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# Method to calculate and express energy consumption of industrial wastewater treatment for the purpose of water reuse —

## Part 2: Accounting for energy recovery

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# Foreword

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This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse*.

A list of all parts in the ISO 21939 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

Anaerobic treatment is a common part of industrial wastewater treatment, for example in the food industry. It is also commonly used in municipal wastewater systems as sludge stabilization, for example anaerobic digester (AD). Anaerobic digestion is a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen.

Anaerobic digestion is widely used as a source of renewable energy. The anaerobic digestion process has two main products: digested sludge and biogas, consisting of methane, carbon dioxide and traces of other contaminant gases.

The anaerobic treatment can be analysed for its energy consumption, like any other treatment process, using ISO 21939-1.[1] The energy consumption in AD is mainly used for mixing and heating systems.

However, anaerobic treatment also produces a potential energy resource, namely biogas, that can offset some or all of its energy consumption and in some cases end up energy positive. The excess energy can be utilized to produce electricity for other systems in the treatment plant, as indicated in ISO 21939-1,[1] such as aeration in aerobic processes, which can be the greatest consumers of energy in the plant.

In biological wastewater treatment, such as activated sludge treatment, a lot of energy is consumed for aeration systems such as blowers and aerators, which are needed to supply oxygen and mixing for the aerobic process.

To expand ISO 21939-1,[1] it is beneficial to account for the energy recovered and the net energy consumption as a basis for evaluation and comparison of biological treatment processes for reuse. It is also important to design and operate efficiency processes to produce and recover the highest amount of energy in order to use it as a source for the anaerobic digestion process and other uses, on site or outside the wastewater plant.



This document relies on the following concepts:

— Energy recovery is an operation encouraged in industrial wastewater treatment for reuse, mainly due to its net energy efficiency, which becomes significant and relevant with high concentrations of organic matter.

— One of the common ways to recover energy from industrial wastewater treatment is by using anaerobic digestion.



— The anaerobic digestion wastewater treatment is characterized by low energy consumption, as well as generation of biogas with a high calorific value.

— The biogas is often used as an energy source for generation of heat or electricity or a combination of both (combined heat and power generation).

— In addition, treated wastewater at high temperature is sometimes used for heating.

This document complements ISO 21939-1,[1] in which the energy consumption for the wastewater treatment process is quantified. Its purposes are:

— to account for energy production, where applicable, in order to obtain a net high energy value;

— to review different conditions and their influence on the biogas and methane yield;

— to outline possible uses of the biogas which have different actual energy production values;

— to define general principles for quantification and accounting for energy recovered and provide guidance on how to integrate these values with the energy consumption of ISO 21939-1;[1]

— to provide general guideline for efficient reuse of biogas for the consumption of relevant systems in industrial wastewater treatment plants, as discussed in ISO 21939-1.[1]

# Method to calculate and express energy consumption of industrial wastewater treatment for the purpose of water reuse —

## Part 2: Accounting for energy recovery

## 1 Scope

This document sets out the general principles for, and provides guidance on, the quantitative characterization of energy recovery from wastewater and sludge treatment, and how to account for this in the total energy consumption calculation.

The scope of this document includes:

— a definition of the main energy recovery processes applicable to industrial wastewater treatment and sludge treatment for reuse, such as anaerobic digestion yielding biogas;

— an introduction to the possible forms of energy generated by energy recovery processes and systems, such as electricity, steam or heat, and how to account for intentional wasting or commercial utilization of biogas;

— guidance on the value to be taken into account as quantification of the energy generated, including the power actually generated on average;

— a limit level for contaminated components in biogas allowed before any utilization;

— principles to integrate the energy recovery results with the energy consumption in accordance with ISO 21939-1.[1]



Energy production which is not recovered from wastewater or sludge treatment processes is not within the scope of this document and is not included in the calculations and results expressed in it.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

### 3.2 Abbreviated terms

| | |
|---|---|
| AD | anaerobic digester |
| CHP | combined heat and power |
| FOG | fat oil and grease |
| RH | relative humidity |

## 4 Energy recovery scenarios from wastewater and sludge anaerobic treatment processes

### 4.1 General

Currently the foremost wastewater treatment process leading to energy production from its own by-products is anaerobic digestion. Biogas produced as a result of anaerobic digestion for wastewater and sludge treatment contains a large fraction (50 % to 70 %) of methane ($CH_4$), which can be utilized in several ways for energy production, as described in the following subclauses.

The amount of biogas and its content (mainly methane) strongly depends on the organic content and the fermentation process: mesophile (temperature range: 25 °C to 45 °C), thermophile (temperature range: 50 °C to 65 °C) and the process efficiency.

### 4.2 Processing biogas from anaerobic digestion



Any processing or treatment of gas coming out of the reactors of the anaerobic digestion results in either recovering or directly generating energy.

The energy production, such as electricity, steam or CHP, is introduced in 4.4 to 4.6.

In general, biogas should be handled and processed according to ISO 19388.[2]



### 4.3 Flaring

Excess biogas that is not used to generate energy is commonly used for combustion by the flare system.

By flaring, the greenhouse gas (GHG) effect of direct emissions of methane is reduced, as the flaring exhaust is carbon dioxide. Methane emissions are 28 times larger than those of carbon dioxide.

See ISO 22580[3] for more information on the flaring system.

See Clause 5 for more information on limitations on the emissions from flaring systems.

### 4.4 Electricity generation

A process resulting from the generation of electricity may be used for other purposes within the industrial area, including production processes or for energy consumption at a wastewater treatment plant.

Generation of electricity and thermal energy by CHP generation systems are performed by a dedicated prime mover, such as a gas engine, a gas turbine or micro gas or fuel cells.

When selecting the prime mover, attention should be paid to the heat rate (KWh/KWh) of the prime mover related to biogas low-heat-value.

### 4.5 Steam generation

Steam generation is a process in which water is heated to a level at which it is converted into vaporous steam.

### 4.6 Heat recovery CHP generation

CHP generation is a process that can recover thermal energy and use it for other purposes (e.g. heating devices or movement).

The residual heat of the prime mover is utilized to generate hot water for use in the anaerobic process.

When using gas engines, the exhaust and the cooling cycle residual heat may be utilized. When using gas turbines, the exhaust residual heat may be utilized. When using fuel cells, the cooling cycle residual heat may be utilized.

Upon utilizing 100 % of the residual heat, the total efficiency (electricity and thermal) should be at least 80 %.

When selecting the prime mover, attention should be paid to the heat rate (KWh/KWh) of the prime mover related to biogas low-heat-value.

The CHP generation system should contain:

— a gas feeding system or gas train that stabilizes the gas pressure and fluctuances to suite the prime mover;

— a prime mover gas engine, gas turbine or fuel cell;

— a comprehensive balance of plant (BOP);

— a control system;

— heat exchangers to utilize the residual heat from the exhaust gas and the cooling water;

— a grid synchronization system, high-voltage and low-voltage panels;

— a transformer.



### 4.7 Discharge of raw or processed gas for offsite use

Discharge of either raw (untreated) or processed (treated) gas from an anaerobic reactor as AD may be transferred for usage in a different location.



## 5 Guidelines for handling data on energy recovery

### 5.1 General

This clause offers guidance on the estimation of energy recovered from a wastewater treatment process, which can encounter the following complications:

— variable conditions resulting in variable gas production capacity and quality;

— intermittent operation of the energy recovery system, such as a high-capacity gas generator operating intermittently or periodically by feeding from a gas storage system;

— limited availability or reliability of some of the data.

### 5.2 Limitation of contaminated components and impurities in biogas

#### 5.2.1 Limit levels for trace substances and impurities

As produced biogas contains contaminated components that can damage the utilizing systems (gas engine or turbine, boiler), biogas should be cleaned and treated before any utilization.

Table 1 shows some of the most commonly contaminated components in biogas and trace substances and impurities value limitations after cleaning and before utilization.

The values in Table 1 should be used only for pre-engineering. Before the actual biogas utilization, the exact contaminating target values should be received from the utilizing systems (gas engine or turbine, boiler) manufacturer.

**Table 1 — Biogas limit levels for trace substances and impurities**

| Designation | Chemical formula | Maximum limitation | Units | Notes |
|---|---|---|---|---|
| Total sulfur | S | ≤ 500 | mg/10 KWh | When active carbon system is used |
| | | ≤ 200 | | When carbon monoxide (CO) catalytic convertor is used |
| | | ≤ 20 | | When formaldehyde ($CH_2O$) catalytic convertor is used |
| Halogen compounds | Total Cl + 2 x F | ≤ 200 | mg/10 KWh | When active carbon system is used |
| | | ≤ 20 | | When carbon dioxide or formaldehyde catalytic convertor is used |
| Ammonia | $NH_3$ | ≤ 50 | mg/10 KWh | — |
| Volatile organic soluble carbon (VOSC) as total silicon | Si | ≤ 0,02 | [a] | When carbon dioxide or formaldehyde catalytic convertor is not used |
| | | ≤ 0,000 5 | | When carbon dioxide or formaldehyde catalytic convertor is used |
| Relative humidity (RH) of the gas at the entrance to the prime mover | | ≤ 80 | % | — |
| | | ≤ 50 | | When active carbon system is used |

[a] For lubrication oil indicator calculation, consult the prime mover manufacturer.



### 5.2.2 Gas cleaning systems

The following are the main gas cleaning systems which should be used to reduce the following elements, to allow efficient use of the biogas:

— Sulfur content: a biological desulfurization scrubber unit is used, where biogas enters at the bottom of the scrubber and flows upward, with an addition of a small percentage of ambient air. The biogas flows through plastic packing trays which are sprayed from the top downwards with nutrient-rich water (reject water from the manure digesters). The nutrient-rich water is continuously recirculated through the scrubber to enhance the growth of sulfur-utilizing microorganisms.

— Water content: biogas flow from anaerobic digestion if fully saturated at RH = 100 %. To remove this excess water, a gas cooling system should be installed to cool the biogas to 4 °C to 6 °C.

— Silicon content: an activated carbon vessel should be installed to absorb the silicon from the biogas. The activated carbon should be replaced upon reaching its maximum silicon absorption according to the manufacturer's instructions.

### 5.2.3 Limitations on emissions from flaring systems

Table 2 shows a guideline for the limitation of emissions from flaring systems.

The limitation values of emissions from flaring systems as indicated in Table 2 should be taken into account.