Overview of methane oxidization at (old) landfills – Global CO_2 Consideration, Trade with CO_2 - Certificates

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1. GREENHOUSE EFFECT

Natural greenhouse effect (the glass panes of a greenhouse): tropospheric solar energy is captured by letting the sunlight through (short-wave incoming radiation high in energy) and then retaining infrared radiation (long-wave heat radiation) res. delaying radiation. This "natural greenhouse effect" prevents infrared radiation from the sun which warms the earth from being re-reflected into space. This results in a heating up of the earth's surface. In the absence of this effect, the average temperature of the earth would not lie at approx. +15°C, but instead at approx. -18°C (WWF report) and most life on earth not be capable of existence.

Furthermore, the greenhouse effect is increased by climate-relevant gases such as carbon dioxide (CO_2), methane (CH_4) or chlorofluorocarbons, resulting in an undesired enhancement of the average temperature on earth (**anthropogenic greenhouse effect**). It is likely that early man's use of fire was the first anthropogenic source. From that moment onwards, WE were the ones to consume fossil energies and biomass for conversion ("generation of") into heat, electricity, motion (traffic), food, waste,

Total greenhouse effect:

Water vapour	Remaining greenhouse gases	**Anthropogenic (undesired) greenhouse effect**
60 – 95 %	5 – 40 %	**0. 5 – 1.5 %**

Anthropogenic (undesired) greenhouse effect:

Tropospheric ozone	Nitrous oxide (N_2O)	Stratospheric H_2O	CFC	**Methane (CH_4)**	Carbon dioxide (CO_2)
2 – 10 %	2 – 10 %	0 – 10 %	5 – 25 %	**10 – 25 %**	35 – 65 %

Anthropogenic (undesired) CH_4 – emissions (in Germany: 380 Mt / a):

Cultivation of rice	Ruminants	**Landfills**	Com-bustion of biomass	Coal-mining industry and utilization	Natural gas, oil generation and utilization	Traffic	Waters
35 %	24 %	**13 %**	9 %	9 %	9 %	0.5 %	0.5 %

Source: Abridged, VDI report entitled "Emissionen und Luftqualität", 1998

1.1 History

Until the mid-eighties, global ecological crises, there was no concrete proof of the anthropogenic greenhouse effect and the reduction of the stratospheric ozone carrying layers. It was only during the seventies that such climatic concerns increasingly became the subject of public attention and were subsequently examined more closely and systematically. The first World Climate Summit in Geneva in 1979 is considered the landmark of climate impact research. Climatic reconstruction models up to 1000 AD carried out by the American Geophysical Union show a long-term cooling-down trend until the era of industrialization. The latter started the acceleration of the changes witnessed up to the present. Within the next fifty years, an irreversible change in the climate must be assumed, the results of which, are already noticeable.

1.2 Present assessments and prognoses

Rise in temperature of the ground-level atmosphere by 0.3 to 0.6 °C since the late 19th century, according to: Assessment Report IPCC dated 1994.

The "US Global Change Research Information Office (GCRIO)" ascertains a rise in temperature of 1 °C since 1860.

According to the "US Global Change Research Information office – GCRIO", it is due to this temperature rise, that the ocean level has risen by 10 to 25 cm (reduced by the expansion of the water, meaning in addition to the latter).

Forecasting on the basis of the present knowledge assumes a rise in temperature of 1.5 to 4.5 K (°C) within the next 50 years, and by 5 to 6 K (°C) in the next 100 years on the surface of the earth.

The "United Nations Framework Convention on Climate Change" expects a temperature rise of 1 to 3.5 K by the year 2100.

1.3 The consequences of an increasing greenhouse effect

According to "Enquete – Kommission des Deutschen Bundestages", the following effects on humans and the environment are to be expected, should current trends concerning emissions continue:

* A further rise in sea level by 30 to 90 cm
* A shifting of the climatic zones by 200 to 400 km towards the pole
* Extensive forest extinction in mid- to high latitudes

* Impairment of water resources
* A worsening of the global nutrition situation

Examples:
* In the Sahara, a rise in temperature of 0.1 to 0.2 K at constant rainfall will result in an expansion of the desert by approx. 100 km.
* In England, a temperature rise of 0.5 K will prolong the vegetation period by approx. 14 days.

1.4 Relative greenhouse effect caused by various gases

The effect of the anthropogenic gases relevant to the climate varies considerably and depends on the emission mass flow and the specific greenhouse potential (Global Warming Potential). Furthermore, the examination period is of importance as the individual substances show different degradation rates in the atmosphere. Quite often, a period of 100 years is used.

According to:
"Wuebbles D. & Edmonds J. – 1991, Primer on Greenhouse Gases, Lewis Publishers Inc. Chelsea, Michigan. First Edition IBN 087371 222 6" and "Intergovernmental Panel on Climate Change Third Assessment Report, 2001" UK
the following GWP must be considered:

(extract)

Greenhouse gas	Estimated lifetime (years)	20 years GWP	100 years GWP	500 years GWP
CO_2	Variable	1	1	1
CH_4	12	62	**23**	7
N_20	114	275	296	156
Various CFCs (Chlorofluorocarbons)				

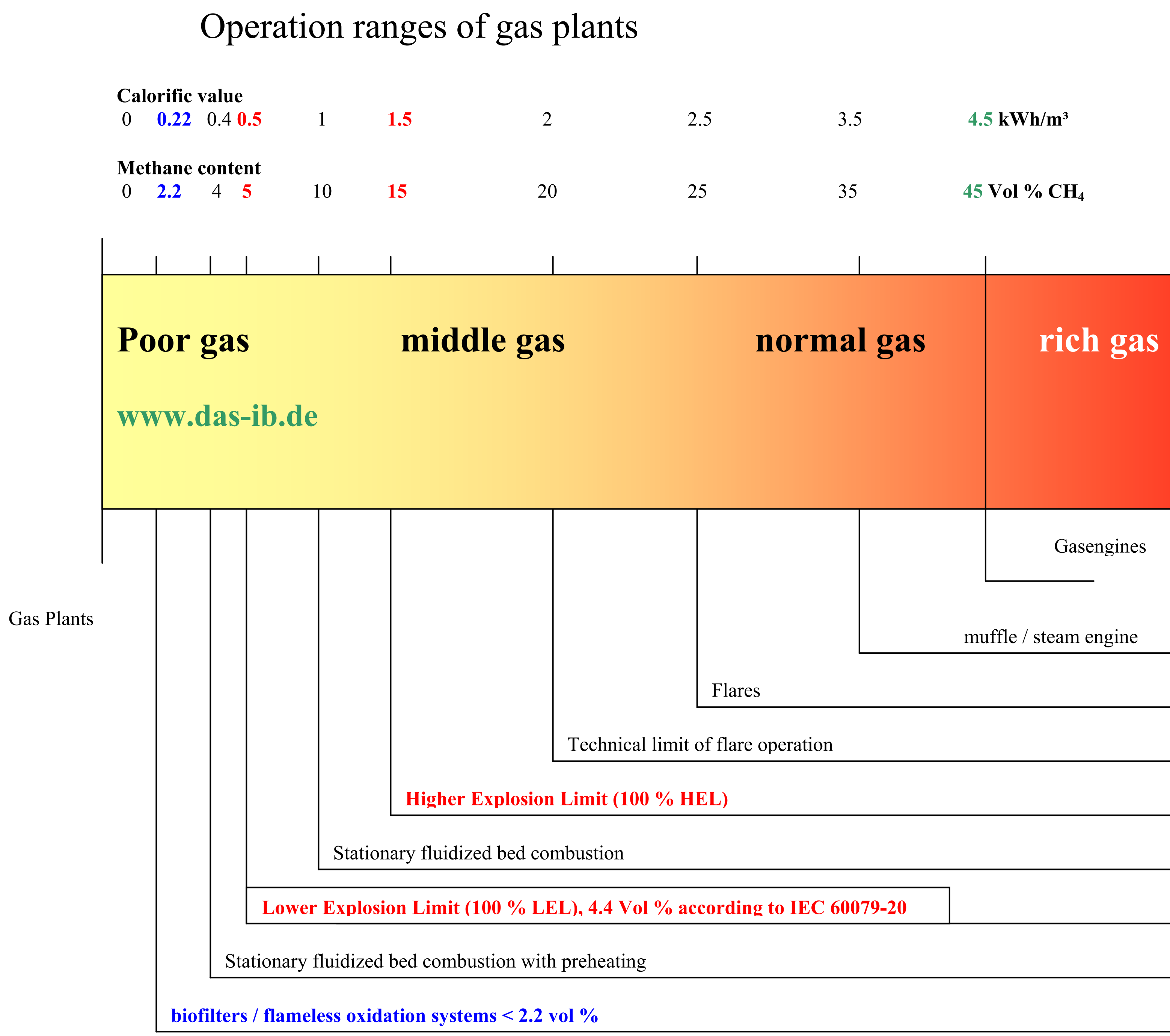
GWP: Global Warming Potential

When fixing the GWP factor, the absorption of heat radiation of the respective molecule and the average retention time of the latter in the atmosphere is taken into consideration.

2. LANDFILL GAS

2.1 Technical fields of application, explosion protection

2.1.1 Firing ranges, state-of-the-art



2.1.2 Ternary diagram (explosion triangle) for the explosive range methane / air / CO2-N2 mixtures

According to Tabasaran / Rettenberger (UBA – research report 12/82, no. 10302207 part 1)

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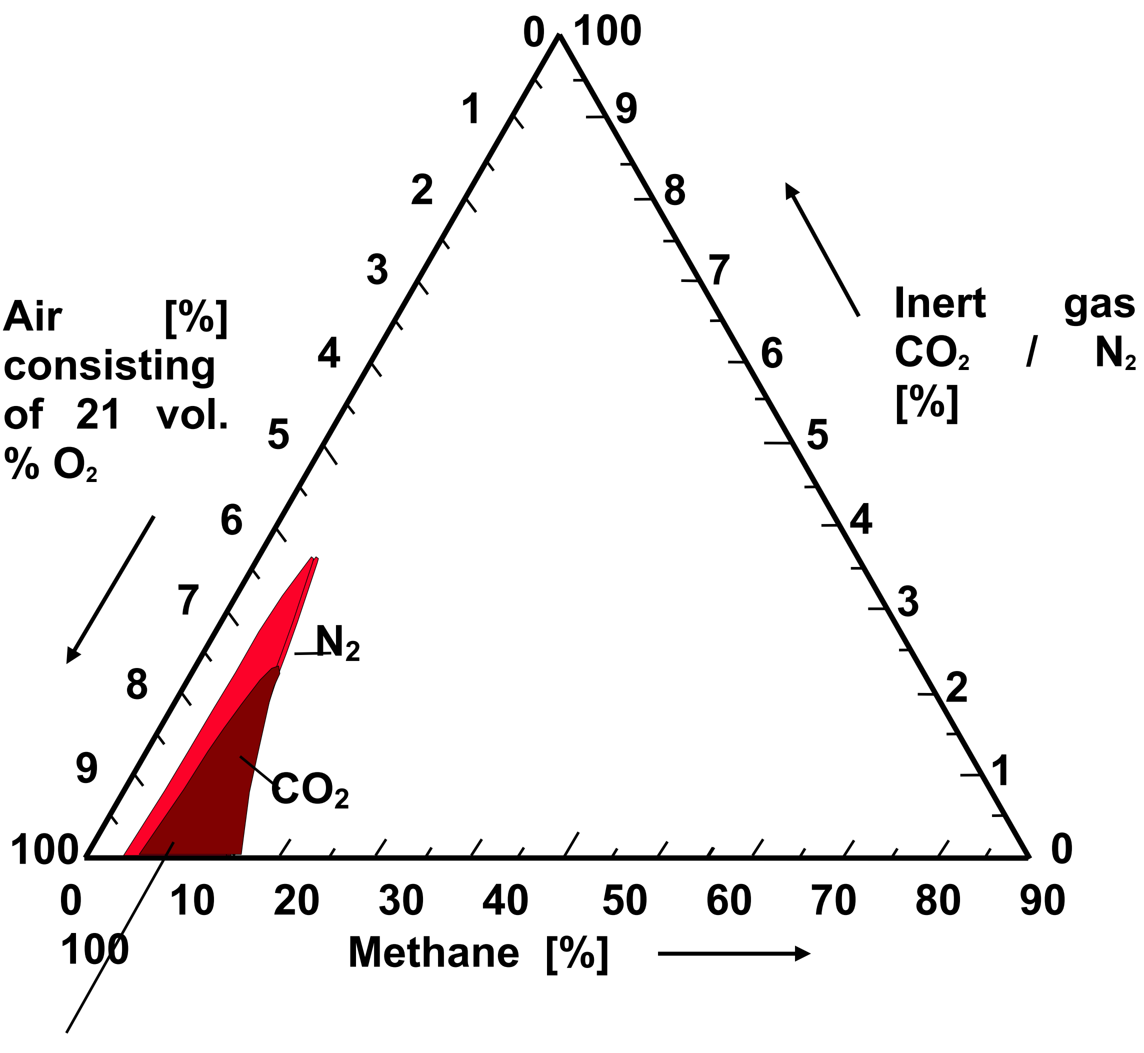

Explosive range: **Exceeding of 11.6 vol.% oxygen**

and

betw. 5 (4.4) vol.% methane (100% LEL) and 15 vol.% methane (100% UEL)

2.2 CO_2 trading certificates for landfill gas?

According to the Council of Ministers of the EU (agreement dated December 11th 2002, dossier 2001/0245), the directive 14935/02 describes the so-called "CO_2 trading certificates" as "authorizations to trade with greenhouse gas emissions". According to addendum II, the greenhouse gases CO_2 (1. Phase),, CH_4, N_2O, SF_6 and fluorocarbons as well as perfluorinated hydrocarbons fall within the scope of this directive. The Institut für Klima, Umwelt, Energie in Wuppertal offers an overview of the procedure regarding the emission trading under: www.wupperinst.org/Projekte/Klima/k28.html.

2.2.1 Introduction and basis

With respect to the following objectives, the trade in emissions (emission rights) will be set up as tool for effective climatic protection:

- EU – liability of Kyoto: Reduction of the greenhouse gas discharge by 8% by the year 2012, taking the year 1990 as a starting point and
- The resolution of the federal cabinet dated November 1990: To achieve the reduction of the most important greenhouse gas CO_2 by 25 % until 2005 (basis also 1990)
- UK: minus 60 % C02 until 2050 (Energy White Paper; **www.dti.gov.uk**).

The basis is the system for the trade with greenhouse gas emissions dated December 12th 2002 of the environment ministers of the EU (EU environmental council meeting dated December 9th and 10th 2002).

According to the DIW (Deutsches Institut für Wirtschaftsforschung / German Institute of Economic Research) weekly report 6/01, the Federal Republic of Germany achieved a reduction in CO_2 emissions of approx. 15% by the year 2000 (temperature effect already taken into consideration (the year 2000 having been a warm year)). In order to achieve the target set for 2005, the CO_2 emissions must be further reduced by approx. 100 million t in the following 5 years, the equivalent of nearly 12%.
In the year 2002 (which was also a warm year), the CO_2 emission decreased by a mere 0.2% (temperature already adjusted), compared with 2001. According to the DIW, in order to be able to fulfill the national aim, CO_2 emissions must be reduced by approx. 11% during this year and in the following 2 years (temperature adjusted). In a press communication dated February 2003, the DIW warns that even the German contribution to the Kyoto protocol (see above) may not be achieved at present.

2.2.2 Landfill gas and possible technologies for the reduction of CO2 emissions

Taking into consideration the reflections under 2.1, state-of-the-art technology, the Waste Management Act and the promotion on the basis of the Renewable Energy Act (EEG), it may be expected that there will be no CO_2 trading certificates for technologies above 25 vol. % CH_4 (pure incineration / oxidation) or approx. 35 – 38 vol. % (used by gas motors), as a double benefit is excluded in Germany. However, a Government support grant (buyback price) does not exist for all countries.

The employment of 95 kWel micro gas turbines (Pro2 Anlagentechnik GmbH) within this range of capacity, (roughly 25 – 30 vol. % CH_4) and the membrane method for the utilization of landfill gas with low methane concentrations (S.T.E.P. Partnerschaft, Aachen) must be reflected separately. Since 2001, Pro2 has gained first hand experience in the utilisation of landfill and biogas employing micro gas turbines. With the membrane method of S.T.E.P, CO_2 is drawn off the landfill medium gas (20 to 35 vol. % CH_4). Due to this drawing-off (CO_2 as permeate), prior to utilization in motors, the CH_4 content in the remaining landfill gas is "increased". At present, an economic benefit (without CO_2 trading certificates) may only arise with an available CHP station at the landfill with CH_4 > 25 vol. % and approx.300m^3/h landfill gas.

In my opinion, a possible trade with CO_2 certificates will only apply to operating ranges below the lower explosive limit (LEL). This would apply to the techniques involving the use of biofilters (several retailers), VocsiBox® (Haase Energietechnik AG), Depotherm® (UMAT – Deponietechnik GmbH) for so-called "noncatalytic oxidation" and the catalytic poor gas disposal (Pro2 Anlagentechnik GmbH).

2.3 Equivalents of the trade with CO_2 certificates

Price per "t"CO_2 equi-valent	"Stock exchange"	Source
€ 6.58	Hessen Tender, spring 2003	Technical journal: wlb 1-2/2003 Pilot project of the Hessian state government **www.Hessen-tender.de**
€ 5 to 30	UBA – Expectation special field II 6.3 "Situation of the emissions"	Mail dated 22.01.03 to the author
€ 40	Fine from 2005 on for companies for each ton of "unapproved" CO_2	Council of the European Union – Political agreements dated December 11th 2002, 14935/02 "Greenhouse gas emission allowance trading", article 16
€ 100	Fine from 2008 on for companies for each ton of "unapproved" CO_2	Council of the European Union – Political agreements dated December 11th 2002, 14935/02 "Greenhouse gas emission allowance trading", article 16
€ 5 – 10	Öko – Institut e.V.	Brief report for the WWF Environmental foundation, December 9th 2002
€ 3 – 5	Certificate sale of the Schmack Biogas AG	Mail to the author dated February 10th 2003
20 – 33 €	IG BCE – Certificate	Information dated April 10th 2002, minister for economic affairs Werner Müller and **www.igbce.de** dated 27.01.2003
$ 5.5 – 7	DIE ZEIT, economy	Schmutz im Angebot 48 / 2000 **www.zeit.de** dated 11.02.2003
7 $	Certificate, Wirtschaftsvereinigung Stahl	Verein Deutscher Eisenhüttenleute, certificate „Emissionsrechtehandel der Europäischen Kommission.." dated 22.10.2002
€ 20 – 40	Fraunhofer Institut	**www.isi.fhg.de/u/planspiel/zsfg.pdf dated 26.02.2003**
£ 15	UK Emissions Trading Group	**www.greenergy.com/our_company/media_centre/arc_april_2000_co2.html**

6- 7 €	Future Camp, Dr. Geres	**Current market price of the EU allowances**

2.4 Technology comparisons for the possible trade with CO_2 certificates

2.4.1 Biofilters

An indispensable requirement for methane oxidation is the establishment of ideal physical and chemical conditions: heat (with a temperature of approx. 30°C), humidity (30 to 70 % of the respective max. water holding capacity), pH values must be neutral to slightly acid, nutrients in/at the biofilter material etc., such that colonies of microorganisms inhabiting the liquid film may continue to thrive. For this purpose, relatively high personnel costs and technical expenditure is required in order to control temperature (also in winter), pH value, and establish the optimum humidity etc.. In the case that these conditions may not be optimally controlled, biodegradation is negatively influenced due to irreversible damage of the microorganisms. According to G. Kobelt, 1999 (symposium entitled "Poor gas" dated March 17th in Offenbach), a reduction of approx. 70% is considered a "good" biological purification of CH_4. In field tests (according to C. Cuhls, J. Clemens, J. Stockinger, H. Doedens; "Gefahrstoffe – Reinhaltung der Luft" 62 (2002) no. 4 – April, p. 141 ff) poor degradability of CH_4 resulted from excessive moisture and a shortage in O_2 due to the formation of anaerobic zones within the biofilter.
According to laboratory tests carried out by J. Streese, B. Dammann and R. Stegmann "Microbial oxidation of methane in biofilters", a desired oxidation capacity of 90% was achieved using a biofilter with a volume of 400 m^3 (meaning > 20 m x 20 m x 1 m). The flow rate was: 50m^3/h landfill gas @ CH_4 = 20 vol. %, or dirty gas with 400m^3/h at 2.5 vol. % (all the aforementioned requirements (pH, T, f) must be met!!). With regard to practical operation, even larger biofilters are expected due to drying and varying temperatures in the biofilter. Earlier publications still indicated a biofilter volume of 276 m^3, based on laboratory tests.
In the opinion of the author, biofilters may, therefore, not be considered for CO_2 trading certificates (due to the uncertainties in the efficiency of methane oxidation).

2.4.2 Technical systems, so-called "noncatalytic oxidation" and "catalytic oxidation"

A short description of the "noncatalytic oxidation": In these systems, methane is converted into CO_2 and H_2O due to thermal oxidation. Thermal oxidation is an exothermic process and takes place at approx. 850°C to 1000°C (depending on the manufacturer of the system) in the insulated reactors. The released thermal energy is emitted into the purified waste gas and used for the heating of the reactor. An autothermic operation is possible from approx. 0.3 to 0.5 vol.% CH_4 on (depending on the manufacturer of the system). An "undiluted" operation is possible up to approx. 1 – 1.5 vol. % CH_4. At higher methane contents, the reactor overheats. This may be avoided by the addition of air. The starting-up / heating of the system is implemented electrically or by means of a small pilot gas burner. It is a discontinuous process as, using a reverse shutter, the flow direction in the "reactor" must be changed due to the temperature profile that develops.
The process of "catalytic oxidation" which is presently being developed aims to reach ranges of operation of 5 to 25 vol.% methane. Hence, there are two good reasons to use this method: the landfill gas need not be diluted, and it would be a continuous process that does not require a reversal of the flow direction.

2.5 Possible proceeds and costs involved due to the trade in CO_2 certificates concerning the application of the technologies under 2.4.2

As the following paragraphs deal with landfill gas (with CH_4 as the main gas), we are talking about CO_2 certificates. However, in the narrower sense these are "carbon dioxide equivalents" with an equivalent global warming potential.

2.5.1 Requirements

a) „Project document" and „Base line"
In these documents, CO_2 reductions and technology are determined, as well as substitutions and the reference situation.
b) Validity / validation
During validation, the method applied for the determination of the emission reduction is examined and fixed one single time.
c) Monitoring report
This report documents and proves the relevant data concerning the emission reduction. An observation period is fixed.
d) Certification
Subsequent to the examination of the monitoring report according to validation, a CO_2 reduction quantity is certified for the observation period (usually a calendar year).

Phases b) and d) must be accompanied and confirmed by independent departments, phases a) and c) may be supplied by the project-executing organization itself.

2.5.2 Example plants

a) High quantity, low loading
1500m^3/h mixed gas, loading 1 vol. % CH_4, energy demand approx. 15 kW el, operating hours p.a. 8400h

CO_2 – additional load only in the case where the power supply company has no allowances:
15 kW * 8400 h * 0.6 to 0.9 kg / kWh = 75.6 t / a to 113 t / a

CO_2 – relief due to methane oxidation:
15m^3/h * 8400h * 23 GWP * 0.7 kg / m^3 = 2030 t / a

CO_2 – savings:
approx. 1960 t / a to 1920 t / a

Equivalent of the savings according to 2.3:
1920 t / a to 1960 t / a * 5 € / t to 100 € / t = 9600 € / a to 196000 € / a

Additional purchase costs in contrast to a biofilter plant approx. 50000 € to 75000 €, depending on the model and equipment.

Costs per t / CO_2 reduction (10 yr with maintenance and servicing at 5 k€ /a without depreciation and interest):

Invest. approx. 110 k€ + 10 * 5 k€ = 160 k€ + 8400 h * 0.1 € / kWh * 15 kW * 10a = 286 k €

CO_2 savings: 10 a * 1920 t / a = 19200 t

Costs arising in this example: approx. 15 € / t CO_2 equivalent

b) Concrete plant "Lampertheim am Sportplatz", installed due to reasons of explosion protection
Observation period: May 2000 to December 2002
(statements of the municipal authorities of the city of Lampertheim, legal department / department for soil conservation, Mister Dipl.-Geol. Stephan Frech and Counsulter ITD Birkemeyer, Mister Birkemeyer).

Oxidized methane: 146631.1 m^3 (documentation only started in May 2000)
Energy demand: 65765 kWh
Investment costs in 1999: costs for engineers, planning, approvals, extra costs (foundations, fencing), compressors and VocsiBox® 173500 €
Maintenance, and servicing costs per year: until 2001: 5000 € , from 2002 onwards: 6400 €

CO_2 additional load only in the case that the power supply company has no allowances:
65765 kWh * 0.6 to 0.9 kg / kWh = 39.5 t to 59.2 t

CO_2 – relief due to methane oxidation:
146631.1 m^3 * 23 GWP * 0.7 kg / m^3 = 2361 t

CO_2 – savings:
approx. 2300 t

Equivalent of the savings according to 2.3 until the end of 2002:
2300 t * 5 € / t to 100 € / t = 11500 € to 230000 €

Costs per t / CO_2 reduction (10 years with maintenance and servicing at 5 k€ /a without depreciation and interest):

Invest. and running costs: 174 k€ + 3 * 5 k€ = 174 k€ + 65765 kWh * 0.1 € / kWh = 196 k €

CO_2 savings until the end of 2002: 2300 t

Costs arising during this period (32 months): approx. 85 € / t CO_2 equivalent

Calculation for 10 years: (120 months): approx. 30 € / t CO_2 equivalent

2.5.3 Consideration of the marginal costs (Break Even Point): EEG (renewable power supply grant in Germany) – support grant or trade with CO_2 certificates ?

The following approach may be established for a relatively simple comparison: when the reduction (combustion in the gas motor in accordance with the german TA - Luft) of the landfill gas (CH_4 oxidation) - as BAT - and the waste gas emissions of the gas motors resulting from it are neglected.

The revenues of the support grant p.a:
x kW el * 0.0767 €/ kWh * operating hours p.a. = annual proceeds

The latter is compared with the possible proceeds of the CO_2 reduction (CO_2 savings of the power plants as the national average):
x kW el * 0.6 – 0.9 kg CO_2 / kWh * equivalent of the CO_2 certificate = annual proceeds

Therefore, the marginal costs are:
Equivalent of the CO_2 certificate = (0.0767 €/kWh) / (0.6 – 0.9 kg CO_2/kWh) = 9 – 13 € / t CO_2 Equivalent

This means that, from proceeds of approx. 9 – 13 € / t CO_2 on, an EEG support grant no longer appears economic, but a better option would be the safe trade with CO_2 certificates, when the landfill gas is used for electricity generation. It must be noted that the "green" power produced (the merchandise in kWh) may also be sold and, thus, is an additional source of revenue (e.g. eco-stock markets). The same applies to the sale of thermal energy, not including further CO_2 certificates resulting from it.

2.5.4 Costs concerning other technical measures with regard to the reduction of CO2

The costs of technical measures range between 163 € and 205 € per ton CO_2 according to the studies by the FhG Karlsruhe, Prognos Basel, BMFT project no.: 0326630 from 1991 and Jochen, E. "Energieszenarien mit reduzierten CO_2 – Emissionen bis 2050", in "Energiewirtschaftliche Tagesfragen", number 8, 1997. In accordance with the Environmental Protection Agency, costs of 205 € per ton may be assumed for the further development of the Transport Network Plan (federal) 2003 (Ministry of Transport, Construction and Housing, last update in February 2002).

3. CONCLUSIONS

An ecological balance is more than necessary as a decision-making tool for the maintenance or discontinuance of the poor gas disposal operation for the CO_2 emissions trade, as by means of these plants, CO_2 emissions of the slightly caloric landfill methane gas may be reduced at a reasonable price.
A trade with CO_2 certificates may offer incentives to the operators of (older) landfills to install low calorific value gas disposal systems. Otherwise, it is very likely that only a few systems would be installed, probably for explosion protection reasons or the operator's preference of the odor-minimizing biofilter technology which only exerts little influence on the reduction of the CH_4 emissions.

Under no circumstances must a "political" definition be adopted, pursuant to the following thesis:
Waste which was collected and emplaced in the year x, caused x emissions over several years which were only emitted later on (TODAY and in the future). From the year 2005 onwards, only pretreated waste without emissions will thus exist, resulting in CH_4 - / CO_2 emissions already reduced by definition.
Following this argument, we, naturally, have higher CO_2 emissions in the basic year of the emission trade which were already "reduced" by definition and without active encouragement.
In this respect, a heretical question may be permitted:

Does this also apply to coal, oil and natural gas? These fossil fuels developed millions of years ago……and if emissions only emerge later on…..
This is the most economic way to present a reduction of CO_2 emissions.

According to the assessment of the Environmental Protection Agency (Mr. Butz and Mr. Kühleis dated March 5th 2003) "the temporal categorization of landfill gas emissions does not result in an inevitable exclusion for the emissions trade". Whether or not, if so, what kind of measures may be included (e.g. poor gas treatment) in the emissions trade is unclear at the moment. A guide is presently being developed.
Furthermore, the Kyoto-protocol provides that green house gases may also be reduced within the scope of private projects when these are in accordance with the regulations relating to the flexible mechanisms of "Joint Implementation" (JI) res. with the Clean Development Mechanism (CDM). The JI comprises joint climatic protection projects of enterprises from industrial nations, whilst CDM includes the environmentally oriented development projects of the latter enterprises in developing countries and threshold nations. The basic principle applies to both JI and CDM: An investor realizes a project which reduces emissions (e.g. the construction of the low CV landfill gas disposal plant or utilization of the gas) and, in reaction to that obtains emission credit entries. Downloads are available at **http://www.bmu.de/fset1024.php**, last update 05.03.03).

Currently (according to a discussion of week number 13), the aforementioned projects are only taken into consideration as JI measure with an external investor or as national compensating projects (e.g. via the KfW – Kreditanstalt für Wiederaufbau / Credit Bank for Reconstruction, Germany). Cooperation is coordinated by the BMU in Berlin (Bundesministerium für Umwelt / Ministry of Environment, Germany), Mr. Thomas Forth. A guideline, as a supplementary directive, is currently being developed for the month of April (draft) and as a draft for an individual directive by June 2003. The BMU (Department of Climatic Protection) is the approving authority for JIs.

Thus, lobbying of landfill operators is required in order to achieve consideration of the trade with CO_2 certificates as long as everything is moving. At this moment, landfill- and mine gas projects are realized abroad.

Every (future) operator of a landfill-gas electricity installation should ask himself which situation (in respect of the proceeds) appears most economic to him at that moment (EEG support grants or sale of the CO_2 certificates plus free energy sale) as, today, there are already companies purchasing CO_2 certificates to enhance their 'green image'.

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