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Biogas Engine Emissions: Standards and On-Site Measurements

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Abstract

The European Union, with 60% of the total global production of biogas, is the world leader. In 2012, the percentage of electrical energy produced by biogas was 6% of the EU-28 electricity generated through renewable sources while, in 2013, the almost 830 biogas units produced 7448 GWh which corresponds to 14% of EU-28 gross electricity production. Germany, U.K. and Italy are the main EU biogas producers with over 78% of the 2013 primary energy production. Electricity production is the main biogas energy recovery form because the engine cooling water is used to maintain the digester required temperature while energy crops and manure are the most used organic matters. Spark-ignition engines with a rated power of 1MWel in which the filtered biogas is burned to produce work is the widely-adopted technology. With the aim of analyzing the emissions of a real biogas engine, in the present work, the authors firstly present an overview of the Italian biogas sector and the most used conversion technologies. Then, the standards which regulate the biogas plant emissions and the emissions data acquired during a one-year monitoring activity on 10 biogas plants are presented and discussed with the aim of assessing the biogas units' real emissions.

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Keywords: Biogas engine, Biogas engine emissions, Biogas architecture.

1. Introduction

The increasing concern about energy resources' availability and pollution problems have forced international administrations to adopt stringent environmental protection measures and energy efficiency policies. In this scenario, the European Renewable Energy Directive 2009/28/EC [1] has established a common framework for the promotion of energy from renewable sources. In a nutshell, the three ambitious targets for 2020 are: a 20% reduction in EU greenhouse gas emissions from 1990 levels, an increase of EU energy consumption produced from renewable resources by 20% and a 20% improvement in the EU's energy efficiency.

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In order to achieve the objectives established in the Directive, each EU Member State has implemented specific action called National Renewable Energy Action Plans.

In addition to the EU Renewable Energy Directive 2009/28/EC [1], the Member States have agreed to the 2030 framework for climate and energy for the period 2020-2030 [2]. The three targets for 2030 are: a 40% reduction of the greenhouse gas emissions, a 27% increase of the energy saving and an increase of EU energy consumption produced from renewable resources by 27%.

Although remarkable contribution to the electricity production is expected to be provided by wind and solar power, the efficient conversion of biomass into electricity is also going to play a key role in the future energy scenario especially if energy is produced by exploiting the large volumes of unused residues and wastes. In particular, biomass allows to meet various energy needs, including space and process heating, vehicle motion and electricity generation, with the advantage of sustainability, environmental friendliness and good adaptability [3]. On account of this, several researches have been carried out to classify biomass, estimate its potential, define how the governmental policies can support its sustainable development and how it can be used for power generation [4, 5, 6].

Biomass is the fourth largest energy source in the world and contributes to nearly 14% of the world's raw energy demand [3]. As an example, in 2008, biomass covered 3.5% and 2.7% of the EU and North America energy share, respectively, while it still supplies most of the energy needs in developing countries such as Nepal (97%), Bhutan (86%), Nigeria (85%), Kenya (76%) and Cote d'Ivoire (75%) [7].

Biomass is the result of natural organic processes and includes wood and wood waste, agricultural crops, aquatics plants, algae and agriculture, animal, municipal and food industry wastes. Generally speaking, wood is derived from trees while wood wastes are available as sawdust, board ends, bark, etc.. Cotton stalks, wheat and rice straw, maize and jowar cobs, rice husks, etc. are classified as agricultural waste while sugar cane and sugar beets, grains, cassava, sunflower, jatropha curcus, etc. are crops sown for energy purposes.

The production of power from biomass can occur through external combustion (e.g. boiler) or internal combustion after gasification, pyrolysis, fermentation or anaerobic digestion (e.g. internal combustion engine). The internal combustion is characterized by higher efficiency than the external one while anaerobic digestion, which produces the so called biogas fuel, is considered an economic and environmentally friendly technique compared to other biofuels production processes [8].

In fact, the generation of biogas for electricity production contributes to the reduction of greenhouse gas emissions and to increase the energy consumption produced from renewable resources: two of the objectives established in [1]. However, as remarked in [5], the production of biogas can also contributes to reduce the environmental impact and the emission of methane (a greenhouse gas more detrimental than CO2) because biogas fuel can be produced from the decomposition of organic waste deposited in rubbish dumps, purines and waste from agricultural, industrial and extractive activity, urban waste and other biodegradable matters.

Despite these import advantages, it is fundamental to analyse the emissions related to the biogas combustion. In the scientific literature, only few works study the emissions of biogas engines using test engines and not machines installed on real biogas plants which operate in the electricity market (see, e.g. [9, 10, 11]). For this reason, in the present work, the authors firstly present an overview of the Italian biogas sector and the standards which regulate the biogas incentives and plant emissions. Then, the most used biogas conversion technologies are presented. Finally, the preliminary results of the biogas composition and engine emissions acquired during a one-year monitoring activity on 10 biogas plants are given and discussed with the aim of assessing the units' real behaviour in term of emissions.

2. The Italian biogas sector: production and legislation

The EU Renewable Energy Directive 2009/28/EC has been transposed by the Italian Governament with the D.lgs. 3 March 2011, n. 28 [12]. In this Degree the Government established two objectives for 2020: an increase of the Italian energy consumption from renewable resources up to 17% and an increase up to 10% of the consumption of renewables in the transportation sector. To promote the use of renewable resources, incentives were established [13].

In accordance with the Budget Act of 2008 and ARG/elt 1/09, generators with an installed power between 1 kW and 1 MW (0.2 MW for wind energy) are entitled to a guaranteed feed-in tariff (tariffa omnicomprensiva) as an alternative to green certificates (Art. 2 par. 145 L 244/07 and Art 2 par. 3 ARG/elt 1/09). Based on this, the biogas plants are eligible to receive the Feed-in tariff I (tariffa omnicomprensiva) if the capacity is between 1 kW and 1 MW

(Art. 2 par. 145 L 244/07 and Art. 2 par. 3 ARG/elt 1/09). In the case of biogas plants, the amount is 0.18 Euro/kWh for landfill gas and gas resulting from purification processes otherwise is 0.28 Euro/kWh. This is the widely adopted support scheme for biogas plants because green certificates are not convenient for generators with an installed power lower than 1 MW. However, since 2008, the value of one certificate is 1 MWh. The value of the certificate can be modified by a decree of the Ministry of Economic Development. For plants put into operation in 2008, the number of certificates is based on the net production of the previous year, which is multiplied by a certain coefficient (Art. 2 par 147, 148 L 244/07) which is 1.8 in the case of biogas from agricultural, livestock and forestry products produced within 70 kilometers of a given power station (filiera corta). The support is granted for a period of 15 years if the plant was put in operation before December 31th, 2012.

After this date, the Ministerial Decree of July 6th 2012 established new procedures for supporting electricity generation by renewable plants (other than photovoltaic ones) with a capacity of at least 1 kW [14]. The incentives covered by the Decree are apply to new, totally rebuilt, reactivated, re-powered/upgraded or renovated plants which will be commissioned on or after January 1st, 2013. The Decree established two separate support schemes, based on plant capacity, renewable source used and type of plant:

- All-inclusive feed-in tariff (To) for plants with a capacity of up to 1 MW. This capacity is given by the sum of a base feed-in tariff (Tb) (whose value is defined for each source, type of plant and capacity class in Annex 1 of the Decree) and a premiums (Pr), if any (e.g. high-efficiency CHP, emission reductions, etc.).
- Incentive (I) for plants with a capacity of above 1 MW and for those with a capacity of up to 1 MW not opting for the all-inclusive feed-in tariff. This incentive is given by the difference between the base feed-in tariff (Tb), increased by the premiums (Pr) if any, for which the plant is eligible - and the hourly zonal electricity price (Pz) (in the zone where the electricity generated by the plant is injected into the grid). The electricity generated by plants benefiting of the incentive (I) remains property of the producer.

It is important to notice that the access to the incentives is alternative to net metering (“scambio sul posto”) and to simplified purchase/resale arrangements (“ritiro dedicato”).

In the case of biogas, the plant life is established for each type of plant and capacity class equal to 20 year while the base feed-in tariff (Tb) depends on plant capacity and type of feedstock. Similarly to the base feed-in tariff (Tb), the premiums (Pr) depend on type of feedstock, plant capacity and if the plant is an high-efficiency CHP.

Finally, the Ministerial Decree of June 23th 2016 updates the support mechanisms for supporting electricity generation by renewable energy plants (other than photovoltaic ones) with a capacity of at least 1 kW that were grated through the Ministerial Decree of July 6th 2012. The incentives covered by the Decree apply to new, totally rebuilt, reactivated, re-powered/upgraded or renovated plants which will be commissioned on or after January 1st 2013. The new incentive starts to be granted from June 30th 2016 until 30 days after reaching one of the following dates:

- December 1st 2016 for all the plants or, for the plants who access directly to incentives (art. 4, paragraph 3), December 1st 2017 or.
- when the indicative cumulative cost of all types of incentives awarded to RES-E plants (other than photovoltaic ones) reaches an overall value of 5.8 billion per year.

The Decree defines three different ways of access to the incentives, depending on plant capacity and type of project:

- Direct access for new, totally rebuilt, reactivated or re-powered/upgraded plants with a capacity not exceeding a given limit (art. 4, paragraph 3) and using specific types of sources or for special projects;
- Enrolment into the Registries for new, totally rebuilt, reactivated or re-powered/upgraded and renovated plants.
- Awarding of incentives after participation in a competitive Dutch auctions (electronic auctions held by GSE) for new, totally rebuilt, reactivated or re-powered/upgraded plants: the capacity of these plants shall exceed a given threshold (5 MW).

To determine the way of access to the incentives for renovated plants, the capacity to be considered corresponds to the increase in capacity obtained as a result of the project. Note that, the total maximum new installed capacity that can be awarded to all technologies through both registries and auctions is 1370 MW of which 800 MW for new onshore wind capacity. The Decree also established that the support shall be granted for the net electricity generated by the plant and injected into the grid. Therefore, self-consumed electricity is not eligible for incentives.

As in the Ministerial Decree of July 6th 2012, the new one established two separate support schemes, based on plant capacity, renewable source used and type of plant:

- All-inclusive feed-in tariff (To) for plants with a capacity of up to 500 kW. This capacity is given by the sum of a base feed-in tariff (Tb) (whose value is defined for each source, type of plant and capacity class in Annex 1 of the Decree) and a premiums (Pr), if any (e.g. high-efficiency CHP, emission reductions, etc.).
- Incentive (I) for plants with a capacity of above 500 kW and for those with a capacity of up to 500 kW not opting for the all-inclusive feed-in tariff. This incentive is given by the difference between the base feed-in tariff (Tb) increased by the premiums (Pr), if any, for which the plant is eligible - and the hourly zonal electricity price (Pz) (in the zone where the electricity generated by the plant is injected into the grid). The electricity generated by plants benefiting from the incentive (I) remains property of the producer.

As in the case of the Ministerial Decree of July 6th 2012, the access to the incentives is alternative to net metering ("scambio sul posto") and to simplified purchase/resale arrangements ("ritiro dedicato").

As before, in the case of biogas, the plant life is established for each type of plant and capacity class equal to 20 year while the base feed-in tariff (Tb) depends on plant capacity and type of feedstock. Similarly to the base feed-in tariff (Tb), the premiums (Pr) depend on type of feedstock, plant capacity and if the plant is an high-efficiency CHP. Obviously, Tb and Pr established in the Ministerial Decree of June 23th 2016 are lower than the ones established in the Ministerial Decree of July 6th 2012.

In 2013, biogas was the fourth European renewable energy source and has produced more than 52.3 TWh: a growth rate equal to 64% compared to 2010 (31.86 TWh). But, as remarked in [15], the EU biogas sector has curbed the expansion in 2013 when the biogas policies changed in Germany and Italy. As an example, in 2010, the Italian biogas plants produced 2056 GWh, in 2013 they produced 7448 GWh (a growth rate equal to 27.6%) while in 2014 and 2015 the production was 8198 GWh and 8212 GWh, respectively. The slowdown in growth of biogas installation is also confirmed by the number of installed plants: in 2013 the installed plants were 1713 (1388.4 MW) while in 2014 and 2015 they were 1796 (1406.1 MW) and 1924 (1405.9 MW). Despite this slowdown in growth, it is important to notice that, in the period 2010-2013, electricity generated from biogas grew by 20467.2 GWh (+64%); a fact that meant that the EU-28 targets for 2015 were fulfilled in 2013. Therefore, biogas sector is essential to fulfill the ambitious targets set by European Union.

As for the support schemes, also the biogas engines exhaust gas emissions are restricted in Europe and are different among the European countries. As an example, in Table 1, the limit values for Austria, Germany and Italy are listed. They refer to 0°C, 1013 mbar, 5% O_2 and to an engine which operates at design point conditions. Note that, in 2016, the Italian Government has reduced the limit for VOC from 150 to 100 mg/m^3 [16].

3. Biogas plants

As previously remarked, internal combustion after gasification, pyrolysis, fermentation or anaerobic digestion is the most efficient way of producing power from biomass while anaerobic digestion is considered an economic and environmentally friendly technique compared to other biofuels production processes.

Anaerobic digestion is a biological process in which the biomass organic matters, contained into the biogas feedstocks, are degraded into the so called biogas fuel in an oxygen-free environment [19]. The anaerobic digestion feedstock need to have a high content of sugar, starch, proteins or fats. For this reason, the feedstock substrates mainly consist of various residues and by-products (the most important are animal manures and slurries collected from farms) but, in the last decade, energy crops, such as maize, grasses, beets, sunflowers, etc., grown for biogas production have become the most used feedstock.

The oxygen-free environment, in which the anaerobic digestion occurred, is generally called digester. In the last century, several types of digester have been developed in order to control the biological processes and the emission of odors, increase the fuel production, stabilize biomass before its agronomic use and reduce the plant cost [20]. Actually,

Table 1. Prescribed limits in Austria, Germany and Italy for plants with a design power of 1 MW_{el}.

Contaminats	Austria [17]	Germany [17]	Italy [18]
Dust	n.s.	n.s.	n.s.
Nitrogen Oxides (NO_x)	400 and 500 mg/Nm^3 lean-burn engines	500 mg/Nm^3 for gas four-stoke engines 1500 mg/Nm^3 for gas compression-ignition engines 1000 mg/Nm^3 for ignition oil diesel engines	500 mg/Nm^3
Carbon monoxide (CO)	650 and 400 mg/Nm^3 lean-burn engines	1000 mg/Nm^3 for gas four-stoke engines 2000 mg/Nm^3 for gas compression-ignition engines or ignition oil diesel engines	800 mg/Nm^3
Non-methane Hydrocarbons	150 mg/Nm^3	n.s.	n.s.
Total organic carbon (COT)	n.s.	n.s.	150 mg/Nm^3
Hydrogen Chloride (HCI)	n.s.	n.s.	10 mg/Nm^3
Hydrogen sulphide (H_2S)	5 mg/Nm^3	n.s.	n.s.
Sulphur dioxide (SO_2)	n.s.	350 mg/Nm^3	n.s.
Formaldehyde	n.s.	60 mg/Nm^3	n.s.

the commercially available biogas plants consist of a fermenter, a secondary fermenter, a residue storage tank and a solids feeder. The fermenter and the secondary fermenter have the same characteristics: a height of 6 m and an internal and external diameter of 23 m and 23.70 m, respectively. In order to maintain a stable digestion process and accelerate the formation of methane, a constant temperature in the digester is needed. For this reason, digesters are insulated and heated. The reactor heating is done with hot water which flows along the pipes placed inside the digester wall. The water temperature is either 35°C or 55°C depending on the used bacteria: mesophilic or thermophilic, respectively.

The residue storage tank is annexed to the fermenters and has an internal and external diameter of 25 m and 25.70 m, respectively and a height of 6 m.

The solids feeder is adjacent to the fermenter, and the tanks are surrounded by green belt from all sides except one side where the horizontal silos are located [20].

The produced fuel, called biogas, is mainly composed by methane (55-70%) and carbon dioxide (30-45% by vol.). Other substances like ammonia (0-0.05% by vol.), nitrogen (0-5% by vol.), hydrogen sulphide (0-0.5% by vol.), dust ($> 5\mu m$), siloxanes (0-50 mgNm^3) and water vapour (1-5% by vol.) are also present [17]. In general, 1 Nm^3 of biogas, is characterised by a lower heating value of 21.5-23.5 MJ/Nm^3 (5.5-6kWh/Nm^3) [21]. But, before converting biogas into electricity or heat of both of them, it is fundamental to remove impurities and harmful substances (droplets, dust, mud, trace gases).

Solid particles in the biogas and sometimes oil - like components are filtered out of the biogas with the usual dust collectors or coalescing filters. Filters usually retain 99.99% of all the particles with a minimum diameter of 0.1 μm. Sludge and foam components are separated in cyclones. For the removal of trace gases, techniques such as scrubbing, adsorption, absorption, and drying are applied.

Note that, if biogas is just burned, for example, in an internal combustion engine (ICE), no requirements exist on the purity of the biogas but, the engine manufacturers prefer to purify the fuel to preserve the machine.

Regarding the biogas conversion into electricity, the following technologies can be employed: a Stirling engine, a gas turbine, a micro gas turbine, high - or low - temperature fuel cells, a combination of a high - temperature fuel cell with a gas turbine, a spark-ignition engine or a dual-fuel engine.

A power unit consisting of an internal combustion engine is the preferred solution; in fact, in Europe, 50% are spark-ignition ICEs, about 50% are dual-fuel engines while fuel cells and micro gas turbines are seldom to be found.

Four-stroke spark-ignition biogas engines were originally developed for natural gas. Then, they were adapted to the special features of biogas. Their capacity normally ranges between 100 kW_{el} and 1 MW_{el} while the electrical efficiency is in the range 34-40%. The engine operates at 1500 rpm, its lifetime is about 60000 h and the specific investment cost is in the range 1000-1300 US$/$kW_{el}$ while the nitrogen oxides (NO_x) contained in the exhaust gases need to be controlled and kept below the prescribed values defined by regulations. Usually, to increase the engine efficiency, the biogas engines are supercharged.

Dual-fuel engines (frequently called ignition oil diesel engines) are mainly used in small agricultural plants because they are cheaper and have a higher efficiency than spark-ignition biogas engines in the lower capacity range. Their lifetime is about 35000 h of operation but they require an oil analysis every 465 h [17].

In Italy, the most widespread technology is the spark-ignition engines with a rated power of 1 MW_{el} in which the filtered biogas is burned to produce work.

In the present work, 10 biogas plants, located in Northern Italy, are considered and monitored. Each plant is constituted by a reception tank, four digestion vessels (two fermenters and two secondary fermenters), a gas holder, an overflow tank and a biogas engine. The internal combustion engines are GE power units [22] with the technical data listed in Table 2.

Table 2. Engine technical data.

Parameter	
Configuration	V 70°
No. of cylinders	20
Bore (mm)	135
Stroke (mm)	170
Displacement/cylinder (lit)	2.433
Speed (rpm)	1500
Mean piston speed (m/s)	8.5
Electrical output (kW)	999
Energy input (kW)	2459
Electrical efficiency (%)	40.58
Thermal efficiency (%)	-
Total efficiency (%)	40.58
Exhaust gases mass flow rate (kg/h)	5312
Exhaust gases temperature (°C)	457

To maintain the digester required temperature (38-42°C), part of the heat contained in the engine cooling water is recovered while the heat contained in the exhaust gases is directly rejected into the environment. Note that the higher incentives are assigned if the plant production is lower than 1 MW_{el}. In fact, the engine net electrical power is maintained equal to 999 kW_{el}.

The entire set of engines entered in operation before december 31, 2012. Then, they are supported with a feed-in tariff of 0.28 Euro/kWh injected into the network and they are subjected to the exhaust gases emissions limits established in [16, 18]. For completeness, the Authors also verified if the the limits prescribed in [17] and related to Hydrogen sulphide (H_2S), Sulphur dioxide (SO_2) and Formaldehyde are respected by the analysed plants.

The feedstock used in the plants are: maize silage, wheat silage, sugar beet, bovine manure, pig manure and chicken manure. Obviously, each plant has its own diet that, at the moment, is not possible to publish.

Note that, the Authors have found that, being the engines exhaust gases temperature higher than 300°C, PM 10, PM 2.5, dust and the entire set of non-regulated emissions are infeasible to measure. For this reason, in future works, the Authors will study biogas cogeneartive plants in which the exhaust gases temperature is reduced by the insertion of, e.g., boiler od the evaporator of an Organic Rankine Cycle (see, e.g. [23]) to a value lower than 300°C.

4. Biogas Composition and Engines Emissions

Firstly, as an example, in Table 3, the main characteristics of 2 of the 10 analysed plant are listed. Regarding the entire set of analysed plant, the produced biogas fuel is characterized by a percentage of methane which ranges between 51 and 55 % while the carbon dioxide one ranges between 44 and 48%. The nitrogen percentage ranges between 0.7 and 1.1 while the percentage of oxygen and hydrogen are 0.1-0.4% and 0.5%, respectively. The ammonia contents ranges between 0.5 and 17 mg/Nm^3 while the lower heating value is in the range 19.6-19.9 MJ/Nm^3.

As presented in Section 2, the biogas engines exhaust gas emissions are restricted and the law establishes the limit values for a certain number of substances. However, an engine emits several other substances that not limited by the law. For this reason, the Authors of the present paper, are interested on monitoring all these substances in order to

Table 3. Diet, biogas composition and engine emissions of two analysed plant.

Parameter		Plant Type 1	Plant Type 2
Diet	Corn silage	39.5 t	46.0 t
	Cattle slurry	60.0 t	-
	Cattle manure	24.3 t	-
	Corn flour	-	3.0 t
	Beets	-	20.0 t
Biogas	Methane	53.0%	51.0%
	Carbon Dioxide	44.0%	48.0%
	Nitrogen	1.9%	0.7%
	Oxygen	0.4%	0.1%
	Hydrogen	0.5%	0.5%
	LHV	19.75 MJ/Nm^3	19.6 MJ/Nm^3
	Ammonia	11.0 mg/Nm^3	2.9 mg/Nm^3
Engine	Power	999 kW	999 kW
	Exhaust Temperature	470°C	505°C
Emissions	NO_x	420 mg/Nm^3	455 mg/Nm^3
	HCl	0.1 mg/Nm^3	0.1 mg/Nm^3
	CO	474 mg/Nm^3	356 mg/Nm^3
	TOC	140 mg/Nm^3	145 mg/Nm^3

understand the benefits introduced by the use of biogas instead of fossil fuels. However, as previously said, being the exhaust gases temperature in the range 470-505°C it is not possible to measure substances like PM 10, PM 2.5, dust, dioxin and polycyclic aromatic hydrocarbons. They are also interested on relating the biogas quality and engine emissions to the introduced feedstock. Obviously, for the sack of compactness, the present work is only dedicated to present the preliminary results of a one year emissions monitoring activity of 10 biogas engines fed with biogas produced by different feedstock.

The measurements have been done in collaboration with a company specialized in plants monitoring activities and the entire set of substances have been measured following the EU or Italian Standards.

In the entire set of analysed plants, Nitrogen Oxides, Carbon monoxide, Volatile Organic Compounds and Hydrogen Sulphide are under the prescribed limits.

In the case of Total Organic Carbon the values are in the range 140-145 mg/Nm^3 while Hydrogen Chloride is every time lower than 0.1 mg/Nm^3 (minimum instrumental value).

Regarding other substances non limited in the Italian Standard, the Hydrogen Sulphide is every time lower than 4 mg/Nm^3 (minimum instrumental value) while Sulphur Dioxide ranges between 24 and 74 mg/Nm^3. Note that these values are lower than the ones prescribed by Austria and Germany Standards, respectively.

The Formaldehyde, limited by the German Standard at 60 mg/Nm^3, ranges, in the plants under investigation, between 0.50 and 0.88 mg/Nm^3 while Acetaldehyde, Acroleina, Benzaldehyde, Butiraldehyde, Crotonaldehyde and n-Butanaldehyde are lower than 0.04 mg/Nm^3 (minimum instrumental value). The concentration of ammonia ranges between 0.7 and 3.7 mg/Nm^3 while the Inorganic Fluoride compounds is in the range 0.5-2.5 mg/Nm^3.

Based on the presented preliminary results, it is possible to conclude that the monitored biogas plants stick the Italian emissions limits imposed by the Standards. In addition, also the limits imposed but other countries are stick by the Italian plants. Obviously, as just included in the ongoing research project, also the non-regulated emissions need to be measured.

Finally, the Authors remarks again that, being the engines exhaust gases temperature higher than 300°C, several substances like PM10, PM2.5, dust and the entire set of non-regulated emissions are infeasible to measure. For this reason, the Authors have enlarged the study to other biogas cogeneartive plants in which the exhaust gases temperature is reduced by the insertion of, e.g., boiler od the evaporator of an Organic Rankine Cycle (see, e.g. [23]). In addition, the same measurements have been done on a 1 MW electric cogeneration engine fed by natural gas. In this manner, when the test results will be available, a critical comparison between biogas and natural gas emissions will be performed.

5. Conclusions

The generation of biogas for electricity production contributes to the reduction of greenhouse gas emissions, to increase the energy consumption produced from renewable resources, to reduce the environmental impact and the emission of methane because biogas fuel can be produced from the decomposition of organic waste deposited in several biodegradable matters. For these reasons, the biogas plants have been supported with generous incentives especially in the period 2010-2013. For these reasons, the biogas plants have been supported with generous incentives especially in the period 2010-2013. A fact that has allowed to install, e.g. in Italy, 1924 biogas plants with an installed power of over 1400 MW. However, this large number of biogas units has local impact on the environment. Therefore, the Authors have developed a project in which the real biogas plants emissions produced by the engines are monitored. Regulated and Unregulated compounds are measured with the support of a certificate company. The presented preliminary results, show that the monitored biogas plants respect the emissions limits imposed by the Italian and other European countries Standards. Obviously, in the near future, a critical comparison between biogas and natural gas emissions will be performed to assess the real environmental benefits coming from the use of biogas fuel.

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