CO_{2e} EMISSION TRADE FOR LANDFILL (POOR) GAS (LFG) / Carbon Trading, Credits, Allowances

Trade with greenhouse gas emissions respectively greenhouse gas allowances

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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…

Table 1: Total greenhouse effect:

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

Table 2: Anthropogenic (undesired) greenhouse effect:

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

Table 3: Anthropogenic (undesired) CH_4 emissions (in Germany: 380 Mt / a):

Cultivation of rice	Ruminants	Landfills	Combustion 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, there was no concrete proof of global ecological crises, such as 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 until 1000 AD carried out by the American Geophysical Union shows 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 19^{th} 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.
* Extinction of 15 – 37% of the terrestrial animals and plants until 2050 (Nature and taz 08.01.04)

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:

Table 4: (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.

1.5 Emission trade – in accordance with the German TEHG (Treibhausgas - Emissionshandelsgesetz (act on greenhouse gas emission trade), EU directive 2003/87/EU and the Kyoto – Protocol

At the beginning of a trading period, the total quantity of allowable CO_2 emissions is determined for each of the plants concerned (approx. 2600 in Germany, as of May 2004); for trading with emission rights each receives tradeable "allowances". The first period starts on January 1st 2005, and ends on December 31st 2007. The amount of allowances received will then be reduced at the beginning of the subsequent periods, that is, from 2008 onwards. The concerned companies have the choice either to take saving measures themselves or to purchase additional emission allowances from the market. They thus have the possibility to select the "prevention option" which they deem cost-effective. The trade is legally binding throughout Europe and the German TEHG participated in the mediation committee on May 5th 2004. The certificates will be issued

first on February 28th 2005 on the basis of the "Nationaler Allokationsplan (NAP)" (national allocation plan). First accounting for the companies involved will take place on April 30th 2006. A company which is able to implement a cost-effective reduction of its emissions (which, according to the author, is unlikely) may sell to others the amount of emission allowances which are not required. On the other hand, and for economic reasons, it may be much more interesting not to reduce own emissions but to buy additional emission allowances (e.g. from biogas or landfill gas projects). This decision will depend on the market prices (€ / t Co_2 e) / marginal abatement costs.
Furthermore, two project-related mechanisms exist abroad (from the emitter's point of view) which are called "Joint Implementation" (JI) and the "Clean Development Mechanism" (CDM).

2. LANDFILL GAS

2.1 Technical fields of application, explosion protection

2.1.1 Firing ranges, state-of-the-art

Net calorific value in kWh / m^3

Operating ranges of gas utilization plants

2.2 CO_2 trading certificates for landfill gas? YES

According to the Council of the EU (October 2003), the directive 2003/87/EC 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^{st} phase), CH_4, N_2O, SF_6 and fluorocarbons as well as perfluorinated hydrocarbons fall within the scope of this directive. The emission trade directive was promulgated on October 25^{th} 2003. It thus constitutes part of European legislation and must be implemented in the member countries. The translation into national law e.g. Germany is called "Treibhausgas-Emissionshandelsgesetz" – the TEHG (act on greenhouse gas emission trade). The official trade starts on January 1^{st} 2005. In March 2004, DAS-IB GmbH has submitted a brief check of the emission reduction project / residue emissions from (old) landfills through poor gas utilization / disposal to the Federal Environment Ministry (BMU) in Germany, for the first concrete projects. In mid-May 2004, the BMU has granted us the permit for the first two JI projects in Germany for landfill poor gas. The lecture will inform you about the latest developments, particularly with regard to the equal treatment of mine gas and landfill gas: do landfill gas flares also fall within the scope of the directive? Furthermore, we participate in projects in Eastern Europe and in the Near East. Methane projects (as JI or CDM) can start e.g. in Rumania, Bulgaria, Poland, Ukraine and other countries with AAUs (Additional Allowances Unit) – certificates and later on with ERUs – Certificates (Emission Reduction Unit).

2.2.1 Introduction and basis

In order to achieve a reduction in the discharge of greenhouse gases by 8% by 2012 (related to base year 1990) (this being an EU liability of Kyoto), and to implement the resolution of the Federal Cabinet dated November 1990: reduction of the most important greenhouse gas CO_2 by 25% by 2005 (base year also 1990), the aforementioned trade in emissions (emission rights) will be set up as a tool for effective climatic protection. The Europe-wide trade in greenhouse gas emission certificates will come! It will start on January 1^{st} 2005 with 15 EU countries + acceding countries + other participants (e.g. Switzerland, Norway etc.). "Early actions" with 1990 as the earliest base year can be taken into consideration.

According to the NAP (National Allocation Plan) in Germany, approx. 17 mio t CO_2 emissions must be reduced annually in German industry from 2005 onwards.

2.2.2 Landfill gas and possible technologies for the reduction of CO_2 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) in Germany res. NFFO in the UK, it may be anticipated that there will be no CO_2 trading certificates for technologies above 25 vol. % CH_4 in the "old" Europe, as a double benefit is excluded. Compared with mine gas, there is a discrepancy though (cold venting to atmosphere or combined heat and power plant - no "flare technology"). However, legal feeding compensations res. regulations regarding the flaring of biogas / landfill gas do not exist in all countries involved, not even in the new member countries.

The employment of 95 kWe 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 / G.A.S. Krefeld) must be reflected separately. Since 2001, Pro2 has gained first hand experience in the utilization of landfill and biogas employing micro gas turbines. In the EEG (2005) / Germany, the feeding compensation for this technology has been increased by 2 ct. With the membrane method of S.T.E.P. / G.A.S., CO_2 is drawn off the landfill middle 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 a landfill with CH_4 > 25 vol. % and approx. $300 m^3/h$ landfill gas.

In our opinion, a possible trade with CO_2 certificates in the "old" Europe will only apply to operating ranges below the lower explosive limit (LEL). This would apply to techniques involving the use of technical biofilters (several retailers), VocsiBox® (HAASE Energietechnik AG), Depotherm® (UMAT – Deponietechnik GmbH) for so-called "non-catalytic oxidation" and catalytic poor gas disposal (Pro2 Anlagentechnik GmbH) or the legal / promoted feeding compensation is set aside.

2.2.3 The "currency" of CO_2 trade

Exchange obligation of: CER (e.g. from CDM or JI projects) into allowances ->
CER (Carbon Emission Reduction) = ERU (Emission Reduction Unit) = allowance

2.3 Values of the trade with CO_2 certificates

Table 5

Price per "t"equi-valent	**"Stock exchange"**	**Source**
€ 6.58	Hessen Tender, spring 2003 Germany	wlb 1-2/2003 Pilot project of the Hessian state government **www.Hessen-tender.de**
€ 25	e.on Energie AG	For new combined gas and steam turbine power plants in exchange for coal-fired power plants
€ 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
£ 15	UK Emissions Trading Group	**www.greenergy.com/our_company/media_centre/arc_april_2000_co2.html**
€ 12	Franzjosef Schafhausen	Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, on November 17th 2003 in Potsdam
€ 7.5 - 12	Own investigation	Market price in May 2004

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 optimum humidity etc. In the event 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, R. Stegmann "Microbial oxidation of methane from old deposits in biofilters", a biofilter volume of 900 m^3 (meaning > 30 m * 30 m * 1 m) may be achieved when meeting the aforementioned requirements (pH, T, f) for: 50 m^3/h landfill gas, CH_4 = 20vol.-%, raw gas with 400 m^3/h at 2.5 vol.-% CH_4 and a desired cleaning rate of 90%. With regard to practical operation, even larger biofilters are expected due to drying and varying temperatures in the biofilter. Earlier publications still indicate a biofilter volume of 276 m^3, based on laboratory tests.
In the opinion of the author, only technical biofilters may therefore be considered for CO_2 trading certificates (due to a more reliable methane oxidation).

2.4.2 Technical systems, so-called "non-catalytic 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 does not need to be diluted, and it would be a continuous process which does not require a switching-over.

2.4.3 Landfill gas electricity generation including / excluding heat extraction – instead of a promoted feeding compensation

On the one hand, conventional current from coal, natural gas, oil, or nuclear power plants is superseded and on the other, fossil fuels, such as oil, gas, coal, etc. are possibly being replaced. For both possibilities, CO_2 equivalence certificates are thus directly regenerated when the EEG feeding compensation is set aside or not paid within the scope of JI or CDM projects abroad. CDM and JI projects may already be initiated. Emissions credits from CDM projects before 2008 may be "saved" whilst emissions credits from JI projects may not be saved – "banking" – (allocation period).

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 and 2.4.3

As the following paragraphs deal with landfill gas (with CH_4 as central 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

„Project document“ and „Base line“
In these documents, CO_2 reductions and technology are determined, as well as substitutions and the reference situation.
Validity / validation
During validation, the method applied for the determination of the emission reduction is examined and fixed one single time.
Monitoring report
This report documents and proves the relevant data concerning the emission reduction. An observation period is fixed.
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 (presently, IHK (Chamber of Industry and Commerce) and environmental experts are "being considered" in Germany); phases a and c may be supplied by the project-executing organization itself.

2.5.2 Process stages

a) Pre-check
b) PDD (Project Design Document)
c) Approval
d) Monitoring and evaluation

2.5.3 Example plant

a) High quantity, low loading
$1500 m^3/h$ 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:
$15 m^3/h$ * 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 years 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! Meaning bad efficiency)
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 Consulter ITD Birkemeyer, Mister Birkemeyer).

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

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

2.5.4 Consideration of the marginal costs / Break Even Point: EEG - feeding compensation (Germany) 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 Ta air) of the landfill gas (CH_4 oxidation) - as state of the art - and the exhaust gas emissions of the gas motors resulting from it are neglected.

The revenues of the feeding compensation 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) =85 – 130 € / t CO_2 equivalent.
This represents the "value" excluding the CH_4 / CO_2 GWP of 23, meaning that mine gas / biogas may work with 3.7 – 5.5 € / t CO_2e.
"Market value" at 5 € / t CO_2: 0.005 – 0.003 €/kWh excluding the GWP of 23.

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 goes for the sale of thermal and exhaust energy, not including further CO_2e certificates resulting from it. This also applies to the retrofitting of already existing plants, according to the principle that landfill gas supersedes fossil oil or gas firing.

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 poor 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 will only be 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 from old waste already reduced by definition.
Following this argument, we, naturally, have higher CO_2 emissions in the base 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.
Furthermore, the Kyoto protocol (and also the EU directive and the draft of the TEHG) 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 (joint implementation) 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.
Note: The Kyoto protocol provides that each country is obliged to hold 90% of its emission rights at home. However, this is not relevant to the European emission trade when Kyoto is not ratified (majority).

Currently, we have submitted to the Federal Environment Ministry a general brief check for such projects and two concrete poor gas projects which were granted verbally in April 2004 (JI – projects).

Furthermore, we are working on projects in Palestine, Hungary and in the Ukraine for the (partial) financing of complete landfill construction projects and for the FEA, for the "Nationalen System Emissionsinventar" (National System Emissions Inventory), workshop: Energy and Waste.

CO2 e - Certifications before 2008 are possible: CDM – projects (CER) and JI – projects (AAUs).

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