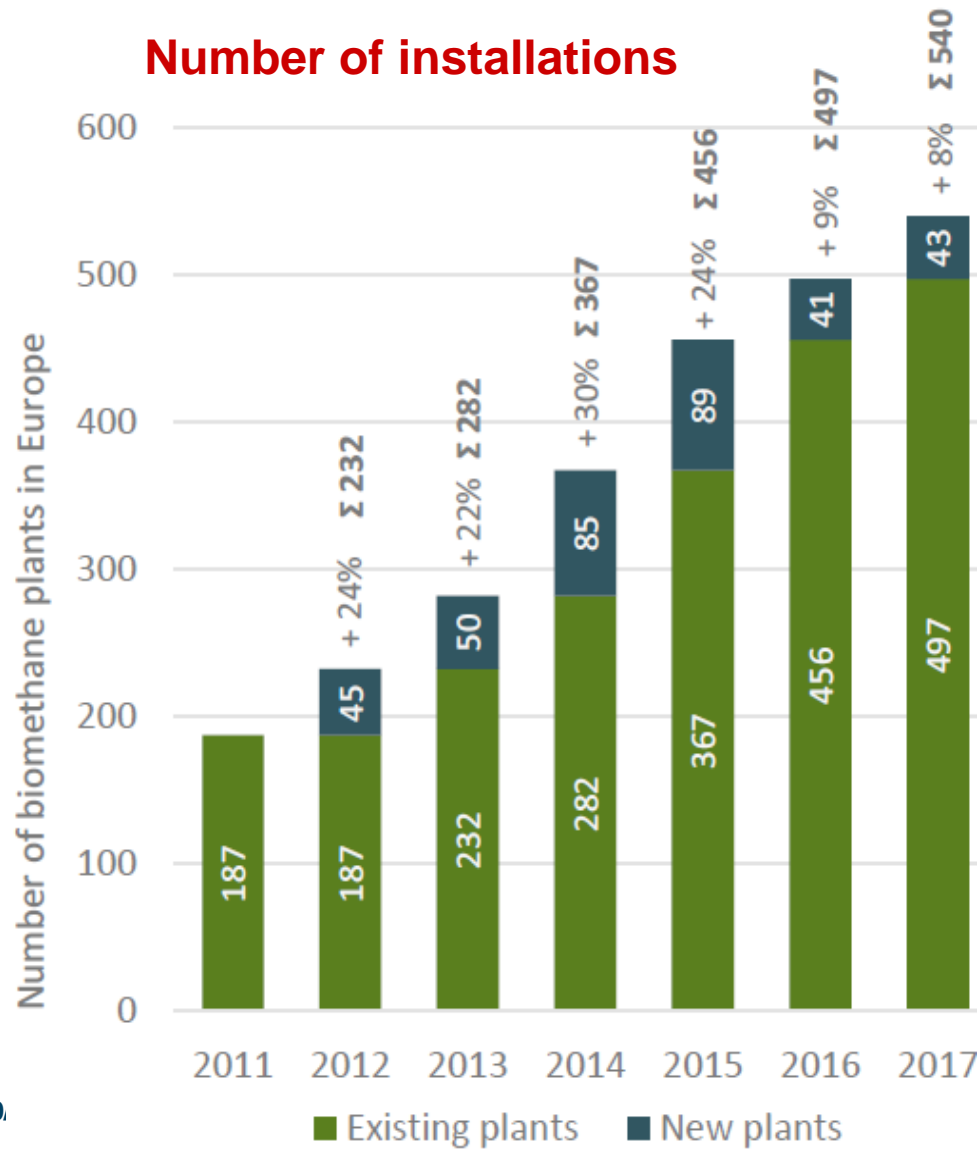


The increase in biogas installed electric capacity (IEC) derives primarily from agricultural biogas plants – that includes the treatment of agricultural residues from plant matter and animal manure but also the digestion of energy crops and catch crops

Source: European Biogas Association (EBA). Statistical Report 2018

# Current situation in Europe (2017)

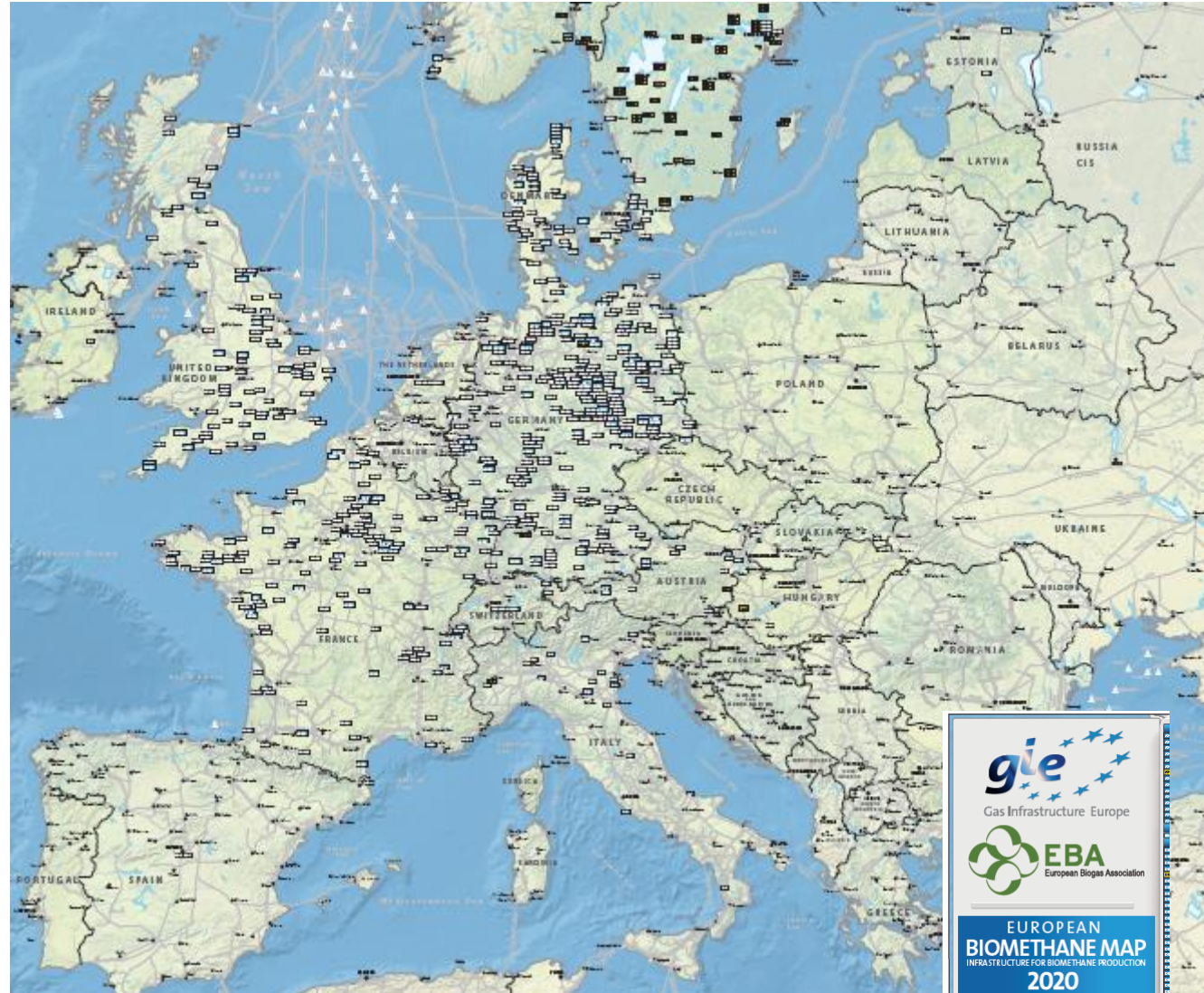
## Development of European biomethane sites





# Current situation in Europe (2020)

## Development of European biomethane sites



European biomethane sector is developing. The number of biomethane plants has risen quickly in recent years, from 187 plants in 2011 up to a total of 540 plants in 2017

Germany still has by far the highest number of biomethane plants (195), followed by the UK with 92 biomethane plants

France (+18 plants) is the European country with the highest growth rate, followed by the Netherlands (+13 plants), Denmark (+8 plants) and the United Kingdom (+7 plants).



## Conclusions



To achieve growth and decarbonization objectives of our society, biogas and biomethane are necessary energies, because they are:

### HEALTHY

Allow management and recycling of our waste, taking care of the quality of the water cycle

### EFFICIENT

Allow better energy system management and security, with the least investment

### SUSTAINABLE

Recycle waste into energy and by-products such as fertilizers, reducing our carbon footprint



Thank you so much  
for your attention

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