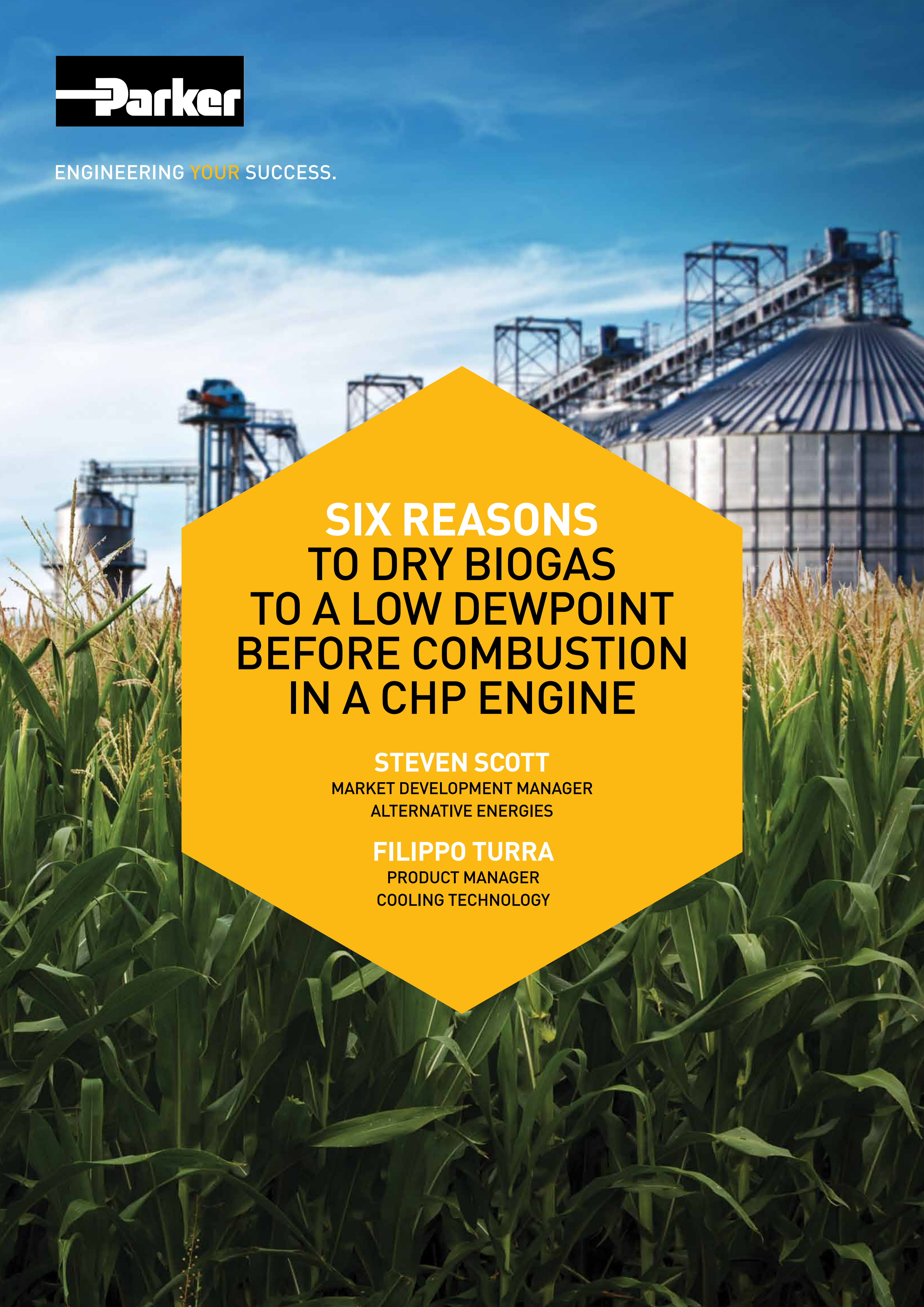

ENGINEERING YOUR SUCCESS.

SIX REASONS TO DRY BIOGAS TO A LOW DEWPOINT BEFORE COMBUSTION IN A CHP ENGINE

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INTRODUCTION

Biogas is renewable energy stored in organic materials such as plant matter and animal waste, known as biomass. The wide variety of biomass fuel sources include agricultural residue, pulp/paper mill residue, urban wood waste, forest residue, energy crops, landfills and animal waste.

Anaerobic digestion is the process that occurs when bacteria decompose organic materials in the absence of Oxygen to generate biogas.

Biogas is primarily composed of Methane and Carbon Dioxide with smaller amounts of Hydrogen Sulphide and Ammonia. Trace amounts of other gases like Hydrogen, Nitrogen or Carbon Monoxide are also present in the biogas.

Usually the mixed gas is saturated with water vapour and may contain dust or dirt particles.

The characteristics of biogas are comparable to natural gas. The energy content is defined by the concentration of methane. For biogas as a fuel, most of the impurities have to be removed, as they may cause corrosion, deposits and damage to equipment. Gaseous constituents which need to be removed (or reduced) as well as water vapour include Hydrogen Sulphide, Carbon Dioxide, Halogen compounds (Chlorides, Fluorides), Siloxanes and aromatic compounds.

It is generally accepted that a reduction in water content is beneficial to the CHP system, however traditional methods such as condensate traps and underground pipework cannot achieve low dewpoints which therefore reduces the benefit of removing water. For underground pipework to have any real cooling effect, long runs of pipe are necessary which is often impractical, expensive and difficult to maintain and service.

Fig 1 – Water condensate in biogas pipework

It is also common to use ‘air conditioning’ type chillers for biogas cooling but these units are not designed to produce low temperature water and either result in higher gas dewpoints or end up operating well outside their design limits resulting in higher energy consumption and reduced service life.

It is therefore essential to use a cooling system such as those in the Parker BioEnergy range, specifically designed to produce low dewpoints and operate in aggressive ambient conditions, such as those experienced in biogas applications.

THE MAJOR BENEFITS

1. **INCREASES EFFICIENCY**
   (OR ENERGY OUTPUT) OF ENGINE
2. **PREVENTS CORROSION OF**
   PIPEWORK AND COMPONENTS
3. **PARTIAL REMOVAL OF HYDROGEN SULPHIDE, AMMONIA, SILOXANES**
   AND OTHER WATER SOLUBLE GASES
4. **REDUCES CONTAMINATION**
   OF ENGINE OIL
5. **INCREASES SERVICE LIFE**
   OF ACTIVATED CARBON
6. **COMPLIES WITH TECHNICAL INSTRUCTION**
   OF MAJOR GAS ENGINE SUPPLIERS

THE MAJOR BENEFITS EXPLAINED

1 INCREASES EFFICIENCY (OR ENERGY OUTPUT) OF ENGINE

Biogas at the Digester Outlet usually has a very high water vapor content (between 30 to 100g water per m^3 gas). This equates to between 4 and 8% of the total gas composition which reduces the calorific value of the biogas and thus the electrical output of the engine. Drying the gas to a dewpoint of 5°C reduces the moisture content to 1% thus increasing the Methane content by 5% which in turn increases the electrical output and revenue by 5%.

As demonstrated in the table at the end of this paper, a 5% increase in electrical output can add more than €100,000 to the annual revenue generated by a 1 MWe biogas engine.

2 PREVENTS CORROSION OF PIPEWORK AND COMPONENTS

Fig 2 – Corrosion in storage vessel

When ambient temperature drops the gas cools causing water vapour to condense in the pipeline. Condensate can combine with Carbon Dioxide, Hydrogen Sulphide etc to form an acidic compound causing accelerated corrosion of machines, gas scrubbers, pipelines, buffer vessels, sensors and instruments (Fig 2).

The combination of Hydrogen Sulphide and water produces Sulphuric Acid and/or ionic Hydrogen and the combination of Carbon Dioxide and water produces Carbonic Acid. The resulting acidic condensate is highly corrosive and will cause a rapid drop in the alkalinity of the engine oil. Drying the gas to a low dewpoint ensures water vapour does not condense and thus prevents the production of these corrosive acids.

3 PARTIAL REMOVAL OF HYDROGEN SULPHIDE, AMMONIA, SILOXANES AND OTHER WATER SOLUBLE GASES

Due to their corrosive, oxidising and incombustibility properties, the small amount of compounds present in biogas must be removed to facilitate a good combustion process and ensure the proper engine functioning. Contrary to the main components, such microelements are impurities of the order of ppm and their effects can be observed only after a certain period of operation of the engine. Most of these impurities are soluble in water: thanks to an efficient dehumidification (dewpoint of about 5°C) with a cooling system composed by aftercooler - separator - chiller – condensate drain, it is possible not only to remove the water vapor content in the biogas but also to partially or completely reduce components such as Hydrogen Sulphide, Siloxanes, Ammonia and Halogen compounds. Decreasing the amount of impurities will increase engine oil life and reduce

Fig 3 – Pipescale in heat exchanger

the accumulation of Silicon Dioxide on the hot surfaces of the combustion equipment (cylinders, valves, engine heads in cogeneration), Mono-Nitrogen Oxides emissions and corrosive phenomena caused by a combination of condensation with Carbon Dioxide and Hydrogen Sulphide.

For instance, by drying 38°C saturated biogas to a dewpoint of about 5°C, it is possible to remove up to 250 ppm of Hydrogen Sulphide and eliminate at least 20% of the concentration of Siloxanes and Hydrocarbons. Ammonia in most cases is eliminated by the same process.

The partial or complete removal of these contaminants improves the efficiency of the whole plant and greatly reduces maintenance costs and plant downtime.

4 REDUCES CONTAMINATION OF ENGINE OIL

Fig 4 – Contamination of engine oil

Biogas, although composed largely of Methane, which represents the "noble" component, is an unclean gas and contains very aggressive impurities which, if not removed, can cause premature ageing of the lubricating oil.

The service life of engine oil is closely linked to the type and quality of biogas used. A very acidic biogas (having an excess of Hydrogen Sulphide) causes a very rapid ageing of the lubricating oil: the acid content in the oil grows rapidly, therefore oil acidifies faster, loses its lubrication properties and should be replaced much more frequently to avoid an excessive wear of engine components.

For instance an engine generating 1 MWe contains about 600 litres of oil and, if clean biogas is used, the oil change happens every 1,600 hours. If biogas is not adequately treated and dried, oil would double the ageing rate and to avoid engine problems it is necessary to double the frequency of oil change (every 800h approx.). This means an increase of about €15,000/year in maintenance costs (considering the loss derived from plant shutdown).

Since most of these impurities are soluble in water, it is possible to remove a large amount by dehumidifying the biogas to a low dewpoint, reducing contamination of engine oil, increasing its life and consequently reducing the costs derived from the frequency of the oil change and from downtime.

5 INCREASES SERVICE LIFE OF ACTIVATED CARBON

As previously mentioned, harmful biogas contaminants such as Hyrogen Sulphide and Ammonia can be partially removed due to their solubility in water. These contaminants are partially dissolved in the condensate which is removed by drying the gas to a low dewpoint.
If activated carbon or other adsorbents are used to remove these contaminants there will be significant savings in either CAPEX (smaller adsorption system) or OPEX (longer adsorbent life).

WITHOUT COOLING	WITH COOLING (250ppm H2S removed)
Biogas flow 700 Nm3/h	Biogas flow 700 Nm3/h
H_2S concentration (at digester outlet) 500ppm	H_2S concentration (at digester outlet) 500ppm
H_2S concentration (at adsorber inlet) 500ppm	H_2S concentration (at adsorber inlet) 250ppm
Amount of Impregnated Carbon for 1 year service life: 20,000 kg	Amount of Impregnated Carbon for 1 year service life: 10,000 kg
Estimated cost/kg (including disposal) €2.00	Estimated cost/ kg (including disposal) €2.00
Annual cost €40,000.00	Annual cost €20,000.00

ANNUAL SAVING €20,000.00

6 COMPLIES WITH TECHNICAL INSTRUCTION OF MAJOR GAS ENGINE SUPPLIERS

- ✓ TECHNICAL INSTRUCTION COMPLIANT
- ✓ ENGINE PERFORMANCE
- ✓ SERVICE LIFE

Unlike petrol and diesel fuels, gaseous fuels generally do not have to comply with strict quality specifications. For this reason, the manufacturers of cogeneration engines issue Technical Instructions to ensure the fuel gas is of sufficient quality to prevent any negative effects on engine performance and service life.

In terms of water content, all the major engine manufacturers are clear in stating that water condensate in the fuel gas pipes or engine is NOT acceptable.

Installing a cooling system to dry the gas to a low dewpoint will ensure that water vapour does not condense in the gas pipe and thus meet the Technical Instructions of the major gas engine suppliers.

SUMMARY

Cooling biogas to a low dewpoint removes a significant amount of water. As illustrated in the following example, cooling to a low dewpoint will remove 672kg of acidic water condensate every day from a biogas system producing 700Nm3/h of biogas.

Example:
700Nm3/h of biogas from digester
35°C/100% saturated = 47g of water per Nm3/h of biogas
700 (Nm3/h) x 24 (hours) x 47 (g/Nm3/h)
= 790kg water produced per day
(almost 1 tonne of water per day!)

Cooling to 5°C dewpoint will reduce moisture content to 7g/Nm3/h
= 118kg water produced per day

COOLING TO 5°C DEWPOINT WILL REMOVE 672KG WATER PER DAY

The six reasons for drying biogas to a low dewpoint all have a considerable effect on the revenue and/or operating cost of a biogas plant. Some can be easily quantified and others are clearly beneficial but less easy to quantify financially. The following table summarises the main financial benefits.

VALUE OF GENERATED ELECTRICITY PER kWh

1 MWe Biogas Engine	**€0.10**	**€0.20**	**€0.30**
Additional annual revenue due to 5% extra electrical output	€42,500.00	€85,000.00	€127,500.00
Annual saving in activated carbon (for H_2S removal)	€20,000.00	€20,000.00	€20,000.00
Annual saving in oil change & engine downtime	€14,000.00	€15,500.00	€17,000.00
Total	**€70,500.00**	**€116,000.00**	**€161,500.00**
Annual operating cost of cooling system	(€7,650.00)	(€15,300.00)	(€22,950.00)
Net total additional annual revenue	**(€68,850.00)**	**(€105,200.00)**	**(€141,550.00)**