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SUSTAINABLE BIOMETHANE: METHANE SLIP REMOVAL APPLYING REGENERATIVE CATALYTIC OXIDATION (RCO) POST COMBUSTION TECHNOLOGY

Short communication

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Abstract

Biomethane is incentivized in Italy and in many other European countries as a substitute fuel for transport, in order to reduce fossil fuel and cut CO_2 emissions. In Italy, Certificato di Immissione in Consumo (CIC) is actually sustaining biomethane production, charging petrochemical companies who need to cover their obligation quotes. Actually, biomethane production has to fulfil sustainability requirements in order to be entitled to get CIC. Sustainability principles are, among others, the type of feeding, total biogas capture during the fermentation process and last but not least, a very low methane loss associated to the off-gas of the upgrading unit, actually set at < 1 % CH_4 in Italy and most probably further reduced in the short. The upgrading unit off-gas, therefore, has to respect the limit, or as an alternative, it has to be treated in a post-combustion unit. There are technical upgrading solutions on the market that can achieve methane loss < 1% CH_4, but incremental energy, operating and investment cost have to be considered in a cost-benefit evaluation. Post-combustion on the other hand can be a serious issue, since the flow to be burnt does not contain oxygen at all, just traces of methane (normally 2-3%) and CO_2 (97-98%), changing dramatically operating conditions of traditional post-combustor units applied to cogeneration engines off-gas. For the biomethane off-gas combustion, a sustainable cost-effective solution is the Regenerative Catalytic Oxidation (RCO), operating at lower temperature than Thermal Oxidation (TO), therefore reducing energy costs and improving environmental footprint. The purpose of this article is to compare the Regenerative Thermal Oxidizer (RTO) with the Regenerative Catalytic Oxidizer (RCO).

Key words: biomethane, methane-slip, off-gas, sustainable biomethane

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1. Introduction

Upgrading of biogas to biomethane can cause GHG emissions (Westerkamp et al., 2014). Every technology for separating methane from biogas leaves a percentage of methane in the off gas. National regulations define the amount of methane to be released to the atmosphere, RED II directive gives specific targets in order to consider biomethane production sustainable and therefore gaining access to incentives.

To satisfy sustainability principles, some requirements must be met, both in terms of feeding of the biogas plant, technical construction aspects and methane loss associated to off-gas (Liebetrau et al., 2017).

In case of biomethane from waste, the target is set to 65% of GHG saving (2021) and will get higher

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for the next future. One of the major aspects affecting negatively GHG saving in biomethane production is the methane loss in the upgrading unit.

Depending on upgrading technology, technical aspects, type of media applied for separation, different percentages of methane slip are achievable, the range is 0.5-2%. (3) UNI 11567 actually under review, is putting a target of 1% maximum of methane slip in the off-gas, in order to consider biomethane production sustainable, or to install a post-combustion system.

There are technical up-grading solutions on the market that can achieve methane loss < 1% CH_4, but incremental energy, operating and investment cost have to be considered in a cost-benefit evaluation (Petersson and Wellinger, 2009). In case of a proper post-treatment of the off gas, the amount of methane emitted can be reduced to negligible values.

During biogas upgrading, the raw biogas is split into two gas streams: the CH4-rich biomethane stream and the CO_2-rich off-gas stream. Since separation technology doesn't achieve 100% efficiency, the CO_2 off-gas stream still contains methane traces, often in higher concentration than allowed. At the moment, in the newest plants, the upgrading plant off-gas does not contain a methane concentration high enough to maintain a flame without the addition of natural gas or biogas. One way of limiting the methane slip is to mix the off-gas with air that is used for combustion. Alternatively, the methane can be oxidized by thermal or catalytic oxidation (Petersson and Wellinger, 2009).

The significant challenge for the thermal oxidation of this off-gas is the fact that it contains mostly no oxygen and principally carbon dioxide. Among the leading principal solutions to be applied to the off-gas combustion there are:

1. Thermal oxidizer;
2. Catalytic oxidizer;
3. Regenerative thermal oxidizer;
4. Regenerative catalytic oxidizer.

Among them, the most valuable technologies are the regenerative ones, principally because these allow to recover energy. A percentage of the produced heat is recovered by passing alternatively hot exhaust gas and more cooling inlet gas through different heat exchanger chambers made of ceramic walls to absorb and release heat.

The purpose of this article is to compare the regenerative thermal oxidizer (RTO) with the regenerative catalytic oxidizer (RCO).

2. Short overview

Classic thermal oxidizers are not designed to operate under this condition. The major challenge of biomethane off-gas thermal oxidation is the complete lack of oxygen associated with a very little methane concentration (Penteado et al., 2018). Regenerative Thermal Oxidizer (RTO) pre-heat the gas flow up to the temperature that ensures complete oxidation reaction in the combustion chamber by means of heat recovery chambers. Hence, in order to oxidize methane, the most stable hydrocarbon molecule (Kundu et al., 2016), operating temperature is very high and energy consumption is increased also due to the increased flow to be treated (vent gas + air).

Regenerative Catalytic Oxidation (RCO) allows to operate at high yields at almost half the temperature required by thermal combustion, thanks to the catalytical action, hence reducing by half energy costs.

Regenerative Thermal Oxydizer (RTO)

Some of these RTO devices consist of a heat transfer made of ceramic media. When the off-gas flows through the ceramic media, it is heated up to a temperature hot enough for methane oxidation to form water vapor and carbon dioxide (Petersson and Wellinger, 2009).

Other commercially available thermal oxidation devices use step-like oxidation without the presence of a real flame. In the first step, the oxidation chamber is heated burning natural gas (or biogas). Once the target temperature is reached, the off-gas is indirectly preheated by the exhaust gas. The residual heat demand can be delivered by the off-gas during oxidation. The surplus heat can be recovered (Petersson and Wellinger, 2009). Another type of RTO system is made of a series of heat regenerators employed for drain exhaust air treatment in the industries which use solvents (VOCs) in their process. Ceramic heat regenerators are employed to recover more than 95% of heat energy alternating flow directions of hot clean air and cold exhaust air.

Regenerative Catalytic Oxydizer (RCO)

RCO achieves emission annihilation through the process of thermal and catalytic oxidation, transforming the contaminants into carbon dioxide and water vapor. At the same time, thermal energy can be recovered. Re-CAT RCO by Resilco S.r.l. is particularly suited for the treatment of large streams with low concentrations of VOC (0,8-4 mg/Nm3). It can be applied to the combustion of all kind of organic compounds, even in the presence of traces of halogenated compounds.

With reference to biomethane production, off-gas flows are normally in the range of 200-1000 Nm^3/h, approximately the same range of biomethane production size, which is low compared to other industrial air streams where RCO is applied.

As a matter of fact, a possible solution in order to reduce investment costs and to provide a smarter solution also suitable for small plants, is to apply RCO with the following scheme (Fig. 1) with thermal recovery on a heat exchanger instead of heat exchange over ceramic media. Thermal recovery will be slightly reduced, 5% less than the regenerative solution, thus simplifying the treatment scheme, reducing the plant footprint and avoiding transitory emissions that occur during flow inversion.

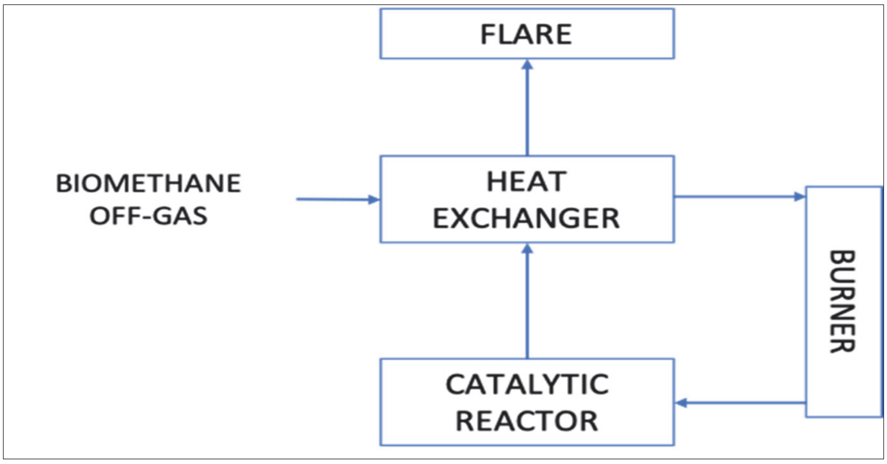

Fig. 1. Process diagram of RCO applied to biomethane off-gas combustion

The off-gas passes through the combustion chamber, where it is heated at maximum 350-400°C and then to the catalytic bed, where methane and the VOC traces are completely oxidised. Hence the hot combustion fumes cross the heat exchanger to preheat the inlet off-gas flow. Compared to high-temperature combustion systems, the Re-cat system is characterized by high efficiency and lower operating temperature. Low-temperature combustion means that NOx is not produced as by-products of conversion, which is usually the major drawback in the thermal conversion at high temperature.

3. Results and discussion

The analysed technologies differ mainly for their emission impact, since RTO operates at higher temperature where NOx is formed, and for energy consumption, since the flow (off-gas + combustion air) have to be heated up much lower temperature applying RCO, the main differences are summarized in Table 1.

4. Conclusions

Post combustion for sustainable biomethane production is necessary, unless very narrow methane-slip is achieved with upgrading systems. In this case, a cost-effective evaluation should be done in terms of major investment and operating costs of the upgrading unit to meet the target.

Among post combustion technologies, the most valuable are the regenerative ones: RTO and RCO, that allow energy reduction. RCO moreover is more environmental-friendly and allows further energy savings.

Table 1. Comparison between different analyzed technologies

	Regenerative thermal oxidizer RTO	***Regenerative catalytic oxidizer RCO (*)***
Operating temperature	800-1000°C	350-450°C
Energy consumption	High	Low
VOC abatement	>95%	>95%
CO abatement	>90%	>95%
NO_x abatement	0% (actual NOx production)	>10% (no NOx production)
Dust abatement	0%	>80%
Plant size	Large	Small

(*) data by Resilco Srl

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