Spracované pre :

Slovenský hydrometeorologický ústav
Jeséniova 17
833 15 Bratislava 37
Slovenská republika

Emisie zo skládok odpadov a ich kvantifikácia.

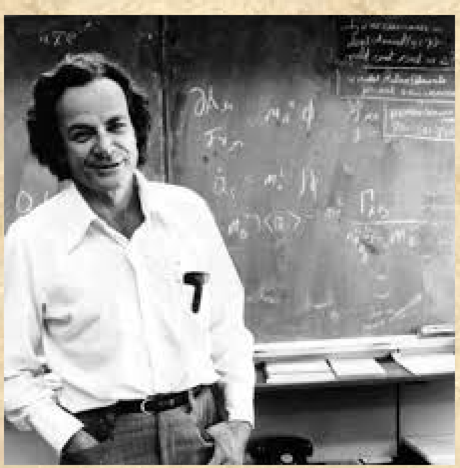
8.IV.2021

Ing. Marek Hrabčák, Prešov – Slovensko

Moji študenti často nerozumejú tomu, čo ich učím.

Lebo ani ja tomu nerozumiem.

***Nikto** tomu nerozumie !*



Teória kvantovej elektrodynamiky popisuje prírodu spôsobom,

ktorý je z hľadiska zdravého rozumu absolútne absurdný !!!

Napriek tomu je v úplnej zhode s našimi experimentmi.

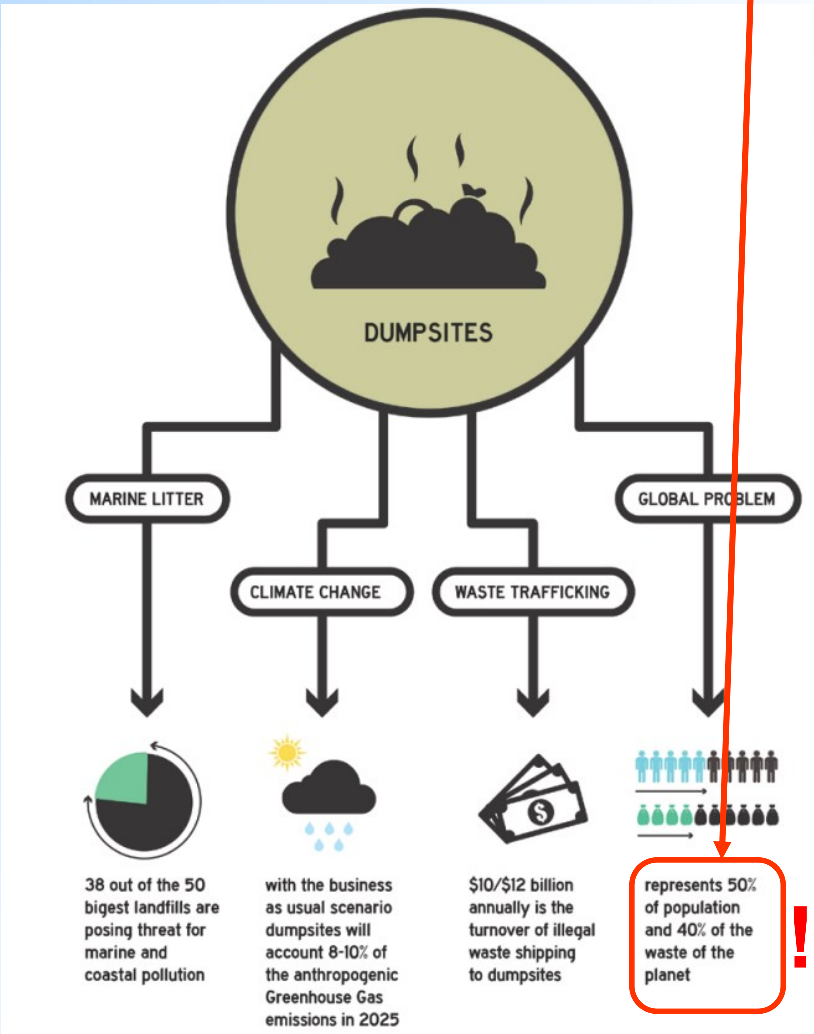
Prírodu musíme prijať takú, aká je.

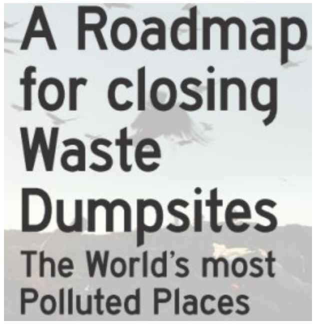
Je totiž ABSURDNÁ ! (Richard Feynman)

Deponie = Dumpsites = Smetisko # Landfill = Skládka

KAŽDÝ DEŇ S VAMI

Keď verejnosť počuje SKLÁDKA
najčastejšie si predstavuje SMETISKO.





SHMÚ
KAŽDÝ DEŇ S VAMI

Skládkovanie a GHG

Podľa SAŽP bolo v roku 1992 na Slovensku povolených celkom 686 skládok odpadov. Po prijatí prvého zákona o odpadoch (1991) a následne aj druhého zákona o odpadoch (2001) klesol ich počet na cca **106 prevádzok** (2010). Cca **90** slúžilo hlavne pre komunálne odpady (MSW).

Regionálne podobnosti v skládkovaní odpadov v krajinách V4.

Česko – Poľsko - Slovensko.

	počet skládok NNO	hustota	obslužnosť	teoretický zvozový rajon
		(1 skládka na km2)	obyvateľov na skládku	(R = km)
Slovensko	106	**456**	54 006	11,9
		228 - 675	38 400 - 77 800	8,5 - 14,7
Česko	179	**470**	56 809	12,1
		277 - 663	25 453 - 89 304	9,4 - 14,5
Poľsko	729	**467**	58 480	12,1
		264 - 689	22 218 - 140 909	9,2 - 14,8

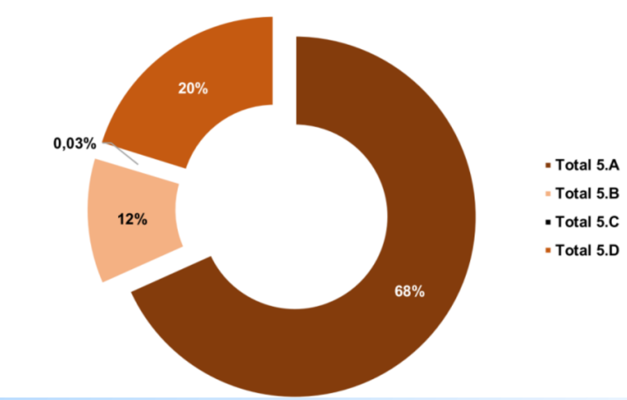
Odpady na Slovensku a GHG

SK_{2019} Waste sector (landfilled):

CH_4 = 44 800 t

Figure 7.2bellow shows that the most important source of GHG emissions is solid waste disposal (68%), followed by wastewater treatment (20%), biological treatment (12%) and incineration of waste without energy recovery (0.03%). Waste sector contributed 3.96% to total GHG emissions in 2019.

Figure 7.2: *The share of categories in waste sector in 2019*



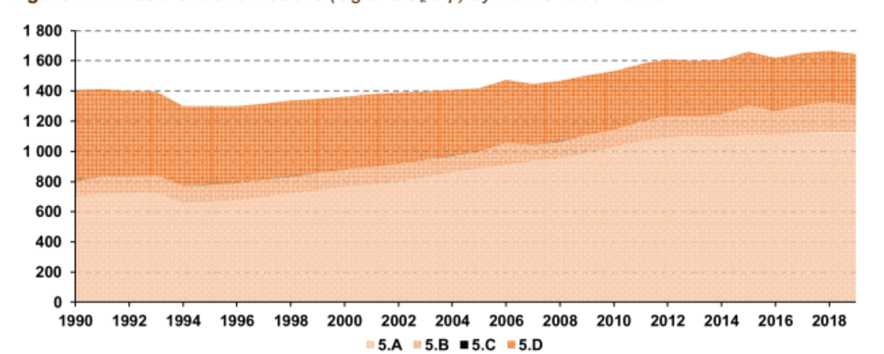
Europa geological seepage of CH_4:

3 000 000 t/yr (1,85%)

Total global geologic CH_4 emission:

64 000 000 t/yr (0,087%)

Figure 7.1: *Waste sector emissions (Gg of CO_2 eq.) by trends 1990 – 2019*



estimates of global natural wetland fluxes:

92 000 000 – 264 000 000 t/yr

Assessing the fugitive emission of CH_4 via migration along fault zones – Comparing potential shale gas basins to non-shale basins in the UK

I.M. Boothroyd [a,*], S. Almond [b], F. Worrall [a], R.J. Davies [b]

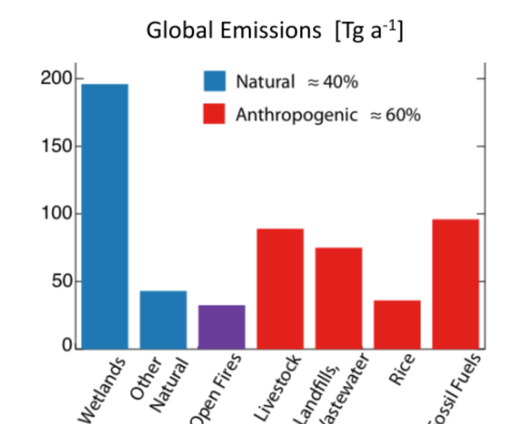
[a] Department of Earth Sciences, Durham University, Science Labs, Durham DH1 3LE, UK
[b] School of Civil Engineering and Geosciences, Newcastle University, Newcastle NE1 7RU, UK

GHG – global emissions

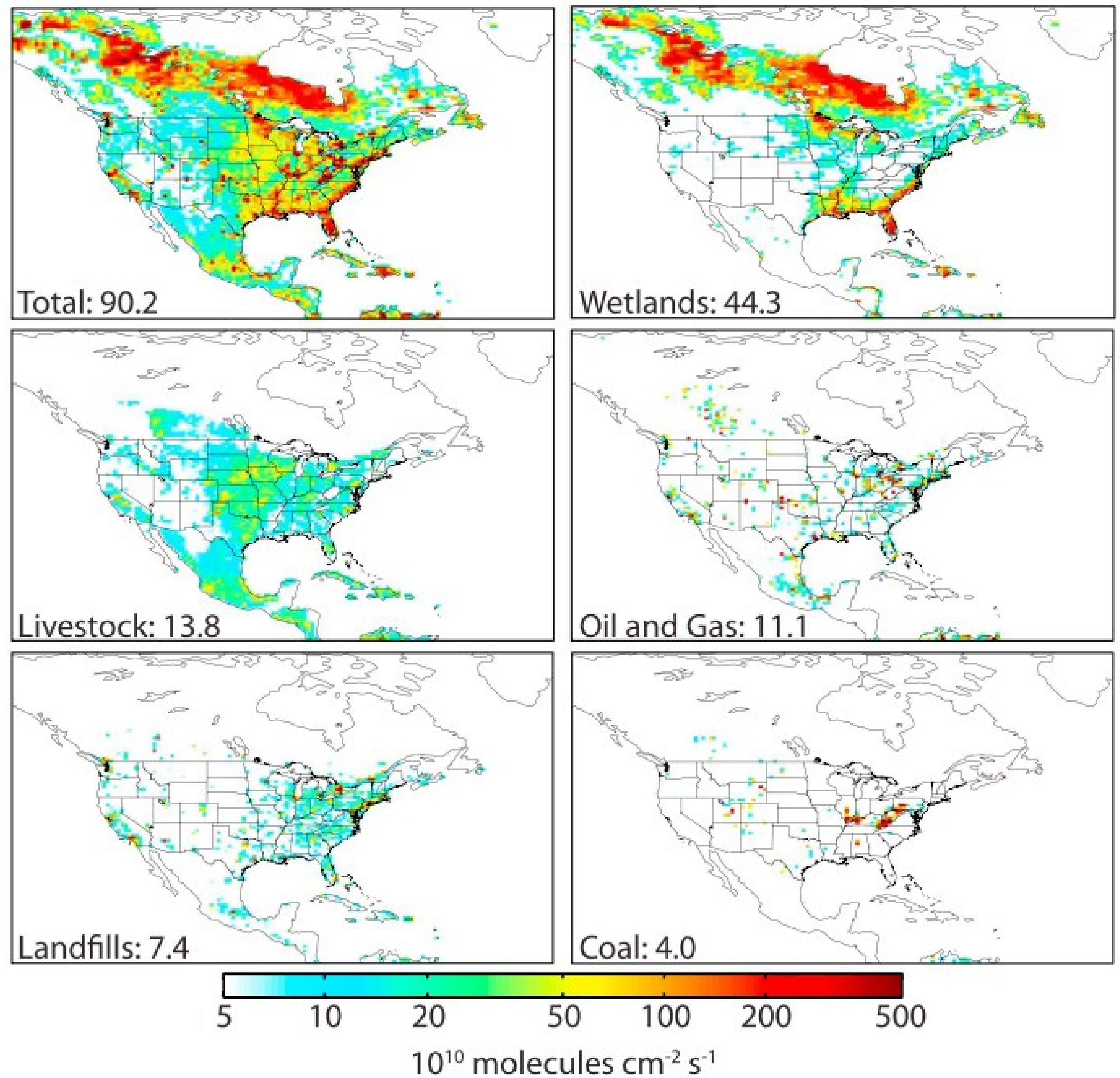
Mapping of North American methane emissions with high spatial resolution by inversion of SCIAMACHY satellite data

Kevin J. Wecht[1], Daniel J. Jacob[1], Christian Frankenberg[2], Zhe Jiang[2], and Donald R. Blake[3]

[1]Department of Earth and Planetary Sciences, Harvard University, Cambridge, Massachusetts, USA, [2]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, California, USA, [3]Department of Chemistry, University of California, Irvine, California, USA



Sources are numerous and uncertain



KAŽDÝ DEŇ S VAMI

Methane Emissions from Landfills

Department of Earth and Environmental Engineering
Fu Foundation School of Engineering and Applied Science
Columbia University
January, 2019

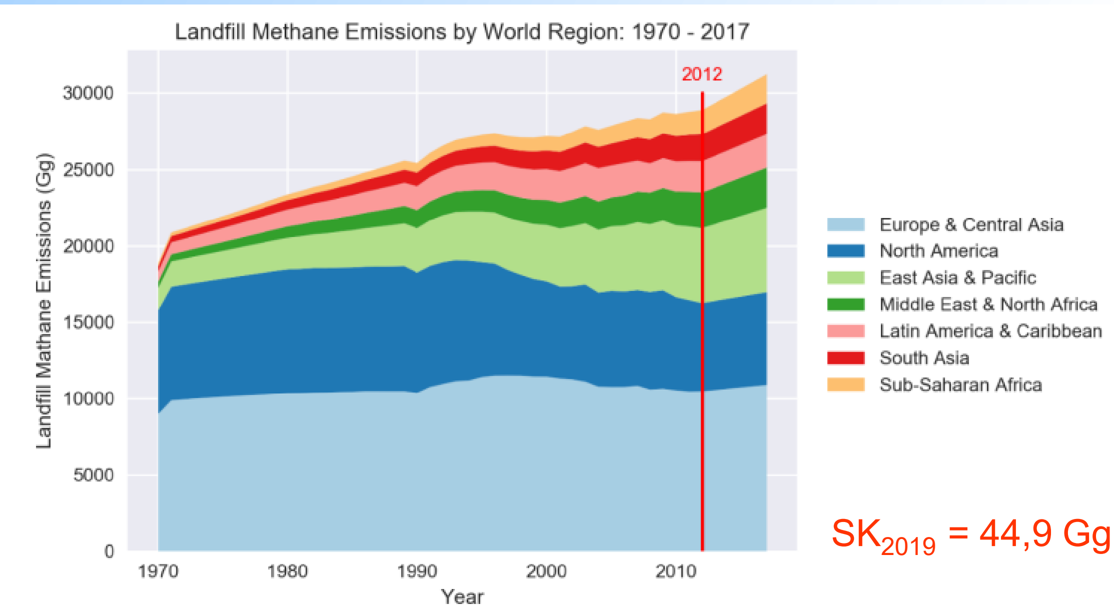
Advisors:
Prof. Nickolas J. Themelis
Prof. A.C. (Thanos) Bourtsalas
Prof. Wade R. McGillis

Table 5-14 Landfill Methane Emissions by World Region: 1970 – 2017 (*Mt CO_2 e*)

Country / World Region	*1970*	*1980*	*1990*	*2000*	*2010*	*2012*	*2017*
Top 10 Emitting Countries							
United States	151.6	180.5	176.2	133.4	130.4	121.9	127.9
China	9.4	14.1	24.5	40.4	63.7	69.2	79.6
Russia Federation	28.3	31.5	33.7	41.5	58.1	63.6	64.7
Turkey	2.6	4.1	7.8	34.4	39.2	41.4	46.5
India	7.3	12.4	17.6	23.7	31.8	33.6	37.9
United Kingdom	52.6	58.9	56.7	54.4	28.6	24.4	25.7
Canada	18.1	22.5	20.8	22.5	22.1	22.6	24.0
Iran, Islamic Republic of	2.4	4.5	7.9	11.2	14.6	15.3	16.9
Brazil	4.4	8.5	12.5	17.0	14.5	14.9	15.8
Indonesia	1.3	2.7	5.1	9.2	13.3	14.3	16.1
Rest of the World Regions							
Europe & Central Asia	141.1	163.7	161.0	155.5	137.6	132.3	135.5
Middle East & North Africa	8.0	14.1	21.9	29.8	40.4	42.9	48.9
Sub-Saharan Africa	5.1	9.3	15.4	23.7	36.0	39.4	47.7
East Asia & Pacific	25.9	34.8	42.8	42.6	40.6	39.0	42.2
Latin America & Caribbean	11.9	19.4	26.5	33.4	34.9	36.3	39.0
South Asia	1.5	2.9	4.6	6.8	9.9	10.7	12.4
North America	0.006	0.007	0.008	0.008	0.008	0.008	0.008
World Total	**471.6**	**583.9**	**635.0**	**679.4**	**715.6**	**721.9**	**780.6**

Table 5-16 Landfill Methane Emissions per capita by World Region: 1970 – 2017 (*kg*)

World Region	*1970*	*1980*	*1990*	*2000*	*2010*	*2012*	*2017*
North America	29.98	32.24	28.39	19.92	17.77	16.57	16.76
Europe & Central Asia	12.32	13.17	12.45	13.42	11.99	11.84	12.03
Middle East & North Africa	3.00	4.01	4.69	5.22	5.72	5.81	5.98
Latin America & Caribbean	2.27	3.07	3.51	3.84	3.31	3.35	3.40
East Asia & Pacific	1.15	1.34	1.61	1.82	2.15	2.21	2.41
Sub-Saharan Africa	0.71	0.97	1.22	1.43	1.66	1.73	1.83
South Asia	0.50	0.68	0.79	0.88	1.02	1.06	1.12
World Average	**5.16**	**5.30**	**4.84**	**4.47**	**4.16**	**4.10**	**4.18**

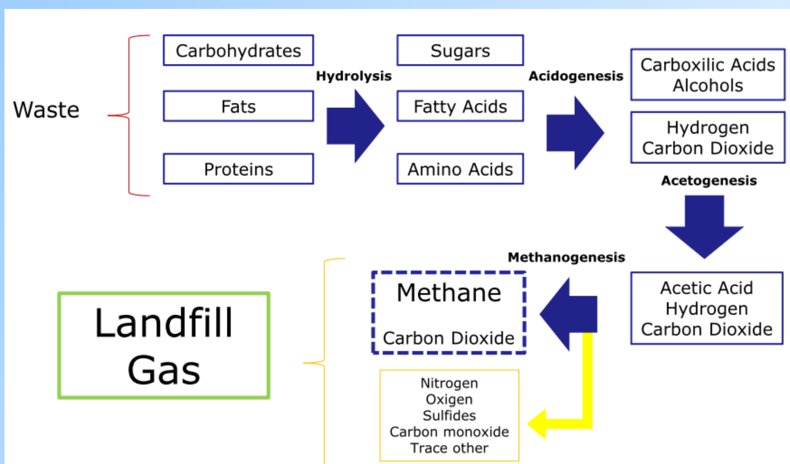


SK/EU = 44,9/65,7 Gg (68%)

SK/World = 44,9/22,4 Gg (200%)

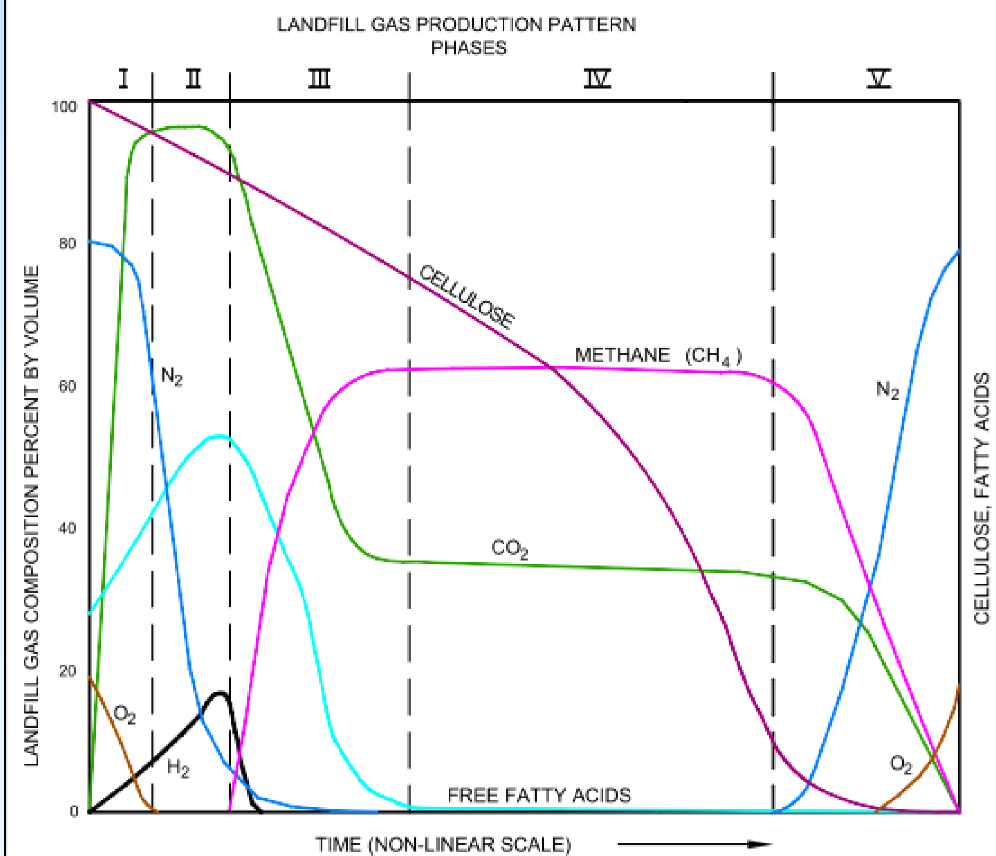
SK_{2019} = 44,9 Gg

Vznik a zloženie LFG



$$C_nH_aO_b + \left(n-\frac{a}{4}-\frac{b}{2}\right)H_2O \rightarrow \left(n-\frac{n}{2}-\frac{a}{8}+\frac{b}{4}\right)CO_2 + \left(\frac{n}{2}+\frac{a}{8}-\frac{b}{4}\right)CH_4$$

$$C_6H_{10}O_4 + 1.5H_2O \rightarrow 3.25CH_4 + 2.75CO_2$$



PHASES	CONDITION	TIME FRAME - TYPICAL
I	AEROBIC	HOURS TO 1 WEEK
II	ANOXIC	1 TO 6 MONTHS
III	ANAEROBIC, METHANOGENIC, UNSTEADY	3 MONTHS TO 3 YEARS
IV	ANAEROBIC, METHANOGENIC, STEADY	8 TO 40 YEARS
V	ANAEROBIC, METHANOGENIC, DECLINING	1 TO 40+ YEARS
TOTAL		10 TO 80+ YEARS

SOURCE:
FARQUHAR AND ROVERS, 1973,
AS MODIFIED BY REES, 1980,
AND AUGENSTEIN & PACEY, 1991.

figure 2.3

TYPICAL LFG PRODUCTION STAGES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Vznik a zloženie LFG

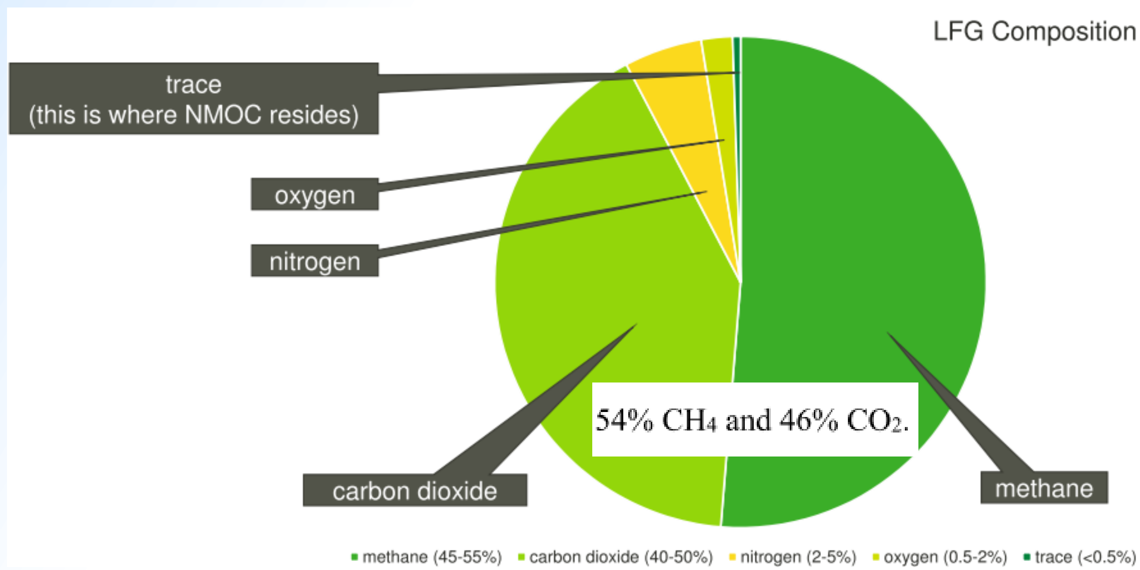
Table 1: Typical Gas Compositions on Landfill Sites

Gas Component	Air (%)	In-Waste Landfill Gas Composition (%)	Landfill Gas in the Gas Collection System (%)	Landfill Gas in Perimeter Borehole (%)	Landfill Gas Surface Emissions (%)
Nitrogen	78	0	<20 N_2+O_2	78	78
Oxygen	21	0	<7	21	21
Methane	0.0002 (2 ppm)	50 - 60	40 - 60	<1	0.0002 - >1 (2 ppm - > 10000 ppm)
Carbon Dioxide	0.03	40 - 50	30 - 50	<1.5	0.03 - >1
Hydrogen Sulphide	0	0.0001 - 5 (1 – 50,000 ppm)	0.0001 - 5 (1 – 50,000 ppm)	<.05 (0.001 – 500 ppm)	<0.00001 (1 – 500 ppb)
Total NMVOCs	<0.0001 (<1 ppm)	0 - >0.1 (0 - >1000 ppm)	0- >0.01 (0 - >100 ppm)	<1	<1

Table 2.4: Typical Parameters of LFG

LFG Parameter	*Value*
Density	
Methane[1]	0.72 kg/m³
Carbon Dioxide[1]	1.98 kg/m³
LFG [1,2]	1.35 kg/m³
Solubility	
Methane	35 mg/L at 17°C
Carbon Dioxide	1.45 g/L at 25°C
Energy Content[3]	
Methane	38 MJ/m³
LFG [2]	19 MJ/m³

NOTES:
- 1 - Assumes LFG is at standard temperature and pressure (0 degrees Celsius and 1 atmosphere)
- 2 - Assume a 50-50 CH_4/CO_2 mixture
- 3 - Gross heating values presented
- All values are approximate and subject to change according gas composition, temperature and pressure



Vznik a zloženie LFG

CHARACTERISTICS OF RAW LANDFILL GAS[1]

Compounds in LFG	Average[2]	Maximum[2]	Minimum[2]
Benzene	3,639	11,787	678
Chlorobenzene	597	4,102	74
Dichlorobenzene	1,842	5,682	308
1,1-Dichloroethane	1,684	5,100	353
1,2-Dichloroethane	250	1,547	23
1,1-Dichloroethylene	169	989	33
Dichloromethane	6,618	26,650	193
Perchloroethylene	1,974	5,160	702
Toluene	33,896	68,809	6,169
1,1,1-Trichloroethane	183	412	50
Trichloroethene	903	2,431	295
Vinyl Chloride	1,710	13,455	131
Xylene	20,228	46,380	7,166
Methane (ppm)	326,699	438,850	223,000

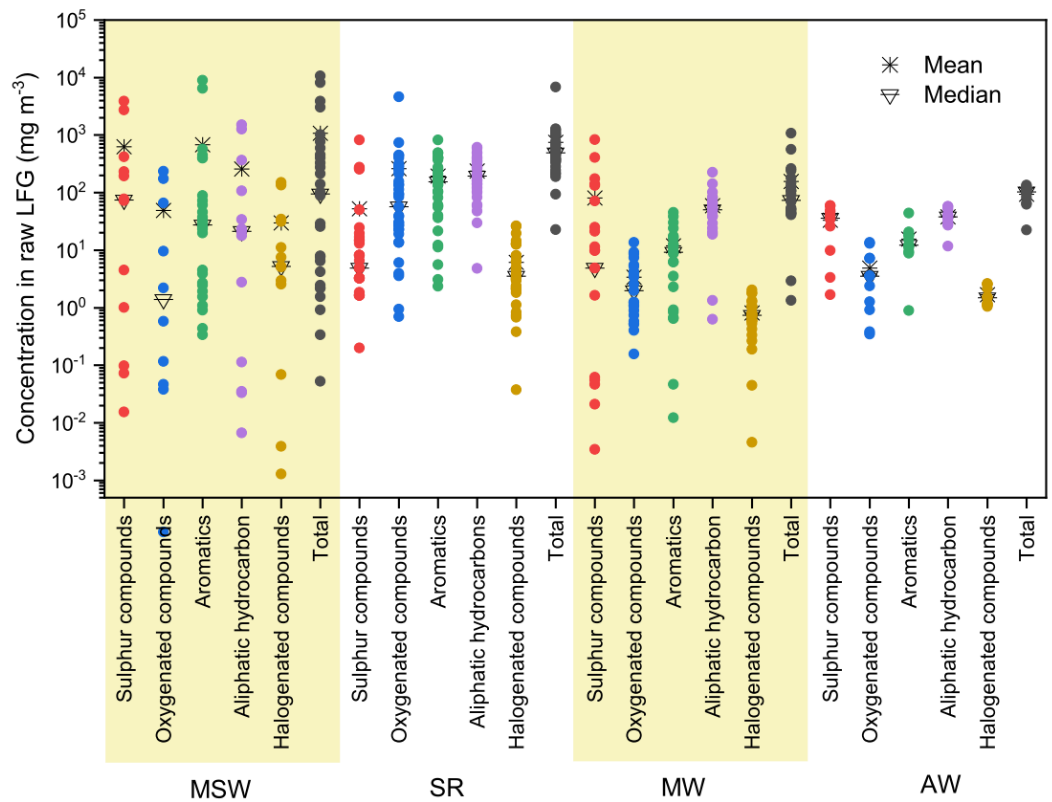


Figure 8. Trace gas concentrations in LFG at conventional MSW landfills (Paper **I**) and at different waste cells in Danish landfills. MSW: municipal solid waste cell; SR: shredder waste cell; MW: mixed waste cell; AW: aged waste cell. Adapted from Paper **III**.

Vznik a zloženie LFG

$$M_{NMOC} = 1.89x\,10^{-3}\,Q_{LFG}\,C_{NMOC}$$

where

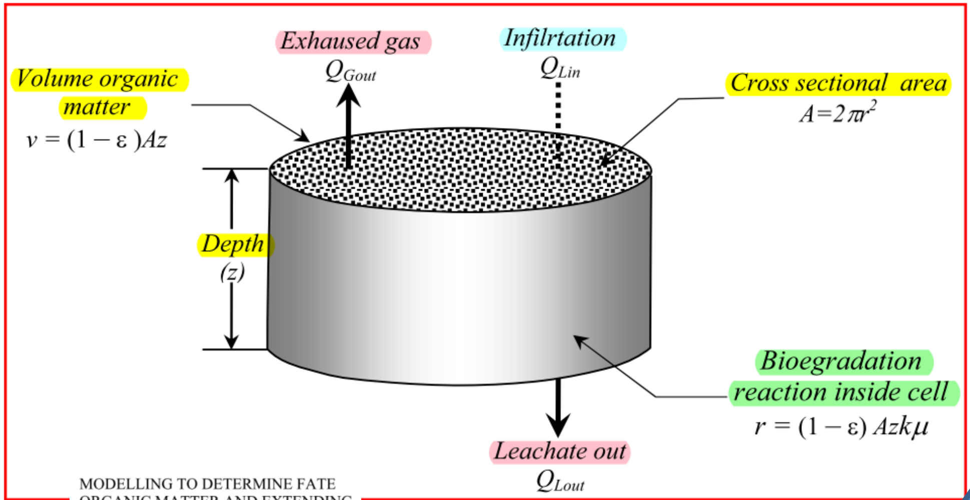
M_{NMOC} = mass emission rate of NMOC, megagrams per year

Q_{LFG} = flow rate of landfill gas, cubic meters per minute

C_{NMOC} =NMOC concentration, parts per million by volume as hexane

		PS-1		PS-2	
CH_4	%	30,7		32,4	
CO_2	%	22,6		25,6	
O_2	%	9,4		8,1	
balastny plyn:	%	37,3	ppm	33,9	ppm
Benzen	mg/Nm3	14,82	4,64	11,83	3,70
Toluen	mg/Nm3	4,64	1,23	4,50	1,19
o-Xylen	mg/Nm3	0,48	0,11	0,54	0,12
m,p-Xylen	mg/Nm3	0,99	0,23	1,09	0,25
Etylbenzén	mg/Nm3	0,67	0,15	0,71	0,16
Σ NMVOC	mg/Nm3	21,60	6,36	18,67	5,42

LFG zo skládok odpadov



MODELLING TO DETERMINE FATE ORGANIC MATTER AND EXTENDING MAINTENANCE PERIOD DUE TO "DO NOTHING" AFTER CAPPING MSW LANDFILL: CASE STUDY BREITENAU LANDFILL, AUSTRIA

E. MUNAWAR[1&2], J. FELLNER[1] AND P. H. BRUNNER[1]

[1] Institute for Water Quality, Resources and Waste Management, Vienna University of Technology, Vienna, Austria
[2] Chemical Engineering Department, Syiah Kuala University, Banda Aceh, Indonesia
Email: e.munawar@iwa.tuwien.ac.at

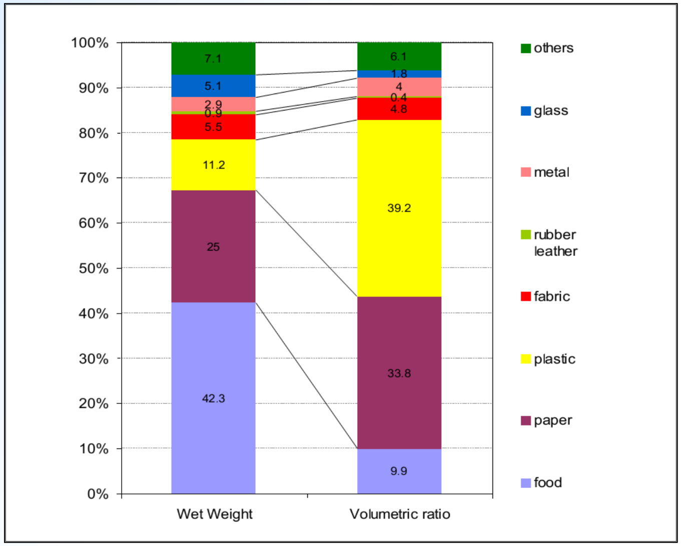


Table 1. Typical Viennese municipal solid waste composition distinguished by its degradability group (Neumayer, 1999)

Waste Composition	Fraction (% dry basis)	Degradability group	Composition (% dry basis)	
Paper and cardboard	14.7	Easily degradable	1.6	
		Slowly degradable	61.3	
		Non-degradable	37.1	
Biogenic waste (including kitchen and garden waste)	20.7	Easily degradable	54.9	12%
		Slowly degradable	35.3	
		Non-degradable	9.9	
Plastic	12.7	Non-degradable	99.9	
Food packaging	15.8	Easily degradable	1.2	
		Slowly degradable	46.1	27%
		Non-degradable	52.9	
Textile and Rubber	4.3	Easily degradable	5.1	
		Slowly degradable	52	
		Non-degradable	45	
Wood	1.3	Easily degradable	10.1	
		Slowly degradable	89	
		Non-degradable	0.9	
Glass	5.9	Non-degradable	100.0	
Metal	6.0	Non-degradable	100.0	
Residual waste	18.7	Non-degradable	100.0	
Total	100.0			

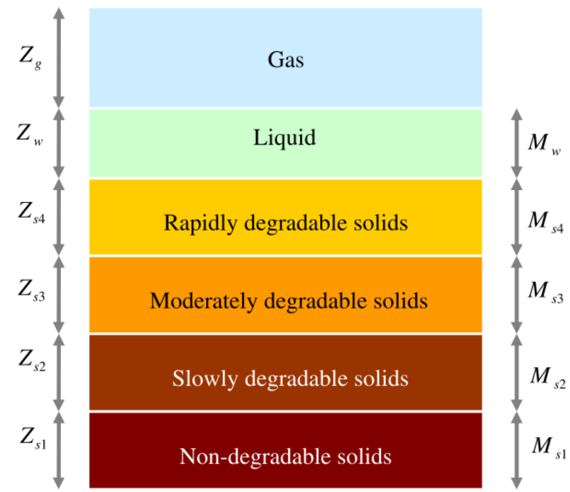


Fig. 1. Phase diagram for solid MSW.

% ≈ kg ≈ m^3

LFG zo skládok odpadov

“Dry Tomb” Landfills—The Past, Present, and Possibilities

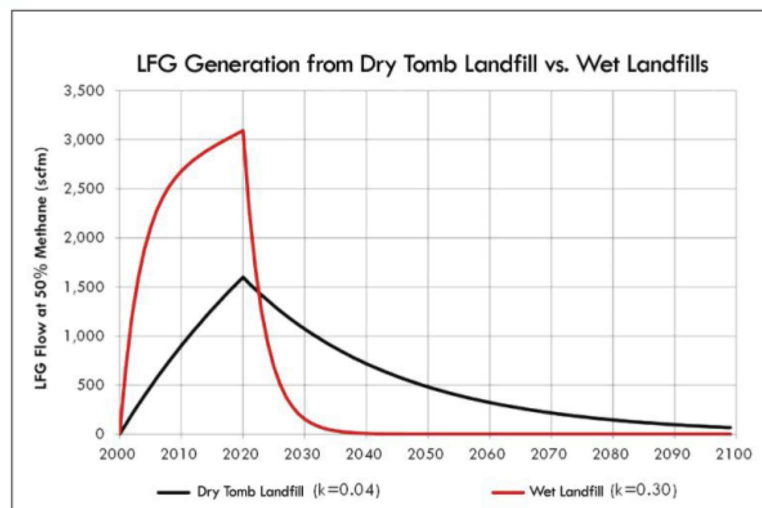
The implications of modern sanitary landfill technology has led to what are known as “dry tombs” and presents a few possible alternatives that have the potential to achieve the same results.

BY ROBERT H. ISENBERG AND DARRIN D. DILLAH

Noviny z roku 1989, 25 rokov v skládke v hĺbke 4,5 m – Švédsko, Lagringsytan.

Initial Waste Moisture Content (% wet)*----	15	20	25	30
Moisture Content Goal (% wet)	Max. Liquids Addition in Gallons/Ton			
30	52	34	17	0
40**	100	80	60	40
50	167	144	120	96

*Assume wet waste density = 1,200 pcy
**Approximate Field Capacity, F’c



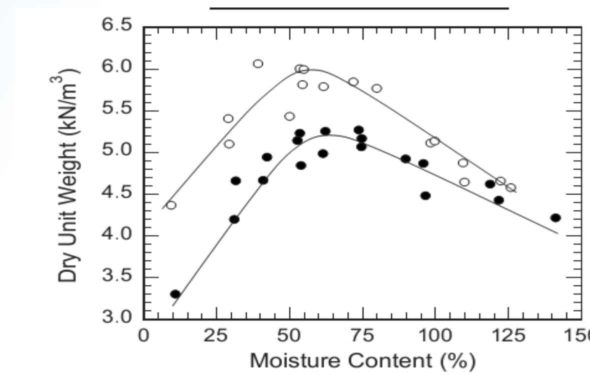
Optimal: 40% = 303 L/t (20%) resp. 151 L/t (30%)

LFG zo skládok odpadov

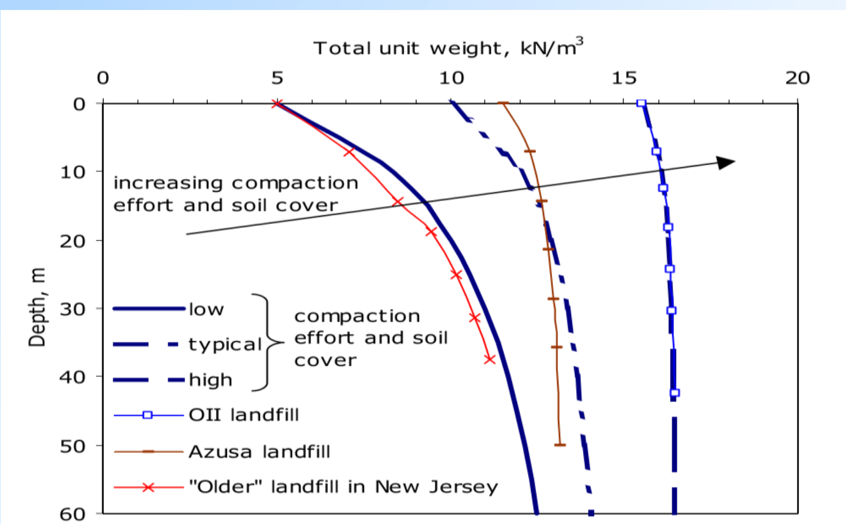
2-3 kN/m^3

Objemová hmotnosť MSW v nádobach	objem nádoby	váha odpadu	objem. hmotnosť	
	(m^3)	(kg)	(kg/m^3)	Ø
	0,11	15	136	175
		17	155	
		20	182	
		25	227	
	1,1	100	91	159
		150	136	
		200	182	
		250	227	

6-8,2 kN/m^3



9-10 kN/m^3

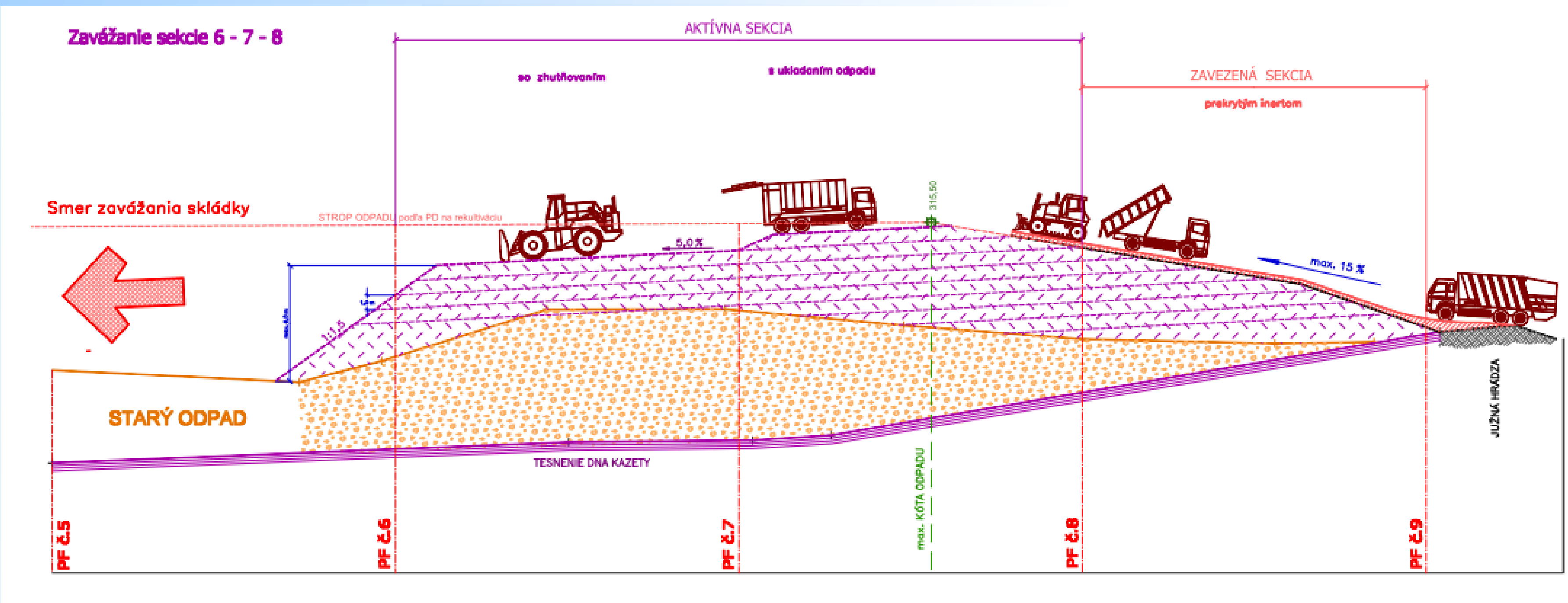


$$C_6H_{10}O_4 + 1.5H_2O \rightarrow 3.25CH_4 + 2.75CO_2$$

Optimal: 40% = 303 L/t (20%) resp. 151 L/t (30%)

Optimum moisture: methanogenesis = 60%

LFG zo skládok odpadov



LFG zo skládok odpadov

Photo 3: Vertical Landfill Gas Extraction Well Drilling and Installation

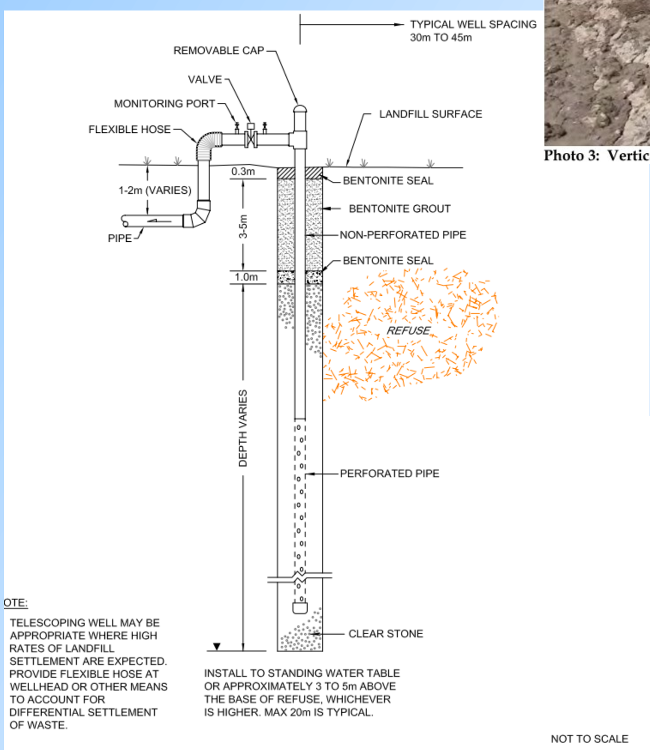
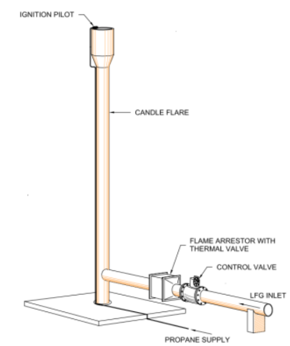
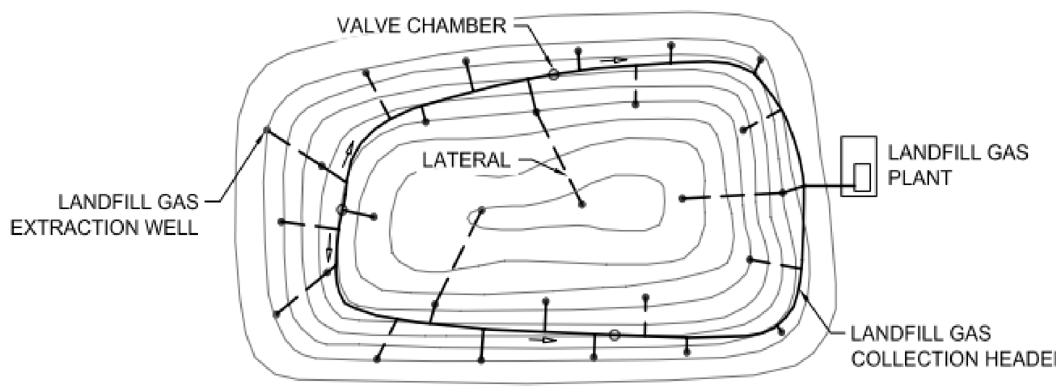
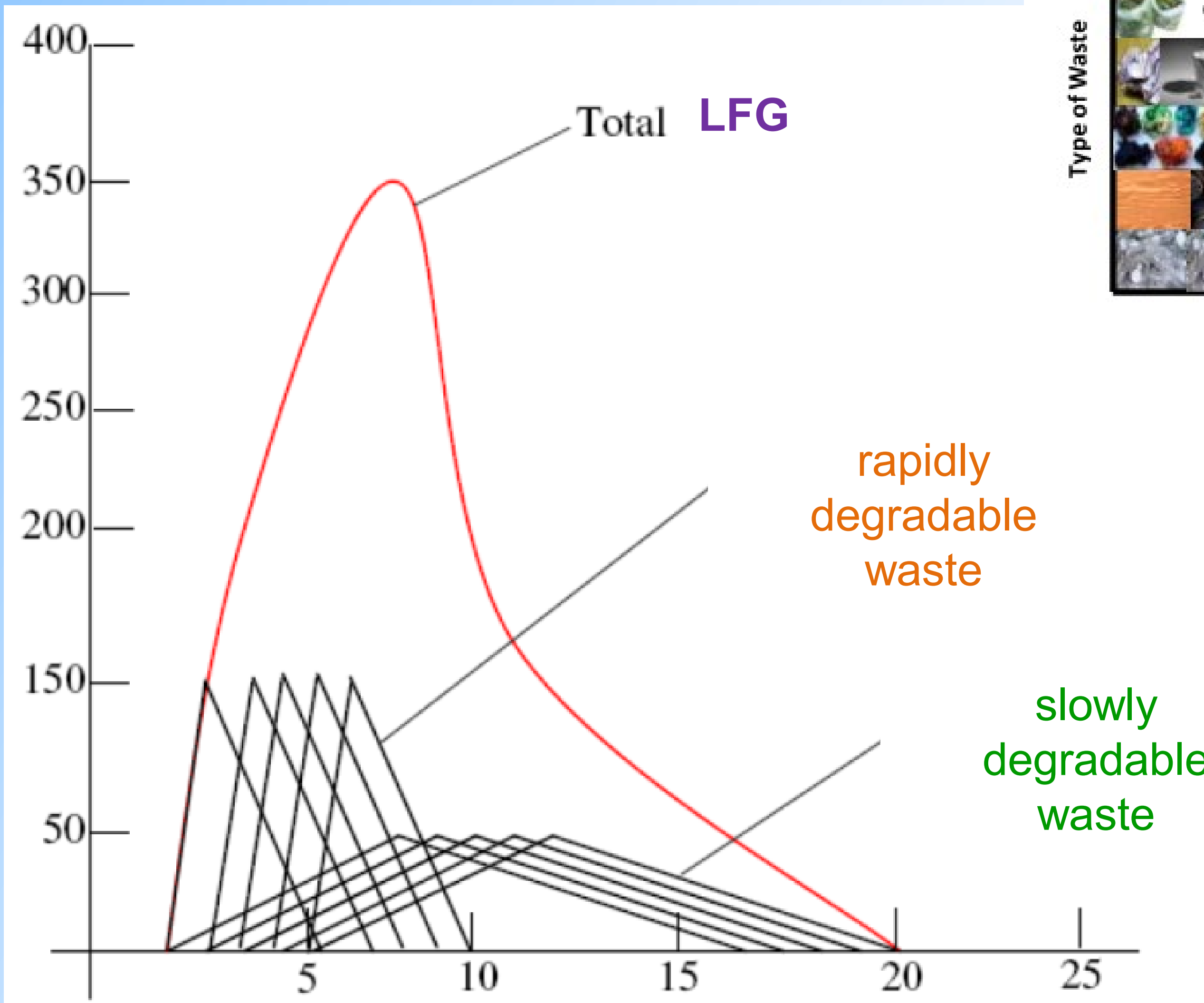


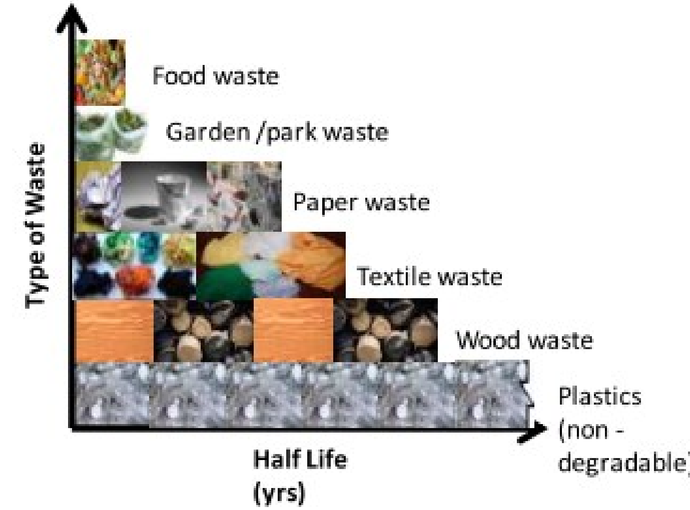
figure 5.1
VERTICAL EXTRACTION WELL, ABOVE GROUND (TYPICAL)



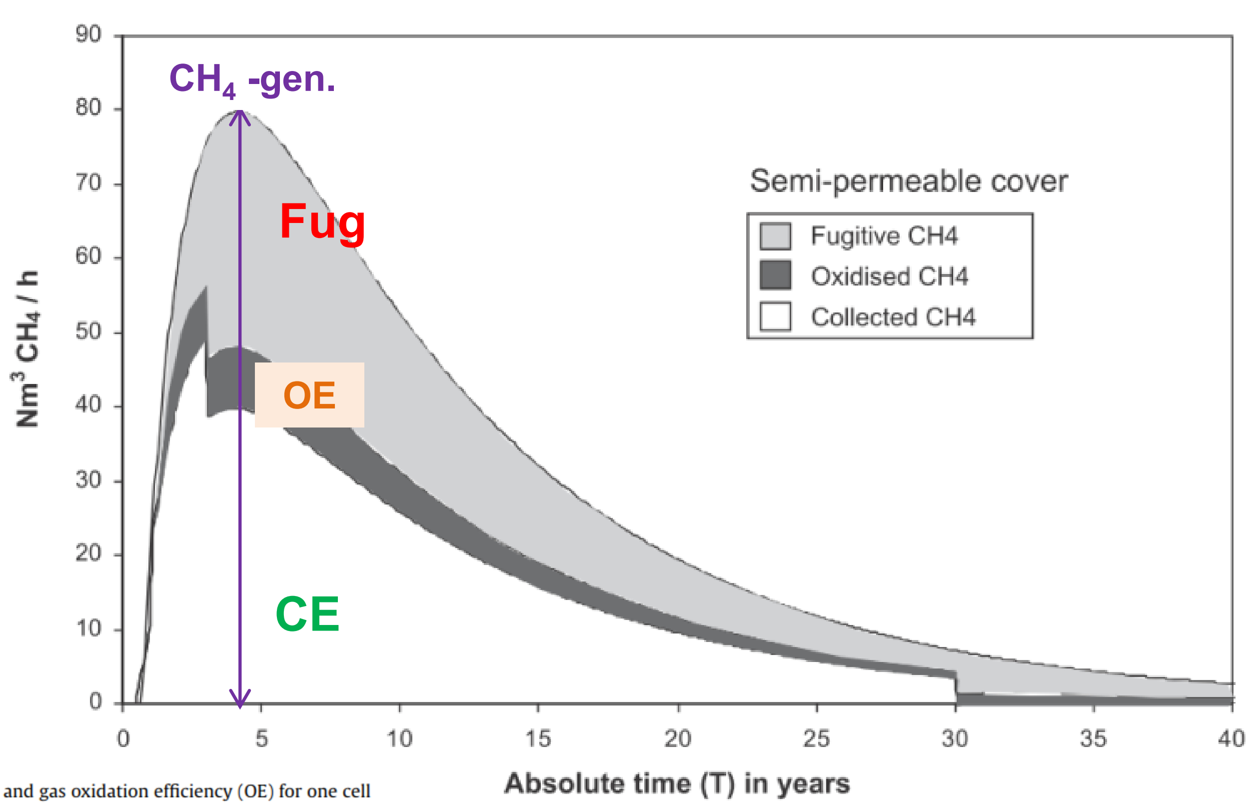


LFG zo skládok odpadov





LFG zo skládok odpadov



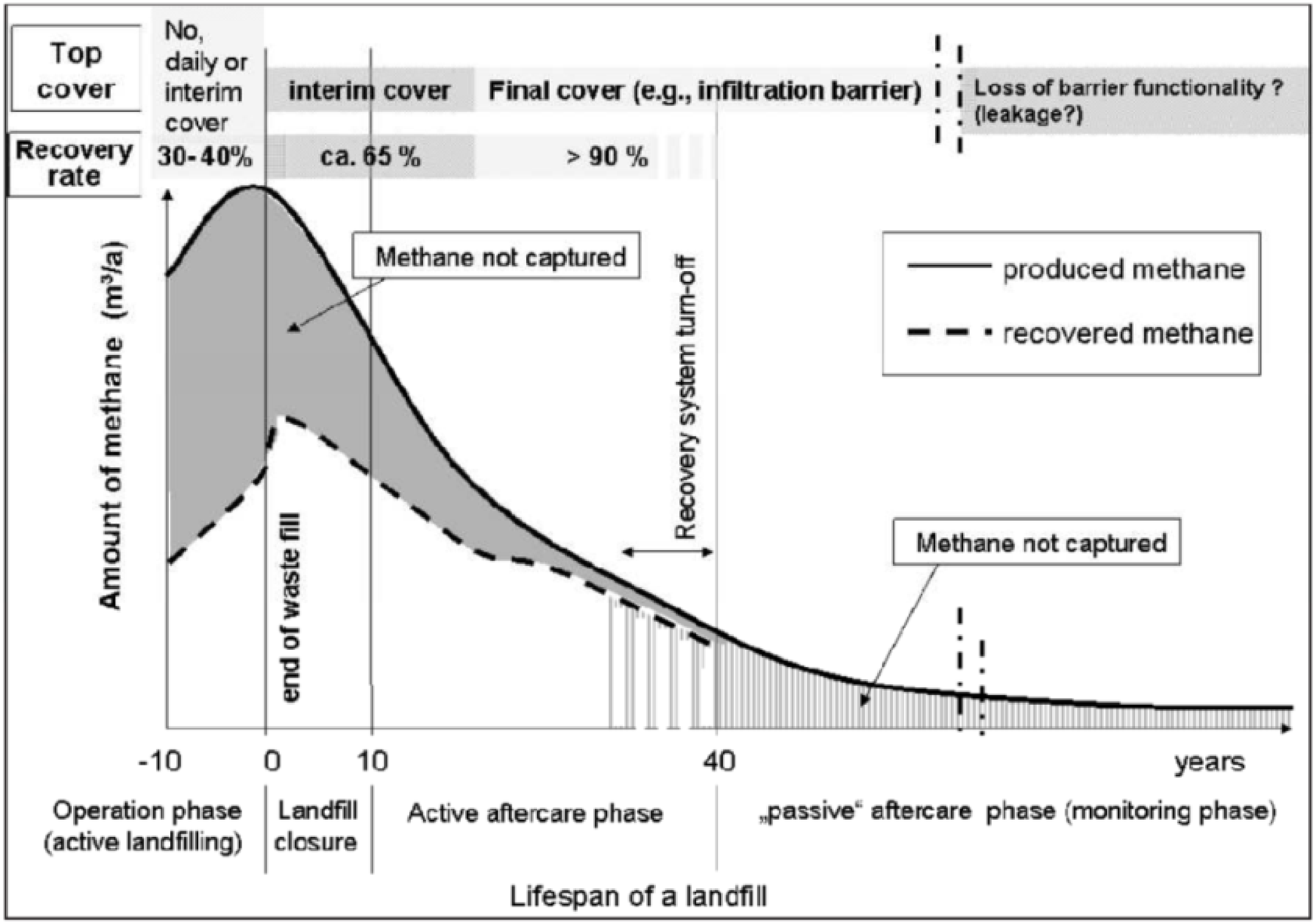
Steps for gas collection efficiency (CE) and gas oxidation efficiency (OE) for one cell in the different scenarios.

Steps	A	B	C	D
Period	Operation	Post-operation	Aftercare	Custodial care
Time of completion	t_c	$t_c + 2$ years	$t_c + 30$ years	100 years
Landfill with semi-permeable cap cover				
Cover type	None	Permanent semi-permeable	Permanent semi-permeable	Final
CE	$CE_A = 35\%$	$CE_B = 65\%$	$CE_C{}^a = 50\%$	$CE_D = 0\%$
OE	$OE_A = 0\%$	$OE_B = 20\%$	$OE_C = 20\%$	$OE_D = 30\%$
Landfill with impermeable cap cover				
Cover type	None	Temporary	Permanent impermeable	Final
CE	$CE_A = 35\%$	$CE_B = 65\%$	$CE_C{}^a = 90\%$	$CE_D = 0\%$
OE	$OE_A = 0\%$	$OE_B = 0\%$	$OE_C = 10\%$	$OE_D = 60\%$

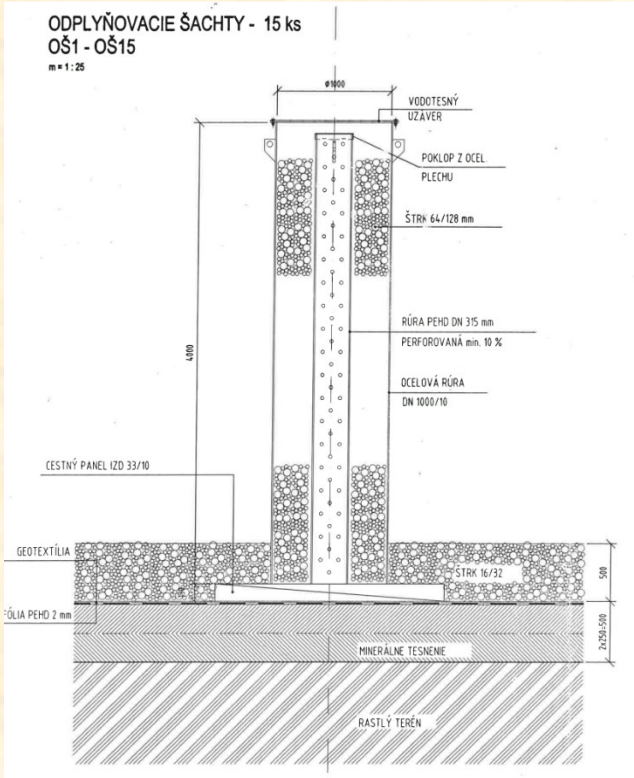
Collection Efficiency

- Daily cover only – 67%
- Intermediate cover – 75 %
- Engineered final soil – 87%
- Geomembrane – 90%

LFG zo skládok odpadov



LFG meranie a zachytávanie

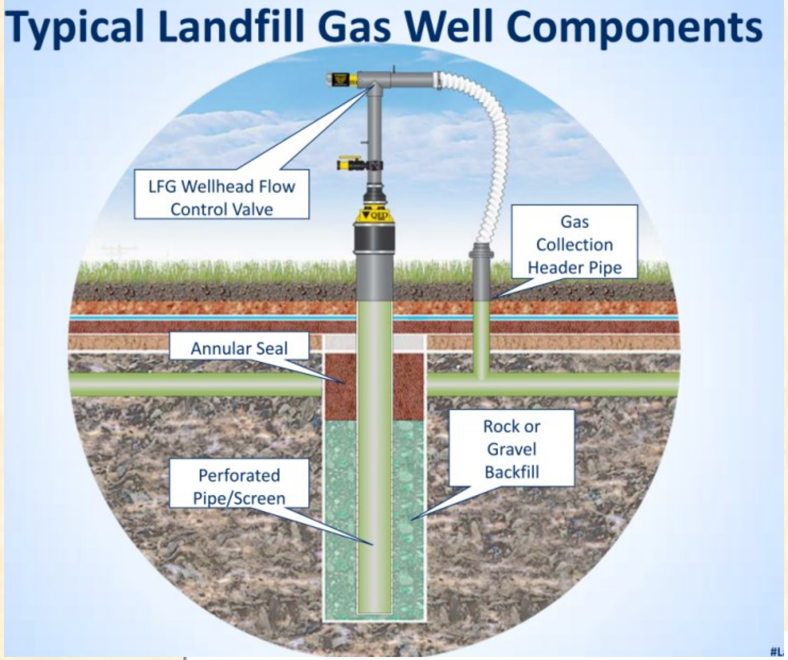


LFG studne zo dna skládky

LFG / Metán - špecifika meraní:

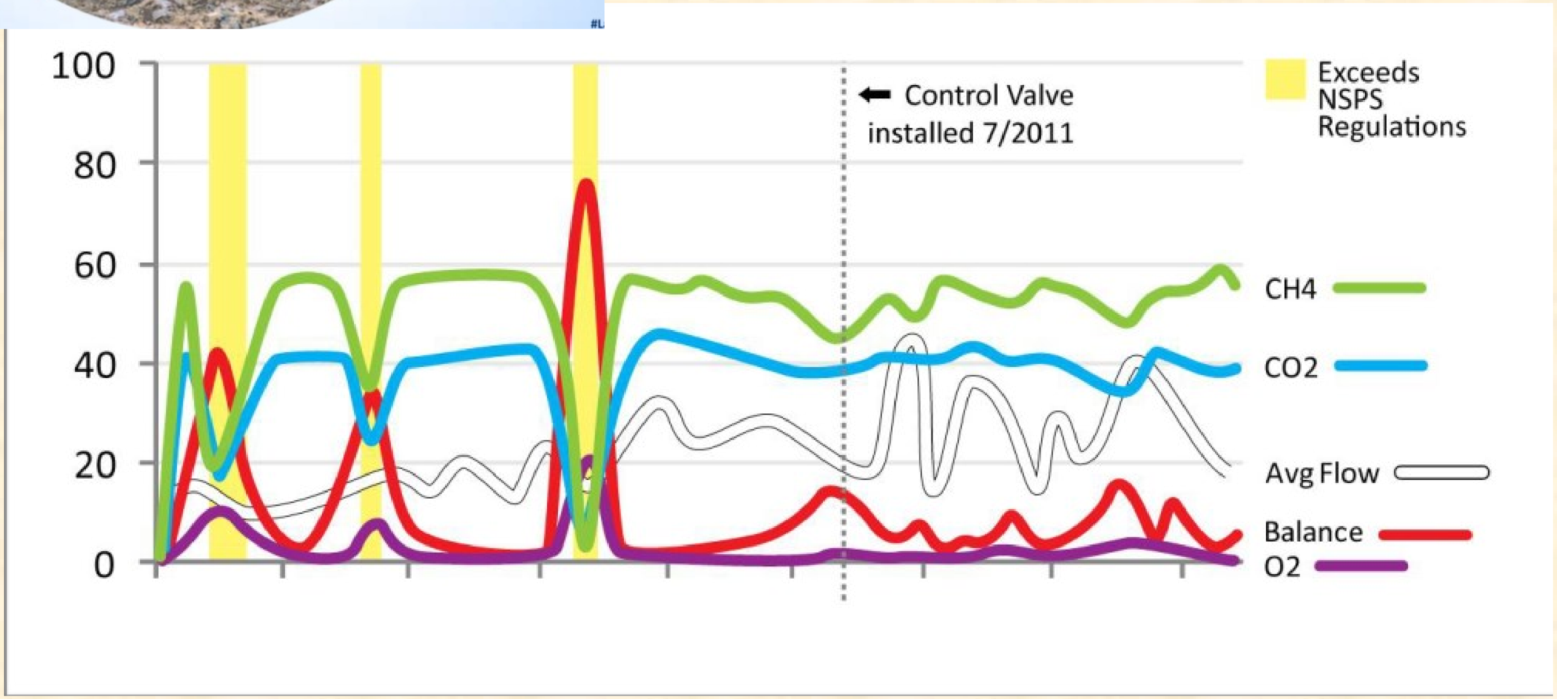
Zachytený LFG:

LFG meranie a zachytávanie



LFG (%)

LFG (m3/h)



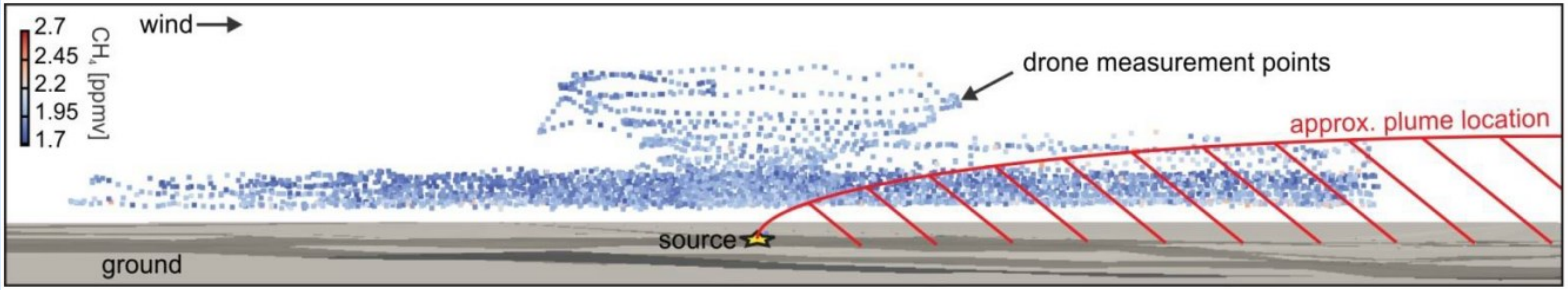
LFG meranie a zachytávanie

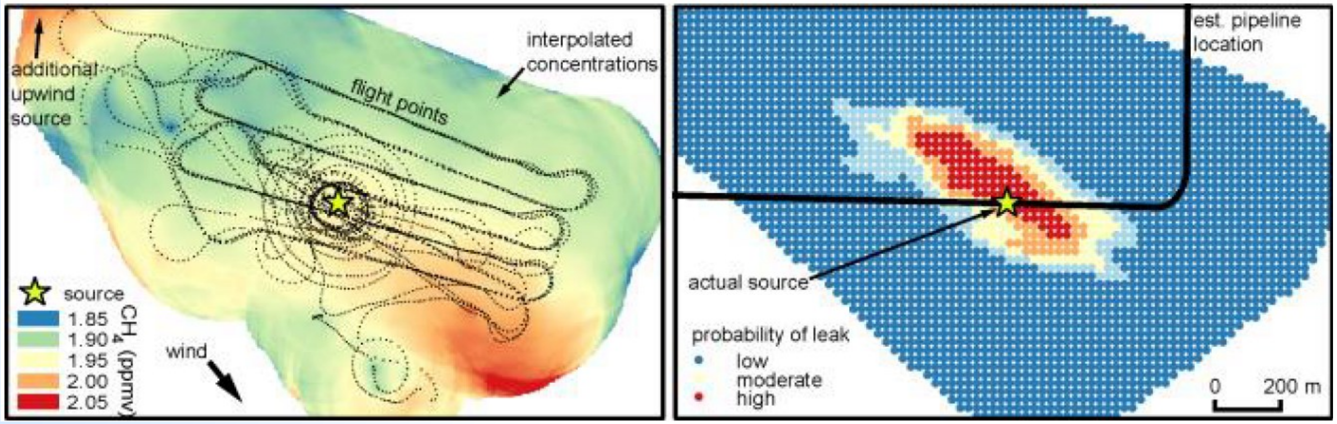
- meranie in situ.

A Drone in Search of Methane

Table 1. Detection limits and expected ranges of selected trace atmospheric gases.

Trace Atmospheric Gas of Interest	Useful Detection Limit	Expected Range
Ozone	10 ppbv	0–150 ppbv
Carbon monoxide	100 ppbv	0–300 ppbv
Carbon dioxide	100 ppmv	350–600 ppmv
Nitrogen dioxide	10 ppbv	0–50 ppbv
Sulfur dioxide	10 ppbv	0–100 ppbv
Methane	500 ppbv	1500–2000 ppbv
VOCs	1 μg m^{-3}	5–100 μg m^{-3} (total)

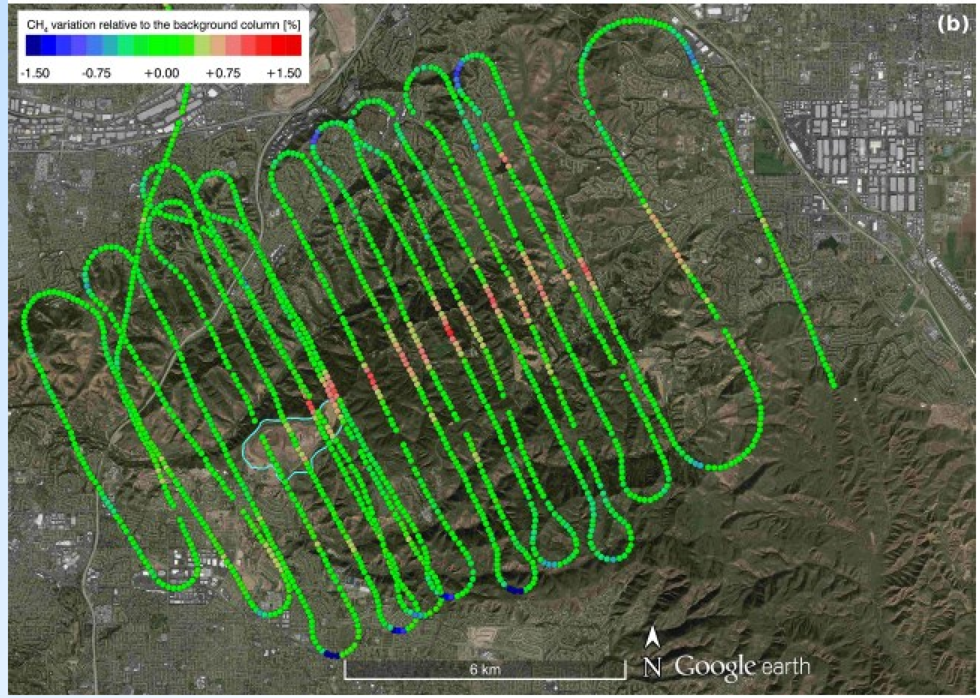


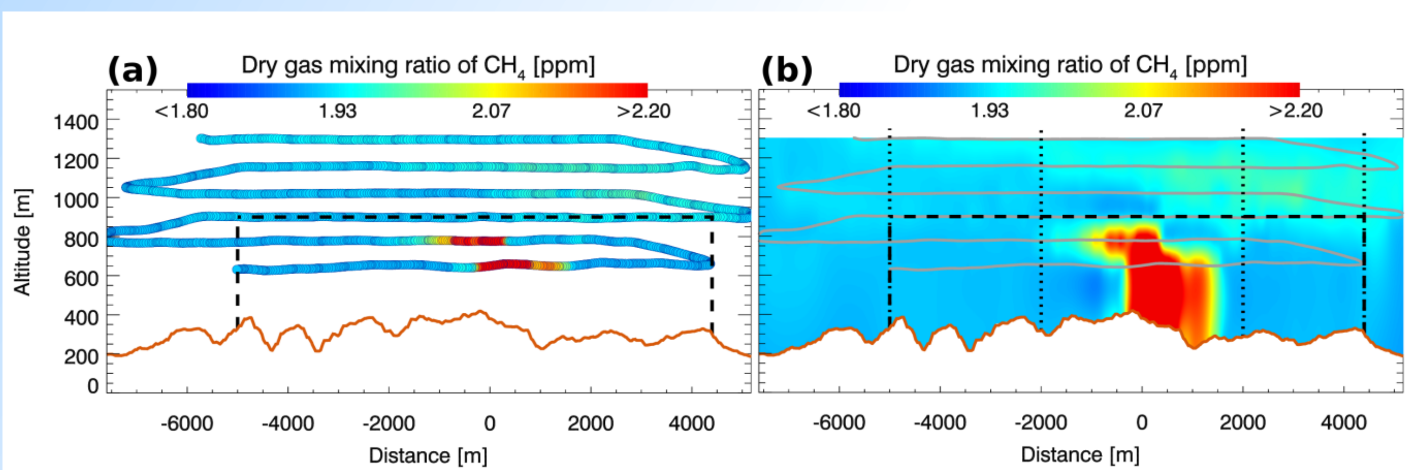


LFG meranie a zachytávanie

Methane emissions from a Californian landfill, determined from airborne remote sensing and in-situ measurements

Sven Krautwurst[1], Konstantin Gerilowski[1], Haflidi H. Jonsson[2], David R. Thompson[3], Richard W. Kolyer[4], Andrew K. Thorpe[3], Markus Horstjann[1], Michael Eastwood[3], Ira Leifer[5], Sam Vigil[6], Thomas Krings[1], Jakob Borchardt[1], Michael Buchwitz[1], Matthew M. Fladeland[4], John P. Burrows[1], and Heinrich Bovensmann[1]





LFG meranie a zachytávanie

Fugitive methane :

CH_4 = OK (ppm) CH_4 = ??? ($L/s/m^2$)

LFG meranie a zachytávanie

Several field measurement methods are used to estimate methane emissions from the surface of a landfill:

- Vertical radial plume mapping (VRPM)
- Tracer gas correlation
- Flux chamber
- Micrometeorological
- Differential absorption LiDAR (DIAL).

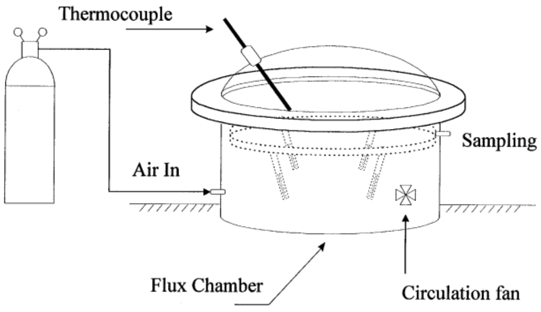


Fig. 2. Schematic diagrams of flux chamber system.

$$F_{net}(t) = \frac{dc}{dt}(t)\ \frac{pV}{RTA}$$

CH_4 = OK (L/s/m^2)

5. LFG / Metán - špecifika meraní: LFG sondy

1. Collect Sample(s) of LFG
- Surface probe samples (geoprobe)
- Existing passive or active gas system

- Qualifying samples must have:
  - Oxygen less than 5%, and
  - Balance gas less than 20%

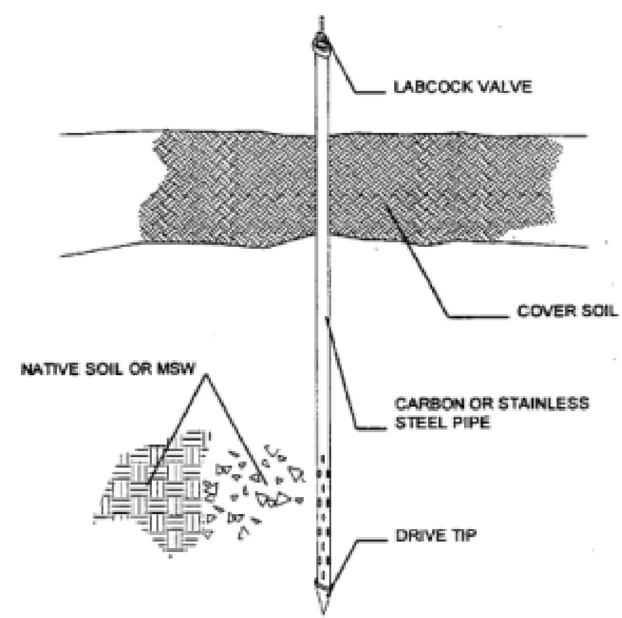
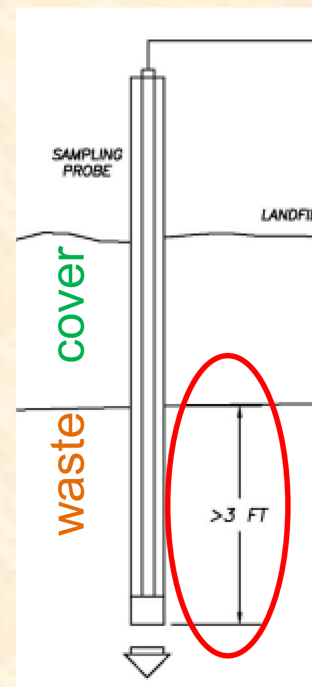
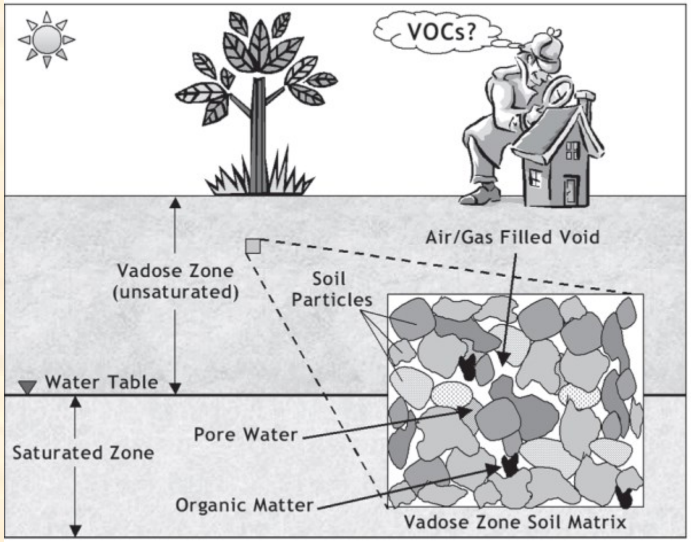


Figure 6.3
Typical Driven Gas Probe



LFG / NMVOC - špecifika meraní: LFG sondy !!!



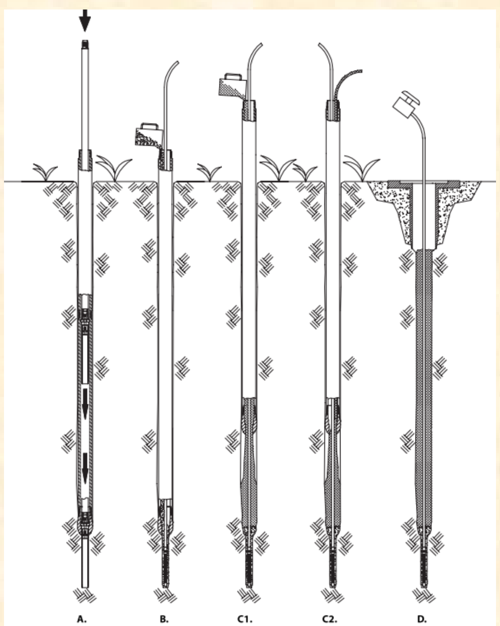


Figure 11: Installation of single-level implants for soil gas monitoring with the DT21 system.

Downhole Sampling System		Sample Collection Method			
		Syringe	Tedlar Bag	Glass Bulb	Summa Canister
	Increasing Quality				
Direct Sampling		*Low / Low*			*Low / High*
PRT System					
Implants					
Gas Wells		*High / Low*			*High / High*

LFG / Metán – „kauza studne“

Označenie sondy:	Ø CH_4 - dno (%)	Ø CH_4 - ústie (%)	Celková hrúbka odpadu: (m)
Oš 1	34,8	14,0	20,9
Oš 7	34,5	4,7	17,2
Oš 4	31,5	7,3	16,8
Oš 8	23,8	13,5	21,3
Oš14	23,3	1,8	22,0
Oš13	20,9	3,3	21,7
Oš11	19,8	16,3	23,0
Oš 3	17,0	6,0	19,3
Oš 2	13,5	10,8	21,4
Oš15	5,0	3,7	20,7
Oš 5	4,5	3,2	16,5
Oš10	3,1	0,5	12,6
Oš12	1,5	0,8	9,5
Oš 9	1,3	1,2	10,3
Oš 6	0,9	2,0	6,8

QA/QC Check

- <5% O_2 or <20% N_2

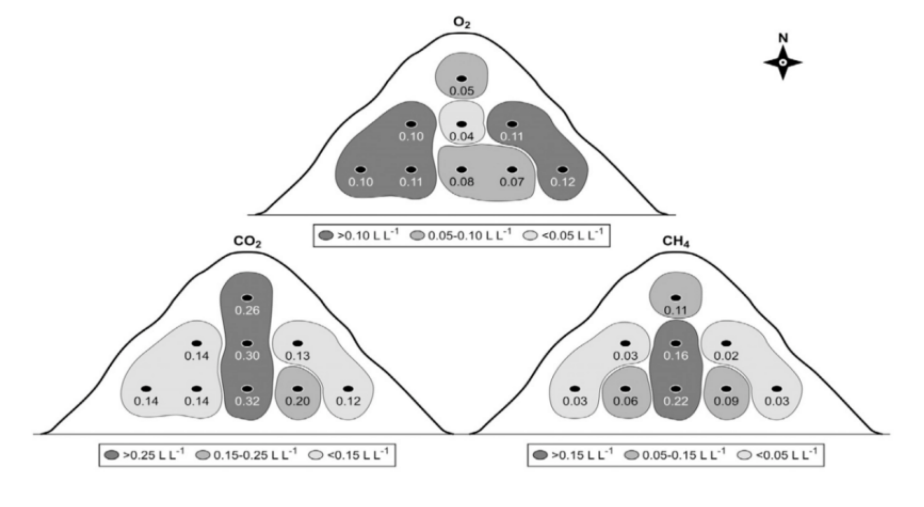
LFG = ako ho meriame ?

	CH_4	CO_2	O_2	balance gas
ZS-1	**57,0%**	42,8%	**0,1%**	**0,1%**
ZS-2	**57,0%**	42,6%	**0,1%**	**0,3%**
PS-3	**34,2%**	27,4%	**6,0%**	**32,4%**
PS-4	**43,4%**	33,0%	**4,6%**	**19,0%**

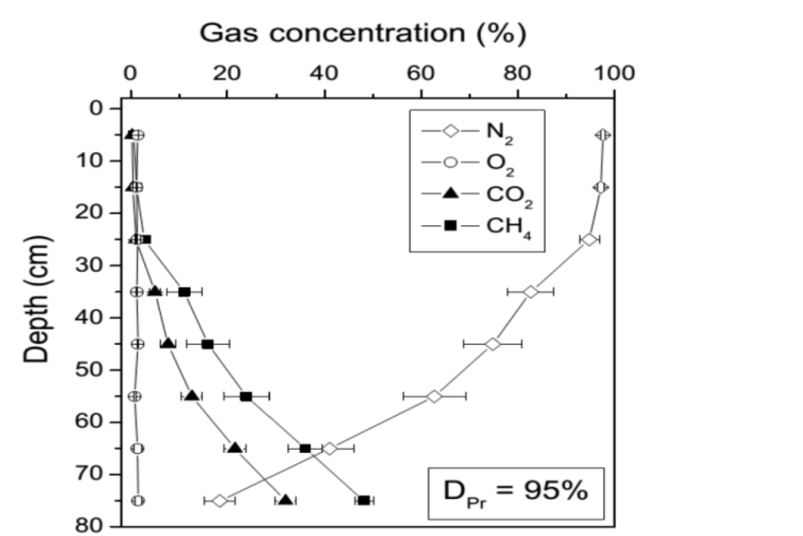
QA/QC Check

- <5% O_2 or <20% N_2

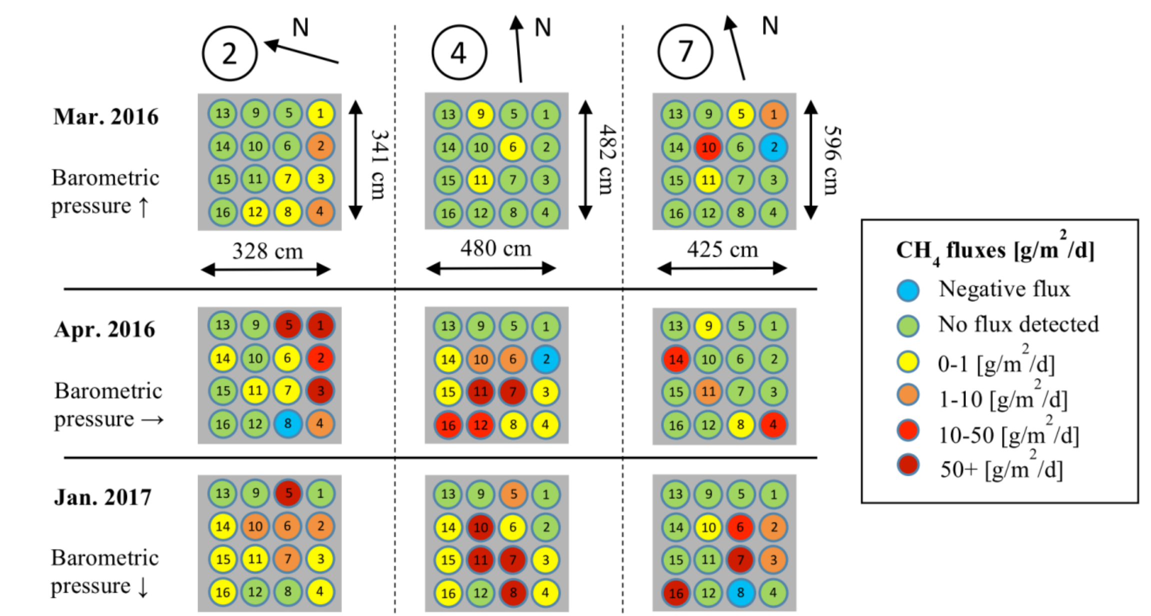
LFG = kde ho meriame ?

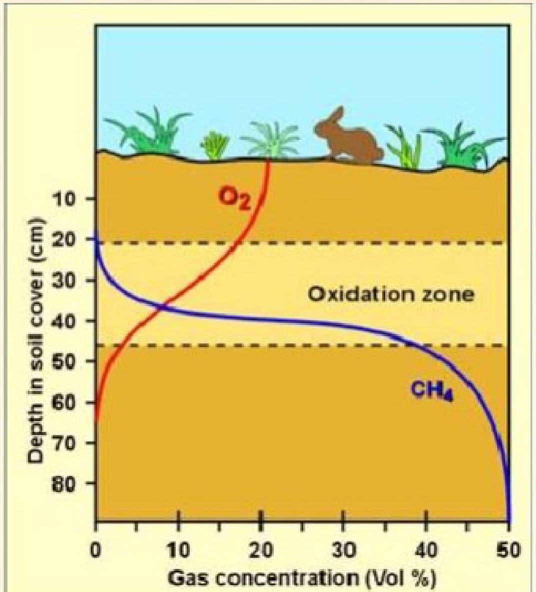


Obrázok 1:Distribúcia plynov vznikajúcich rozkladom organickej hmoty v komposte. Vek kompostu 243 dní, šírka hromady: 9 m, výška hromady: 4 m. (Andersen. 2010)

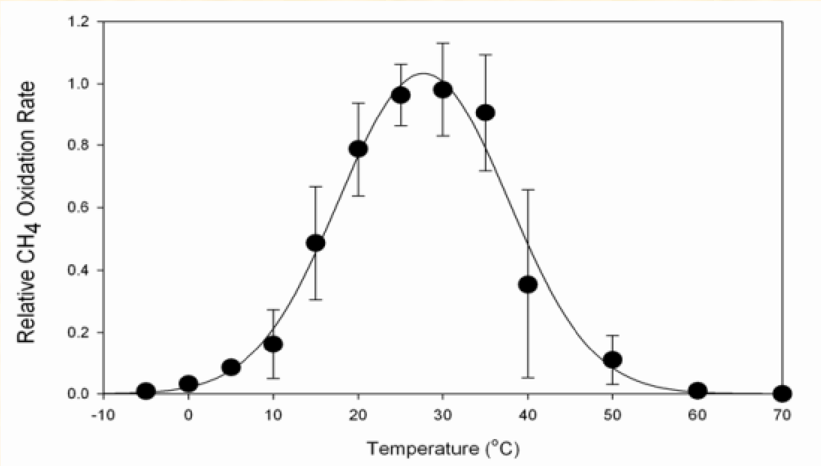


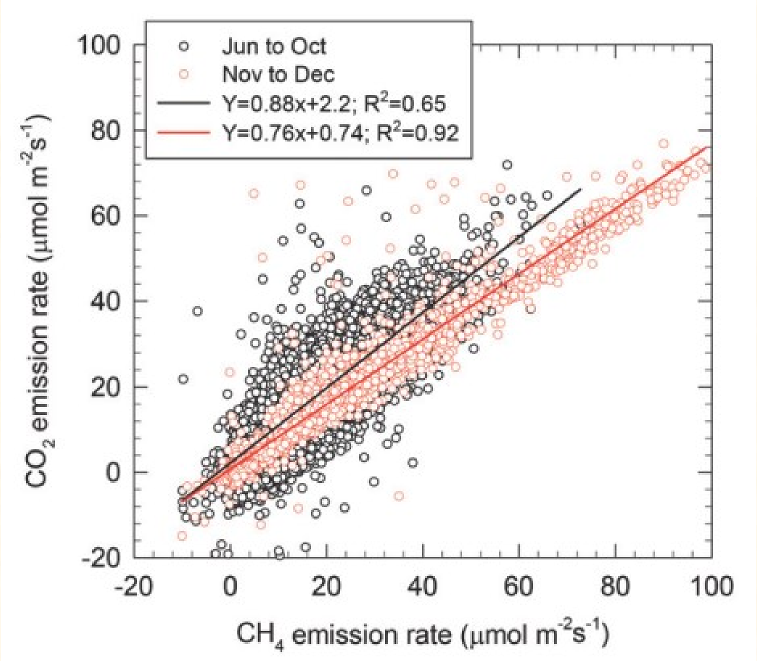
Obrázok 2: Zmena zloženia LFG v závislosti od hĺbky merania plynu. (Gebert 2012)





LFG = kedy ho meriame ?





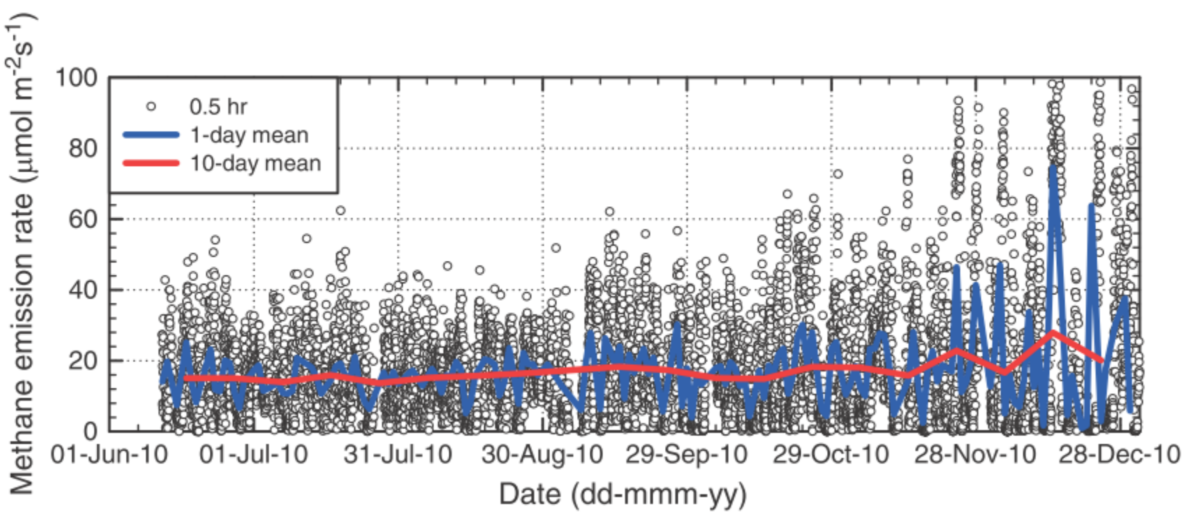


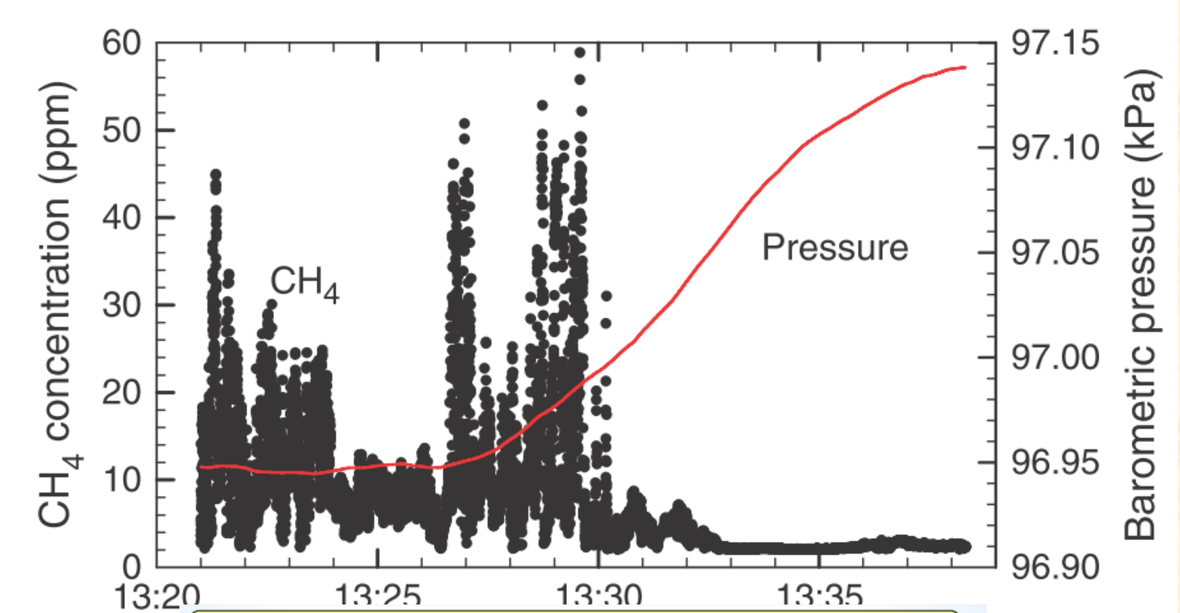
Figure 5. Seasonal variations in hourly methane emission rate (open black circles), 1 day mean (solid blue line), and 10 day mean (solid red line) methane emission rate over the experiment period. The mean methane emission over the entire experiment was 17.7 μmol m^{-2} s^{-1}.

LFG = kedy ho meriame ?

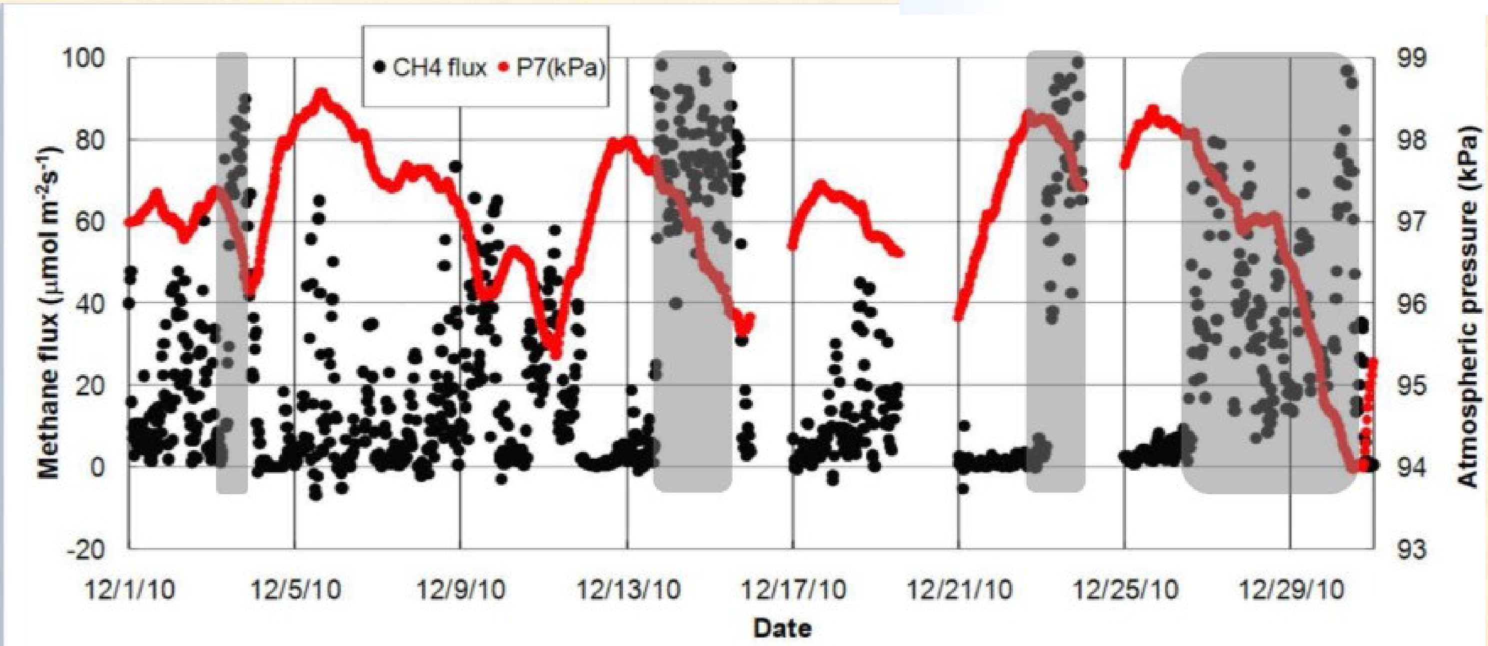
Liukang Xu, Xiaomao Lin, Jim Amen, Dayle McDermitt
LI-COR Biosciences, Lincoln NE 68504 USA

Karla Welding
City of Lincoln, Lincoln NE 68517 USA

Impact of Changes in Barometric Pressure on Landfill Methane Emission



Fast pressure increases can almost stop CH_4 emission.

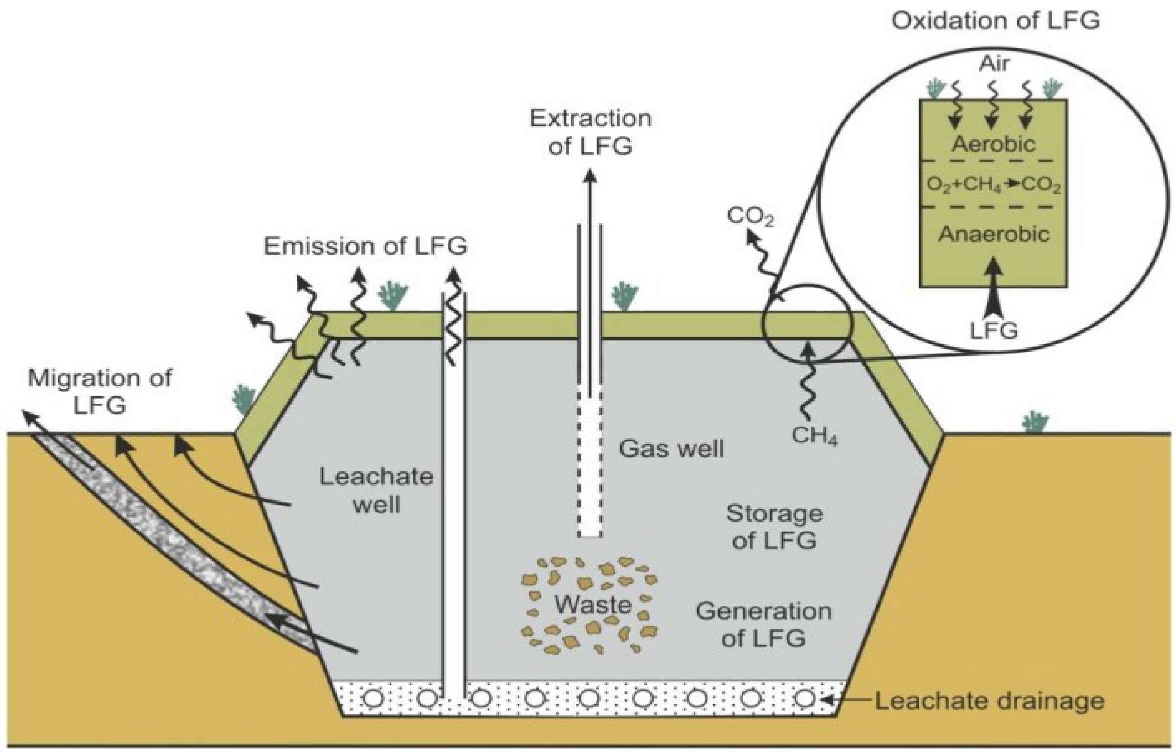


KAŽDÝ DEŇ S VAMI

Koncepčný model LFG

Emisie metánu zo skládky (zdroj Kjeldsen, P. 2015)

$$CH_{4,\ generated} = CH_{4,\ extracted} + CH_{4,\ emitted} + CH_{4,\ migrated} + CH_{4,\ oxidized} + CH_{4,\ stored}$$



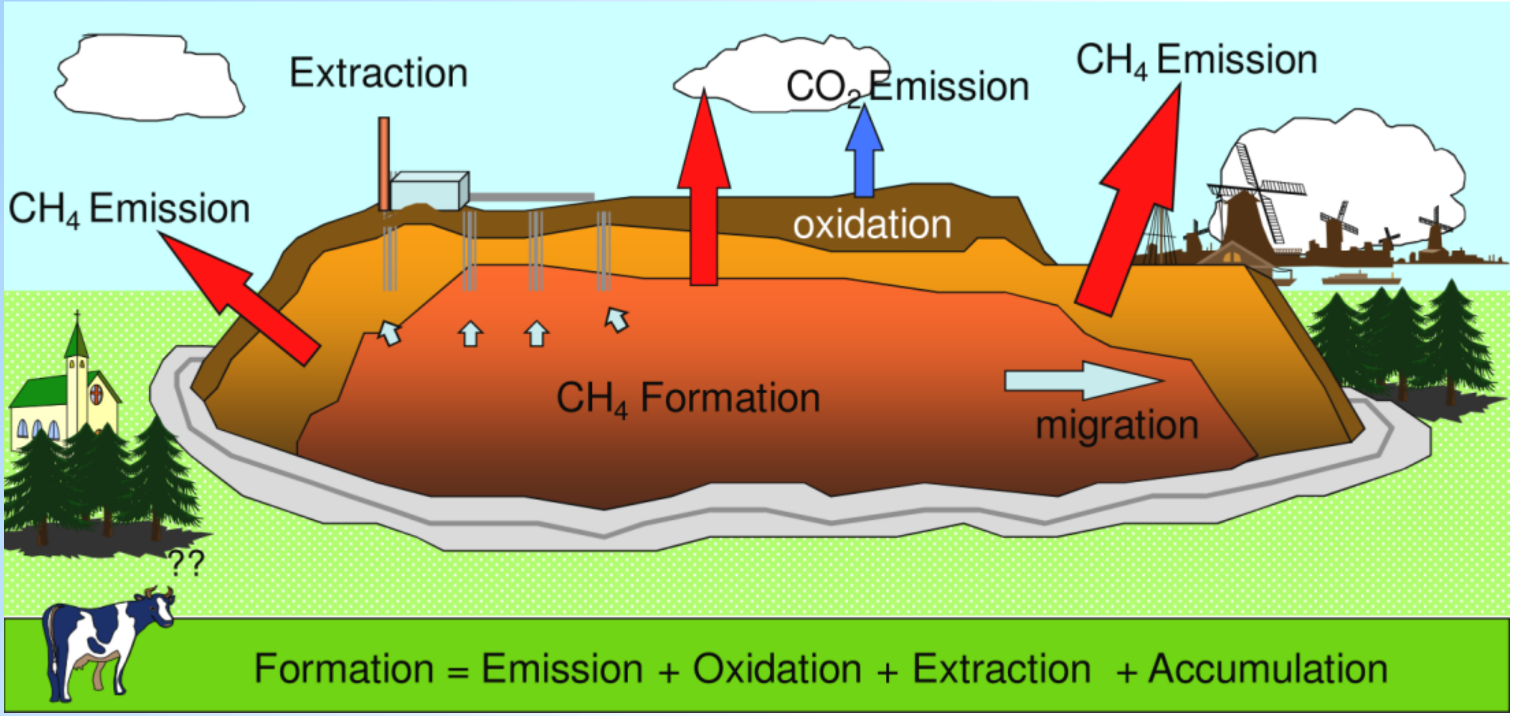
Building a better methane generation model: Validating models with methane recovery rates from 35 Canadian landfills

Shirley Thompson [a,*], Jennifer Sawyer [b], Rathan Bonam [a], J.E. Valdivia [a]

[a] Natural Resources Institute, University of Manitoba, 70 Dysart Rd., Winnipeg, Manitoba, Canada R3T 2N2
[b] Faculty of Environment, Earth and Resources, University of Manitoba, 440 Wallace Building, Winnipeg, Manitoba, Canada R3T 2N2

Koncepčný model LFG

Emisie metánu zo skládky (zdroj: Scharff, H. / Kjeldsen, P.)



!!!

J. Dairy Sci. 101:6655–6674
https://doi.org/10.3168/jds.2017-13536

Symposium review: **Uncertainties in enteric methane inventories, measurement techniques, and prediction models**[1]

A. N. Hristov,*[2] E. Kebreab,† M. Niu,† J. Oh,* A. Bannink,‡ A. R. Bayat,§ T. M. Boland,# A. F. Brito,‖
D. P. Casper,¶ L. A. Crompton,$ J. Dijkstra,€ M. Eugène,¥ P. C. Garnsworthy,** N. Haque,††
A. L. F. Hellwing,‡‡ P. Huhtanen,§§ M. Kreuzer,## B. Kuhla,‖‖ P. Lund,‡‡ J. Madsen,†† C. Martin,¥
P. J. Moate,¶¶ S. Muetzel,$$ C. Muñoz,€€ N. Peiren,¥¥ J. M. Powell,*** C. K. Reynolds,$ A. Schwarm,##
K. J. Shingfield,†††[3] T. M. Storlien,‡‡‡ M. R. Weisbjerg,‡‡ D. R. Yáñez-Ruiz,§§§ and Z. Yu###

Ako určiť fugitívne emisie zo skládky ?

ISWA/UNEP Workshop on GHG and SLCP Emission Quantification Methodologies

September 19-20, 2013 Paris

Workshop Report

ISWA International Solid Waste Association UNEP

Fugitive CH_4 emissions are then calculated as follows:

Potential CH4 release = CH_4 generation as of theoretical model - effectively captured CH_4

G R ? 0 ≈10%

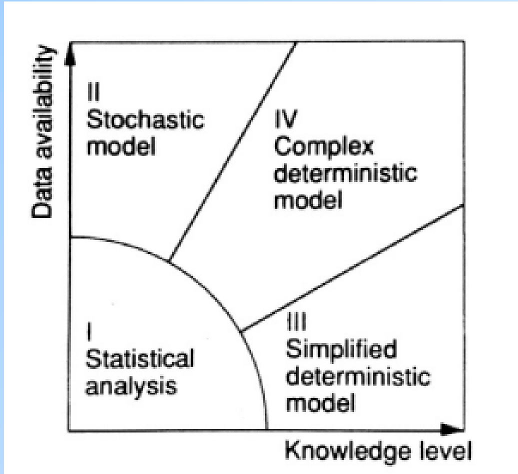
$$CH_{4,\ generated} = CH_{4,\ extracted} + CH_{4,\ emitted} + CH_{4,\ migrated} + CH_{4,\ oxidized} + CH_{4,\ stored}$$

CH4em = (G-R) *0,9

Modely výpočtu generovaného metánu zo skládok.

KAŽDÝ DEŇ S VAMI

G=



1 Introduction

At the 13th Article 19 meeting in Luxembourg in November 2003 Germany agreed to compose a supporting document on the methodologies for determination of diffuse emissions from landfill sites for the European Pollutant Emission Register (EPER). Member States were requested to submit any information on methodologies they use or are planning to use before 12 March 2004. Nine Member States answered[1] in different ways.

The methodologies of eight Member States are listed in the table in chapter 3.

Belgium	- first order decay model to take into account the various factors which influence the rate and extent of methane generation and release from landfill - the overall methodology follows the *Tier 2 IPCC* methodology (equation 5.1, IPCC GPG) $S_{P,Y} = Q_Y * DOC * k * C * \exp^{(-k * \Delta t)}$ where : $S_{P,Y}$ = biogas generation rate at year P (m^3) Q_Y = the quantity of waste disposed year Y (Mg) DOC = initial degradable organic carbon (kg/Mg) k = biodegradation rate constant (% / yr) C = % of DOC really degraded (%) Δt = the time since initial disposal (Y-P) (yr) - recovered methane is subtracted from total emissions

Ireland	*LandGem (USEPA)* - simple first order decay equation which needs the following information: ○ the design capacity of the landfill, ○ the amount of refuse in place in the landfill, or the annual refuse acceptance rate for the landfill, ○ the methane generation rate (k), ○ the potential methane generation capacity (L_o), ○ the concentration of total non-methane organic compounds (NMOC) and speciated NMOC found in the landfill gas, ○ the years the landfill has been in operation, and ○ whether the landfill has been used for disposal of hazardous waste (co-disposal).

Nether-lands	*TNO – First order model* - landfill gas formation in a certain amount of waste is assumed to decay exponentially in time $\alpha_t = \varsigma 1.87 A C_0 k_1 e^{-k_1 t}$ where: α_t = landfill gas formation at a certain time [m^3/yr] ς = dissimilation factor [-] A = amount of waste in place [Mg] C_o = amount of organic carbon in waste [kg/Mg waste] k_1 = model parameter first order model [yr^{-1}] t = time elapsed since depositing [yr] *Afvalzorg – Multi phase model* - takes into account typical fractions of slow, moderate and fast degadables $\alpha_t = \varsigma \sum_{j=1}^{3} 1.87 A C_{0,i} k_{1,i} e^{-k_{1,i} t}$ For both models: recoverd and oxidised methane is substracted from total emissions

United Kingdom	*GasSimLite, Realease 1.01* - multi-phase, first order decay equation $C_t = C_0 - (C_{0,1} e^{(-k_1 t)} + C_{0,2} e^{(-k_2 t)} + C_{0,3} e^{(-k_3 t)})$ And $C_x = C_t - C_{t-1}$ where: C_t = mass of degradable carbon degraded up to time t (Mg) C_0 = mass of degradable carbon at time t = 0 (Mg) $C_{o,i}$ = mass of degradable carbon at time t = 0 in each fraction (1, 2, 3, rapidly, moderately and slowly degradable fractions respectively) (Mg) C_x = mass of carbon degraded in year t (Mg) t = time between waste emplacement and LFG generation (yrs) k_i = degradation rate constant for each fraction of degradable carbon (per yr)

KAŽDÝ DEŇ S VAMI

Modely výpočtu generovaného metánu zo skládok.

JACOBS, J.; SCHARFF, H.: Comparison of methane emission models to methane emission measurements. NV Afvalzorg

- First order model (TNO) (Oonk and Boom, 1995).
- Multi-phase model (Afvalzorg, developed in 1996).
- LandGEM (US-EPA) (US-EPA, 2001).
- GasSim (Environment Agency UK and Golder Associates) (Gregory et al., 2003).
- EPER model France (ADEME) (Budka, 2003).
- EPER model Germany (Umwelt Bundesamt) (Hermann, 2005).

Table 2: CH_4 emissions prognoses for exemplary landfill obtained by type of model

Model		Methane emission prognosis ($m^3 CH_4 * h^{-1}$)
First order		853
Multi phase		483
GasSim	Multi phase	883
	LandGEM	2765
EPER France		192
EPER Germany		375
LandGEM (US EPA)		4760

Namerané množstvo CH_4 bolo **515 m^3/hod**

Modely výpočtu generovaného metánu zo skládok.

Applying guidance for methane emission estimation for landfills

Heijo Scharff *, Joeri Jacobs

NV Afvalzorg, Postbus 2, 1566 ZG Assendelft, The Netherlands

Accepted 18 November 2005
Available online 26 January 2006

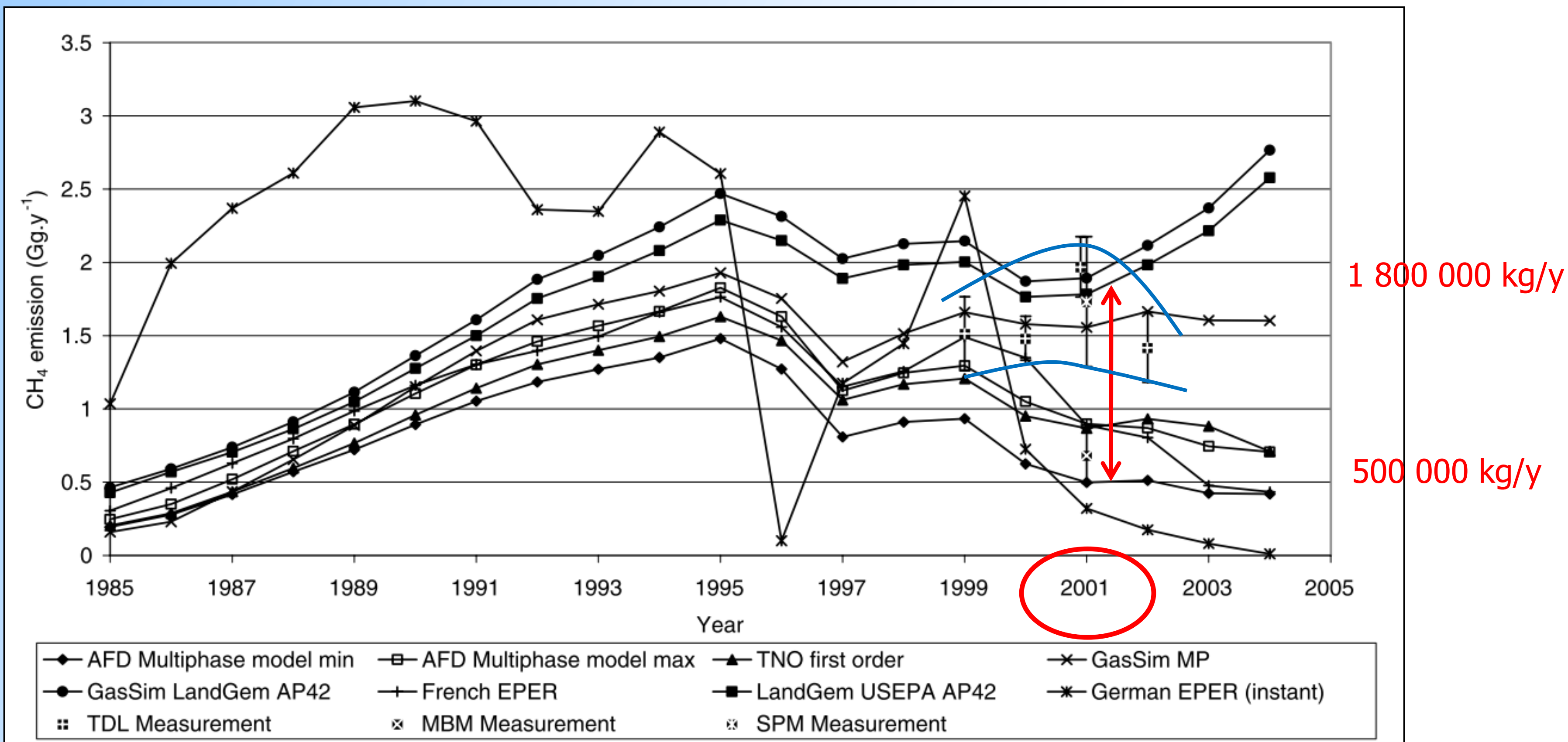


Fig. 5. Modelled and measured methane emission at Braambergen landfill.

Modely výpočtu generovaného metánu zo skládok.

Table 2. Summary of Emissions Measurements and Modeling Calculations

Landfill	Average CRDS (g CH_4/min)	Standard Deviation	n	EPA MRR (tons CH_4/yr)	SWICS (tons CH_4/yr)
Center Point	978	403	8	1,565	1,217
Seneca East	424	51	2	1,394	1,085
South Wells	937	399	9	1,176	915
Springfield	384	86	6	1,365	1,061

Measured and Modeled Methane Emissions at Closed MSW Landfills Without Gas Collection

Roger B. Green,[1] Nathan D. Swan,[2] Eben D. Thoma,[3] Tracey L. Footer,[4] Jeffrey Chanton,[5] and Gary R. Hater[6]

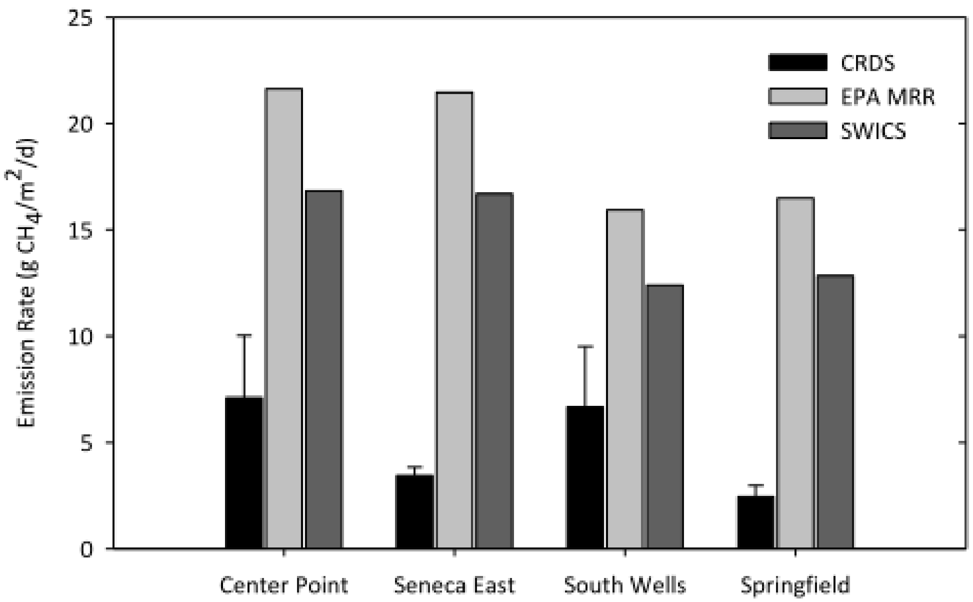


Figure 1. Comparison of Methane Emission Results from CRDS Measurements and Models (error bars represent 1sd)

Measurements: The tracer correlation approach utilized in this study simultaneously measures methane and an acetylene tracer gas at distances up to 2 km from the landfill. Similar measurements techniques have been previously applied to the study of landfill emissions (Czepiel et. al., 1996; Galle et. al., 2001). In this study, measurements were made by traversing the downwind plume with a vehicle-mounted cavity ring down spectrometer (CRDS). An acetylene tracer was released from the landfill surface at a controlled rate. This allows the methane mass emission rate to be calculated from the ratio of the methane and acetylene concentrations measured downwind from the landfill as shown in Equation 1.

„Porovnaním sme zistili, že modelom (EPA/SWICS) vypočítané hodnoty sú **2-7x vyššie**, ako skutočné in-situ namerané.“

Modely výpočtu generovaného metánu zo skládok.

Evaluation and application of site-specific data to revise the first-order decay model for estimating landfill gas generation and emissions at Danish landfills

Zishen Mou,* Charlotte Scheutz, and Peter Kjeldsen
Department of Environmental Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

Model ≥ merania

0,7- 3,3x

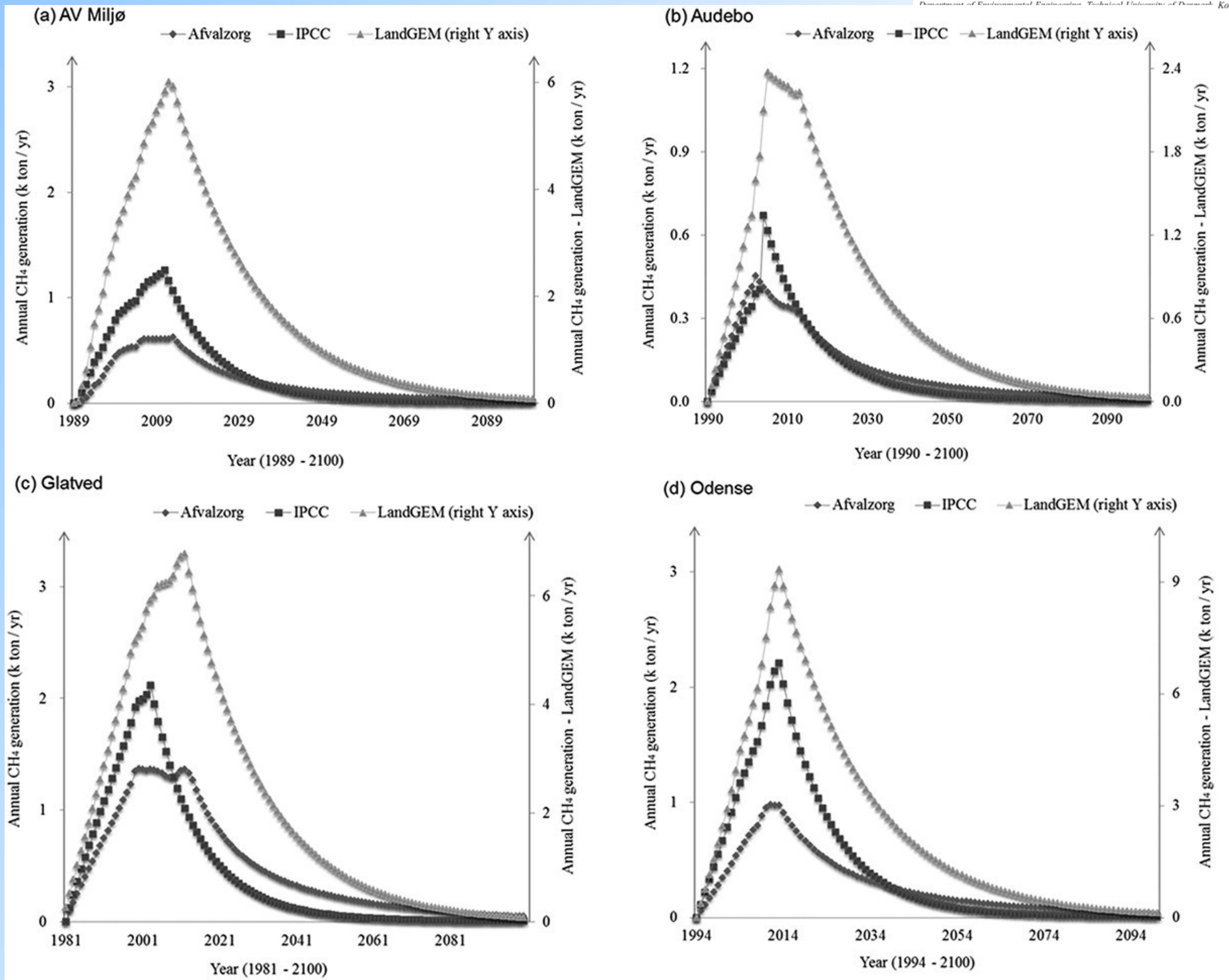
Table 1. Literature review in terms of comparison studies between LFG generation rates using FOD model estimations and field generation and emission measurements

Landfill	Model	BMP and/or k-value	Applied measurement method[a]	Ratio[b]	Reference
1 Unsanitary MSW landfill in Jordan	GasSim	Default values	Pump testing via drilled wells (G)	1.1	Abu Qdais et al., 2011
7 MSW landfills in Sweden	IPCC	Default values	Tracer dispersion (E)	0.7	Börjesson et al., 2009
1 Active MSW landfill with MBT in Italy	LandGEM	Default values	Testing via LFG extraction system (G)	1.1–2.6	Calabrò et al., 2011
1 MSW landfill and 1 open dump in Thailand	IPCC and LandGEM	Default values	Flux chamber (E)	1.1–3.3	Chiemchaisri and Visvanathan, 2008
9 MSW landfills in Thailand	IPCC	Default values	Flux chamber (E)	0.7–3.3	Wangyao et al., 2010
1 Low-organic waste landfill in Denmark	GasSim and Afvalzorg	Default values	Flux chamber and tracer dispersion (E)	2.5–3.3	Scheutz et al., 2011a
3 MSW landfills in United States	LandGEM	Estimated BMP based on waste composition; estimated k based on LFG extraction data	Tracer dispersion (E)	0.9–1.3	Amini et al., 2013
2 MSW landfills in United Kingdom and Austria	LandGEM	Estimated BMP based on waste composition	Testing via LFG extraction system (G)	1.3	Lamborn, 2012
35 MSW landfills in Canada	LandGEM	Estimated k based on landfill precipitation rates	Testing via LFG extraction system (G)	1.3	Thompson et al., 2009

Modely výpočtu generovaného metánu zo skládok.

Evaluation and application of site-specific data to revise the first-order decay model for estimating landfill gas generation and emissions at Danish landfills

Zishen Mou,* Charlotte Scheutz, and Peter Kjeldsen



Zhrnutie:

ISWA/UNEP Workshop on GHG and SLCP
Emission
Quantification Methodologies

September 19-20, 2013 Paris

Workshop Report

Metódy a nástroje

- Existuje mnoho spôsobov reportingu GHG
- Existujú rozdiely medzi IPCC, PI, LCA , GHG ... – pretože každý bol navrhnutý pre konkrétny účel
- Pre každú metódu existuje viacero nástrojov
- Nástroj je len prostriedkom na dosiahnutie cieľa

Možnosti a prístupy

- Existujú zásadný rozdiel medzi metódami na meranie lokálnych emisií a na komplexnom (národnom) audite
- Lokálne emisie sú dôležité pre reguláciu, ale nie v strategickom kontexte
- Pre strategické plánovanie sú potrebné holistické metódy

Nezodpovedané otázky:

- Čo je účelom emisného účtovníctva ?
  (lokálne emisie alebo národná inventarizácia ?)
- Čo je základom našej analýzy ?
- Ktoré dáta sú základom našej analýzy a ktoré naopak môžeme rozumne vylúčiť bez straty presnosti ?

Nakoniec naše výsledky nebudú závisieť od toho, čo sme poznali, ale skôr od toho, čo sme neodhalili.

Rozhodujúcim faktorom bude, aké dáta sú potrebné, aby výpočty dávali zmysluplné výsledky !

One size will not fit all.

Zhrnutie:

Applying guidance for methane emission estimation for landfills

Heijo Scharff *, Joeri Jacobs

NV Afvalzorg, Postbus 2, 1566 ZG Assendelft, The Netherlands

Accepted 18 November 2005
Available online 26 January 2006

Odporúča sa :

-pokúsiť sa harmonizovať existujúce rôzne modely

s cieľom zabezpečiť porovnateľné výsledky budúcich reportov o emisiách metánu hlásených do EPER alebo UN-PRTR.

Harmonizácia modelov nemusí nutne vyriešiť aktuálnu neistotu.

Môže však viesť k porovnateľným výsledkom z konzistentných a transparentných dát.

One size will not fit all.

Zjednodušený výpočet emisií metánu podľa IPCC 1996

KAŽDÝ DEŇ S VAMI

1996 IPCC Guidelines Default Method

EQUATION 1

$$\text{Methane emissions (Gg/yr)} = (MSW_T \bullet MSW_F \bullet MCF \bullet DOC \bullet DOC_F \bullet F \bullet 16/12\text{-}R) \bullet (1\text{-}OX)$$

Drake Equation:

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Parametre rovnice

N – predpokladaný výsledok, počet vyspelých inteligentných civilizácií schopných medzihviezdnej komunikácie

R* – prírastok nových hviezd v Galaxii za 1 rok

f_p – percentuálny podiel hviezd, ktoré (podobne ako Slnko) majú okolo seba planetárne systémy

n_e – priemerná hodnota počtu planét v planetárnom systéme, na ktorých panujú vhodné podmienky pre život

f_l – percentuálny podiel planét, na ktorých sa život skutočne vyvinul

f_i – percentuálny podiel planét, kde život vznikol a rozvíjal sa až k inteligentnej forme života

f_c – percentuálny podiel inteligentných foriem života, ktoré dosiahli schopnosť aktívnej medzihviezdnej komunikácie

L – odhad dĺžky existencie inteligentnej životnej formy schopnej medzihviezdnej komunikácie

Na odhad počtu mimozemských civilizácií Frank Drake sformuloval tzv. Drakeovu rovnicu. Výsledok veľmi záleží od vstupných predpokladov a **výsledné čísla sa líšia** podľa toho, či ju použili optimisti alebo pesimisti.

Zjednodušený výpočet emisií metánu podľa IPCC.

EQUATION 1

$$\text{Methane emissions (Gg/yr)} = (MSW_T \bullet MSW_F \bullet MCF \bullet DOC \bullet DOC_F \bullet F \bullet 16/12\text{-}R) \bullet (1\text{-}OX)$$

MSW_T :	total MSW generated (Gg/yr)
MSW_F :	fraction of MSW disposed to solid waste disposal sites
MCF :	methane correction factor (fraction)
DOC :	degradable organic carbon (fraction) (kg C/ kg SW)
DOC_F :	fraction DOC dissimilated
F :	fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 :	conversion of C to CH_4
R :	recovered CH_4 (Gg/yr)
OX :	oxidation factor (fraction – IPCC default is 0)

Parameter	Parameter Description	Parameter Value
MCF	Methane correction factor (dimensionless)	1
DOC_F	Fraction of DOC degraded	0.5
F	Fraction CH_4 in generated gas	0.5
OX	Soil oxidation factor (dimensionless) [IPCC model only, in the Recovery_OX tab]	0.10
Delay Time	Time (in months) prior to the start of anaerobic decay [IPCC model only]	6

MSW_T :	total MSW generated (Gg/yr)
MSW_F :	fraction of MSW disposed to solid waste disposal sites
MCF :	methane correction factor (fraction)
DOC :	degradable organic carbon (fraction) (kg C/ kg SW)
DOC_F :	fraction DOC dissimilated
F :	fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 :	conversion of C to CH_4
R :	recovered CH_4 (Gg/yr)
OX :	oxidation factor (fraction – IPCC default is 0)

Zjednodušený výpočet emisií metánu podľa IPCC.

IPCC 2006

TABLE 3.1
SWDS CLASSIFICATION AND METHANE CORRECTION FACTORS (MCF)

Type of Site	Methane Correction Factor (MCF) Default Values
Managed – anaerobic [1]	1.0
Managed – semi-aerobic [2]	0.5
Unmanaged [3] – deep (>5 m waste) and /or high water table	0.8
Unmanaged [4] – shallow (<5 m waste)	0.4
Uncategorised SWDS [5]	0.6

IPCC 2019

TABLE 3.1 (UPDATED)
SWDS CLASSIFICATION AND METHANE CORRECTION FACTORS (MCF)

Type of Site	Methane Correction Factor (MCF) Default Values	Remarks
Managed – anaerobic	1.0[a]	These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste.
Managed well – semi-aerobic	0.5[b]	When semi-aerobic managed SWDS type is managed under one of the following condition, it is regarded as well magement ; (i) permeable cover material; (ii) leachate drainage system without sunk; (iii) regulating pondage; and (iv) gas ventilation system without cap, (v) connection of leachate drainage system and gas ventilation system.
Managed poorly – semi-aerobic	0.7[c]	When semi-aerobic managed SWDS type is managed under one of the following condition, it is regarded as poor management; (i) condition of sunk of leachate drainage system; (ii) closing of valve of drainage or atmosphere-unopening of drainage exit; (iii) capping of gas ventilation exit.
Managed well – active-aeration	0.4[d,e,f]	Active aeration of managed landfills includes the technology of in-situ low pressure aeration, air sparging, bioventing, passive ventilation with extraction (suction). These must have controlled placement of waste and will include leachate drainage system to avoid the blockage of air penetration, and (i) cover material; (ii) air injection or gas extraction system without drying of waste.
Managed poorly – active-aeration	0.7[f,g,h]	When SWDS, that is equipped as well as active aeration of managed SWDS, is managed under one of the following condition, it is judged as poor management; (i) blockage of aeration system due to failure of drainage; (ii) lack of available moisture for microorganisms due to high- pressure aeration.
Unmanaged – deep (>5 m waste) and /or high water table	0.8[a]	All SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 metres and/or high water table at near ground level. Latter situation corresponds to filling inland water, such as pond, river or wetland, by waste.
Unmanaged – shallow (<5 m waste)	0.4[a]	All SWDS not meeting the criteria of managed SWDS and which have depths of less than 5 metres.
Uncategorised SWDS	0.6[a]	Only if countries cannot categorise their SWDS into above four categories of managed and unmanaged SWDS, the MCF for this category can be used.

Výpočet emisií podľa IPCC.

The fraction of degradable organic carbon (DOC) can be calculated by Equation (4-3):

$$DOC = 0.4A + 0.17B + 0.15C + 0.30D$$

- A per cent MSW that is paper and textiles
- B per cent MSW that is garden waste, park waste or other non-food organic putrescibles
- C per cent MSW that is food waste
- D per cent MSW that is wood or straw

Waste composition

Default data provided for :

1. food waste
2. garden (yard) and park waste
3. paper and cardboard
4. wood
5. textiles
6. nappies (disposable diapers)
7. rubber and leather
8. plastics
9. metal
10. glass (and pottery and china)
11. other (e.g., ash, dirt, dust, soil, electronic waste)

MSW_T :	total MSW generated (Gg/yr)
MSW_F :	fraction of MSW disposed to solid waste disposal sites
MCF :	methane correction factor (fraction)
DOC :	degradable organic carbon (fraction) (kg C/ kg SW)
DOC_F :	fraction DOC dissimilated
F :	fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 :	conversion of C to CH_4
R :	recovered CH_4 (Gg/yr)
OX :	oxidation factor (fraction – IPCC default is 0)

Výpočet emisií podľa IPCC.

IPCC 1996 **IPCC 2006** **IPCC 2019**

$DOC_F = 0,77$

$DOC_F = 0,50$

TABLE 3.0 (NEW)
FRACTION OF DEGRADABLE ORGANIC CARBON WHICH DECOMPOSES (DOC_f) FOR DIFFERENT WASTE TYPES

Type of Waste	Recommended Default DOC_f Values	Remark
Less decomposable wastes e.g. wood, engineered wood products, tree branches (wood)	0.1	An average value of 0.088 was derived from DOC_f values for engineered wood products, sawn woods, tree branches reported in 3 references[1-3]
Moderately decomposable wastes e.g. paper, textile, nappies	0.5	An average value of 0.523 was derived from DOC_f values for paper products, textile and nappies reported in 4 references[4-7].
Highly decomposable wastes, e.g. food wastes, grasses (garden and park waste excluding tree branches)	0.7	An average value of 0.706 was derived from DOC_f values for food wastes and grasses reported in 3 references[4-6]
Bulk waste*	0.5	

TABLE 3.2
OXIDATION FACTOR (OX) FOR SWDS

Type of Site	Oxidation Factor (OX) Default Values
Managed [1], unmanaged and uncategorised SWDS	0
Managed covered with CH_4 oxidising material [2]	0.1

[1] Managed but not covered with aerated material
[2] Examples: soil, compost

KAŽDÝ DEŇ S VAMI

FOD model výpočet emisií metánu podľa IPCC 2006.

IPCC default method

$$G_{CH4} = \sum_{x=S}^{T-1} \left\{ W_x \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12} \times \left(e^{-k(T-x-1)} - e^{-k(T-x)}\right) \right\}$$

where:

G_{CH4} = Modeled methane generation rate in reporting year T (metric tons CH_4).
x = Year in which waste was disposed.
S = Start year of calculation.
T = Reporting year for which emissions are calculated.
W_x = Quantity of waste disposed in the landfill in year x (metric tons).
MCF = Methane correction factor; default value = 1.
DOC = Degradable organic carbon (metric tons C/metric ton waste).
DOC_F = Fraction of DOC dissimilated; default value = 0.5.
F = Fraction by volume of CH_4 in landfill gas; default is 0.5.
k = Rate constant.

$$A = \left[\sum_{x=S}^{T-1} \left\{ W_x L'_x \left(e^{-k(T-x-1)} - e^{-k(T-x)}\right) \right\} \right]$$

where

A = CH_4 generation (Mg/yr)
x = Year in which waste was disposed
S = Start year of inventory calculation
T = Inventory year for which emissions are calculated
W_x = the quantity of waste disposed at the solid waste disposal site (Mg)
L' = CH_4 generation potential (Mg CH_4/Mg waste)
= MCF × DOC × DOC_F × F × 16 / 12 [IPCC nomenclature]
= $L_0 \times 16/0.02367 \times 10^{-6}$
L_0 = CH_4 generation potential (m^3 CH_4/Mg waste) [AP-42 nomenclature]
MCF = CH_4 correction factor (fraction), typically 1 for managed landfills
DOC = degradable organic carbon [fraction (Mg C in waste/Mg waste)]
DOC_F = fraction of DOC decomposed (fraction), generally assumed to be 0.5
F = fraction by volume of CH_4 in landfill gas, generally assumed to be 0.5
k = decay rate constant (yr^{-1}).

Metoda FOD - tier 2

Table 4-1 Three Tiers of Method to Estimate CH_4 Emissions from SWDS [20]

Tier	*Method*	*Activity Data*	*Parameters*
Tier 1	IPCC FOD method	default	default
Tier 2	IPCC FOD method	good quality country-specific activity data on current and historical waste disposal at SWDS[a]	default (some)
Tier 3	1) IPCC FOD method, or 2) country specific methods	good quality country-specific activity data on current and historical waste disposal at SWDS[a]	1) nationally developed key parameters[b], or 2) measurement derived country-specific parameters[b]

a. Historical waste disposal data for 10 years or more should be based on country-specific statistics, surveys or other similar sources. Data are needed on amounts disposed at the SWDS.

b. Key parameters should include the half-life, and either methane generation potential (L_o) or DOC content in waste and the fraction of DOC which decomposes (DOC_f).

KAŽDÝ DEŇ S VAMI

FOD model podľa IPCC 1996 – 2000 - 2006.

Table 2
A simulated landfill: emissions calculated by the models referred to in this paper.

Time Indication	A	B	C	D	E	F	G	H	I	J
	IPCC (1997) no delay	IPCC (1997) UNDER delay 6 m	IPCC (1997) OVER delay 6 m	IPCC (2000) factor A no delay	IPCC (2000) factor A delay 6 m	IPCC (2000) factor A′ delay 6 m	CDM tool no delay	Modified CDM tool delay 6 m	IPCC (2006) delay 6 m	
	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk	Fractions	Fractions	Bulk	Fractions
			t CH_4							
Total in first 7 years	9,199	6,576	7,048	8,888	6,353	6,809	16,158	12,939	6,809	12,939
Total in first 10 years	16,977	13,229	14,179	16,402	12,781	13,699	26,727	23,071	13,699	23,071
Total in first 60 years	108,269	100,774	108,007	104,602	97,361	104,349	104,213	104,016	104,349	104,016
Diff. in first 7 years >>	*35.1%*	*−3.4%*	*3.5%*	*30.5%*	*−6.7%*	*0.0%*	*24.9%*	*0.0%*	*Exact model*	*Exact model*
Diff. in first 10 years >>	*23.9%*	*−3.4%*	*3.5%*	*19.7%*	*−6.7%*	*0.0%*	*15.8%*	*0.0%*	*0%*	*0%*
Diff. in first 60 years >>	*3.8%*	*−3.4%*	*3.5%*	*0.2%*	*−6.7%*	*0.0%*	*0.2%*	*0.0%*	*0%*	*0%*
2001	375	–	–	362	–	–	932	–	–	–
2002	724	350	375	700	338	362	1,607	932	362	932
2003	1,051	676	724	1,015	653	700	2,107	1,607	700	1,607
2004	1,355	980	1,051	1,309	947	1,015	2,487	2,107	1,015	2,107
…	…	…	…	…	…	…	…	…	…	…
2059	281	281	301	272	272	291	209	221	291	221
2060	262	262	281	253	253	272	198	209	272	209

KAŽDÝ DEŇ S VAMI

Table 2-1. Recommended DOC (Degradable Organic Carbon) and Decay Rate Values for Landfills[a]

Waste Model/Waste Type	DOC (weight fraction, wet basis)	k [dry climate[b]] (yr^{-1})	k [moderate climate[b]] (yr^{-1})	k [wet climate[b]] (yr^{-1})
MSW Landfills—Bulk Waste Option				
All waste materials	0.2028	0.02	0.038	0.057
MSW Landfills—Bulk MSW Option				
Bulk MSW	0.30	0.02	0.038	0.057
Construction and demolition waste	0.08	0.02	0.03	0.04
Inert waste (glass, metal, plastic)	0.0	0.0	0.0	0.0
MSW Landfills—Waste-Specific Option				
Food waste	0.15	0.06 [c]	–[c]	0.185 [c]
Garden waste	0.20	0.05 [c]	–[c]	0.10 [c]
Paper waste	0.40	0.04 [c]	–[c]	0.06 [c]
Wood and straw waste	0.43	0.02 [c]	–[c]	0.03 [c]
Textile waste	0.24	0.04 [c]	–[c]	0.06 [c]
Diapers	0.24	0.05 [c]	–[c]	0.10 [c]
Sewage sludge	0.05	0.06 [c]	–[c]	0.185 [c]
Inert waste (glass, metal, plastic)	0.0	0.0	0.0	0.0
Industrial Waste Landfills				
Food processing industry	0.22	0.06	0.12	0.18
Pulp and paper industry	0.20	0.02	0.03	0.04
Wood and wood products	0.43	0.02	0.03	0.04
Construction and demolition waste	0.08	0.02	0.03	0.04
Inert waste (glass, metal, plastic)	0	0	0	0
Other industrial solid waste (not otherwise listed)	0.20	0.02	0.04	0.06

Table 1
Default BMP values (kg CH_4/ton waste, wet weight) and DOCC (%, kg C/kg waste, wet weight) for the various waste categories that were used in different models.

FOD models	BMP (DOCC)[a] values				Country based	Latest version
	Industrial waste		MSW			
E-PRTR (Fr)[b]	28 (4)		55 (8)		French	2003
LandGEM[c]	Not specified		122 or 72 (18 or 11)		U.S.	2005
IPCC (waste fractions)[d]	Sludge	33 (5)	Food	100 (15)	International	2011
	Industrial	67 (10)	Garden	133 (20)		
			Paper	267 (40)		
			Textiles	160 (24)		
Afvalzorg (waste fractions)[e]	Soil	3 (2)	Household	91 (18)	Holland	2014
	C&D	11 (3)	Bulky mixed	80 (19)		
	Shredder	13 (4)	Garden	47 (9)		
	Sludge	25 (6)	Commercial	56 (13)		
	Cleansing	19 (4)	RDF	63 (18)		

Table 1
Default k values (yr^{-1}) for various waste categories provided in FOD models.

Models	Country	Version	Category of waste or landfills	k Value (yr^{-1})	$t_{½}$ (yr)	Data resource	Reference
E-PRTR (Fr)	France	2003	Fast degradable Moderate degradable Slow degradable	0.5 0.1 0.04	1.5 7 17	k Values were determined based on field measurements in approximately 50 French landfills	ADEME (2003), Oonk (2010)
LandGEM[a]	US	2005	Wet area landfill Conventional landfill Arid area landfill	0.7 0.04–0.05 0.02	10 14–17 35	k Values were determined by US Clean Air Act 1990.	US EPA (2012, 2005)
IPCC	International	2011	Food, sludge Garden, disposable nappies Industrial waste Textile, paper Wood, straw	0.185 0.10 0.09 0.06 0.03	4 7 8 12 23	k Values were cited from the literature or determined by international experts (only values for wet temperate countries are shown in this table)	IPCC (2011, 2006)
GasSim	UK	2012	Fast degradable Moderate degradable Slow degradable	0.116 0.076 0.046	6 9 15	k Values were determined based on water saturation level of different waste categories	Arnold and Yang (2005), GasSim (2012), Gregory et al. (1999)
Afvalzorg	Holland	2014	Fast degradable Moderate degradable Slow degradable	0.187 0.099 0.030	3.7 7 23	k Values were determined based on IPCC model default values and field measurements in three Dutch landfills	Afvalzorg (2014), Scharff and Jacobs (2006)

[a] CAA – Clean Air Act (US EPA, 1990); LandGEM model also defined different k and $t_{1/2}$ values for landfills in dry and wet area.

	Relatively Inert	*Moderately Decomposable*	*Decomposable*
Paper			
Office Paper		x	
Newsprint		x	
OCC		x	
Boxboard		x	
Tissue Paper/towelling		x	
Beverage Containers - Drink Box / Aseptic Containers		x	
Single Serving Drink Cups (coffee, tea, fountain, etc.)		x	
Organics			
Food Waste			x
Natural Textiles		x	
Leather		x	
Wood - Unpainted		x	
Wood - Painted		x	
Leaves			x
Plant Clippings			x
Grass			x
X-mas Trees			x
Slaughterhouse Waste			x
Plastics			
Rigid Plastics	x		
Films (plastic bags)	x		
Synthetic Textiles (i.e.. nylon, polyester, etc.)	x		
Carpet	x		
Rubber	x		
Tires	x		

Table 5.2 – Methane Generation Rate Selection Matrix

	Methane Generation Rate (k) Values		
Annual Precipitation	*Relatively Inert*	*Moderately Decomposable*	*Decomposable*
<250 mm	0.01	0.01	0.03
>250 to <500 mm	0.01	0.02	0.05
>500 to <1,000 mm	0.02	0.04	0.09
>1,000 to <2,000 mm	0.02	0.06	0.11
>2,000 to <3,000 mm	0.03	0.07	0.12
>3,000 mm	0.03	0.08	0.13

Table 1
Summary of empirical landfill gas generation model applications.

Study	Years of data	Models	Landfill characteristics	k (yr^{-1})	L_0 ($m^3\ g^{-1}$)	Error[a]	References
Validating LFG generation models based on 35 Canadian landfills	NA	Zero-order German EPER TNO Belgium Scholl Canyon LandGEM version 2.01	35 Canadian landfills	0.023–0.056	90–128	(-81%) – (+589%)	Thompson et al. (2009)
The CDM landfill gas projects by the World Bank	1–3 years	IPCC First-order Rettenberger First-order E-PLUS US EPA LandGEM Dutch Multiphase Scholl Canyon	Six landfills in South America and Europe	0.014–0.28	68–102	(-3%) – (+1109%)	Willumsen and Terraza (2007)
Comparison of landfill methane emission models: A case study	NA	US EPA LandGEM French ADEME UK GasSim IPCC Tier 2	Four French landfills	0.04–0.50	44–170	(−65%)–(+140%)	Ogor and Guerbois (2005)
Landfill gas energy recovery: economic and environmental evaluation for a case study	NA	Scholl Canyon	Casa Rota Landfill, Tuscan, Italy	0.07–0.36	13–30	+5%	Corti et al. (2007)

NA: not available.
[a] The error comparing model estimations to actual data, with negative indicating model estimation is lower than actual.

Determination of first-order landfill gas modeling parameters and uncertainties

Hamid R. Amini *, Debra R. Reinhart, Kevin R. Mackie
University of Central Florida, Department of Civil, Environmental, and Construction Engineering, Orlando, FL 32816, USA

Výpočet LFG podľa modelu

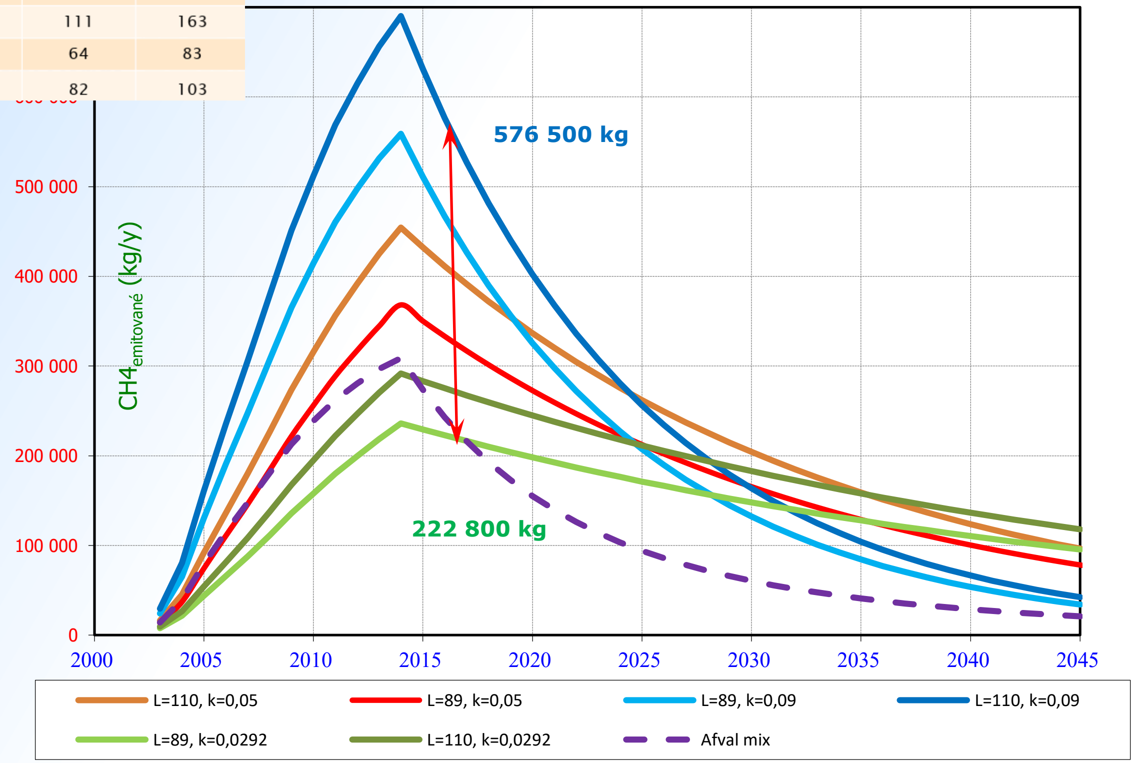
Case Study Landfill Results

Landfill	k, yr^{-1}			L_0, m^3Mg^{-1} (1)		
	Likliest	Minimum	Maximum	Mean	Minimum	Maximum
A – Cell 1	0.08	0.05	0.13	62	54	72
A – Cell 2	0.04	0.02	0.05	56	49	61
B – traditional	0.04	0.01	0.05	70	59	81
B – wet	0.10	0.01	0.11			
C	0.13	0.04	0.25	63	55	70.8
D	0.13	0.06	0.13	61	51	72
E	0.06	0.05	0.09	140	111	163
F	0.09	0.07	0.23	74	64	83
G	0.04	0.03	0.04	93	82	103

Ktorý model použiť ?

Aké parametre nastaviť ?

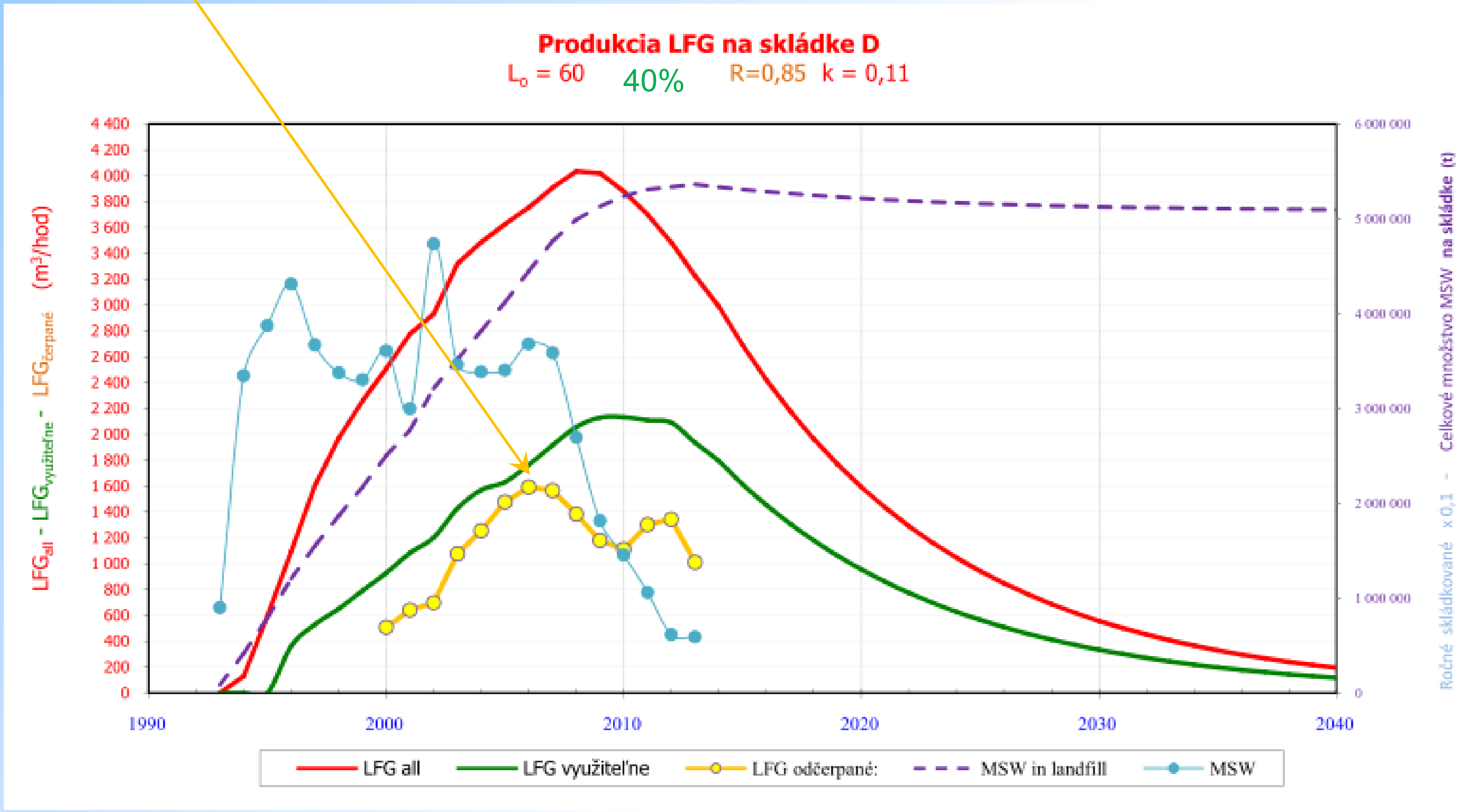
Porovnanie emisií CH_4 zo skládky pri rôznych hodnotách **k** a **Lo.**



Model ≥ merania !!!

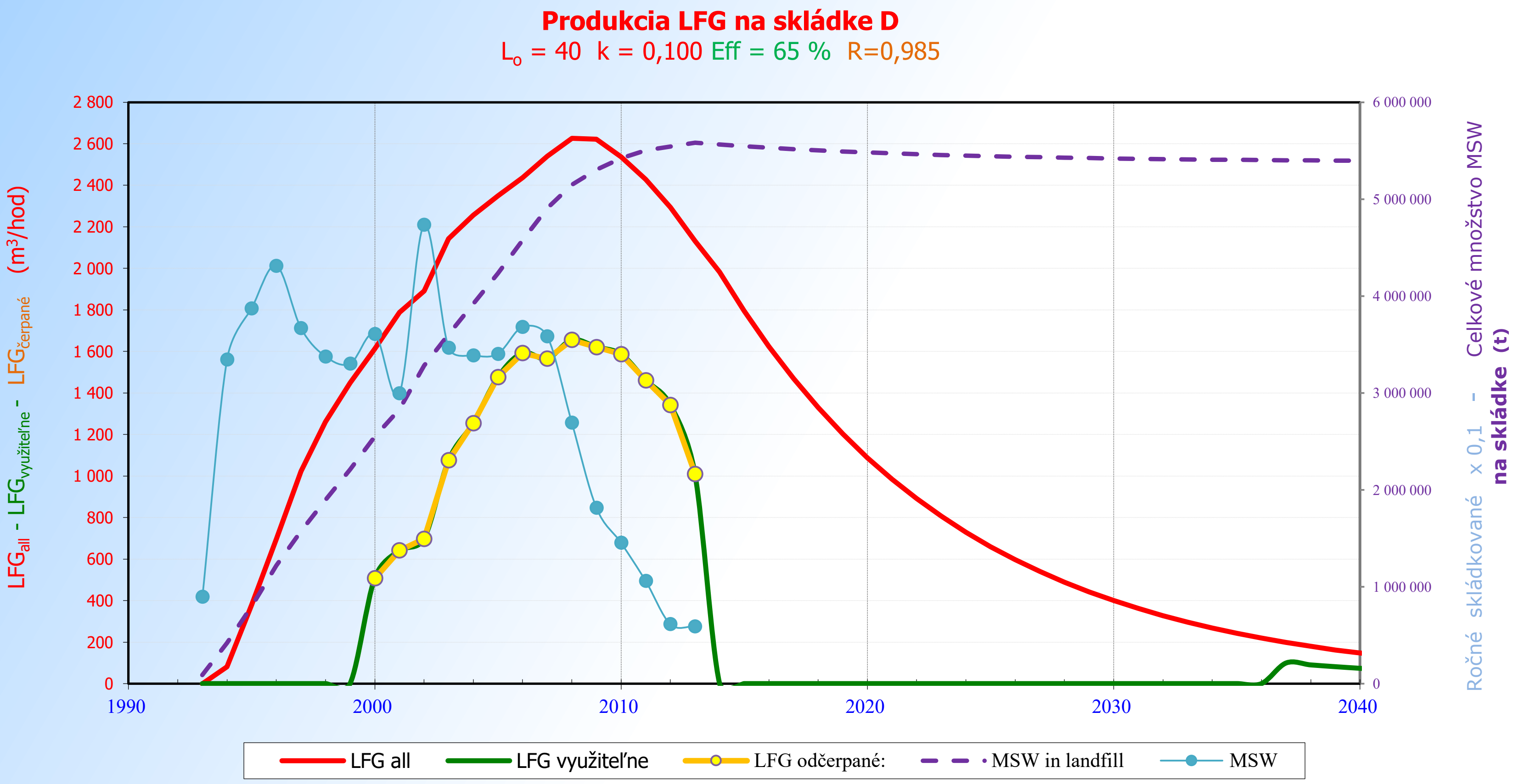
Verifikáciu výpočtu LFG pre reálnu skládku

1 400 m3/h = 12,3 mil. m3/r LFG ≈ 8 094 t/y CH_4



Verifikáciu výpočtu LFG pre reálnu skládku

Lo = 60	Lo = 100	Lo = 100	Lo = 40	Lo = 40
k = 0,11	k = 0,09	k = 0,105	k = 0,08	k = 0,10
r = 0,85	r = 0,977	r = 0,985	r = 0,962	r = 0,985
Eff = 40 %	Eff = 28 %	Eff = 25 %	Eff = 74 %	Eff = 65 %



Výpočet LFG a fugitívnych emisií pre skládku

Teoretická produkcia skládkového plynu (LFG)

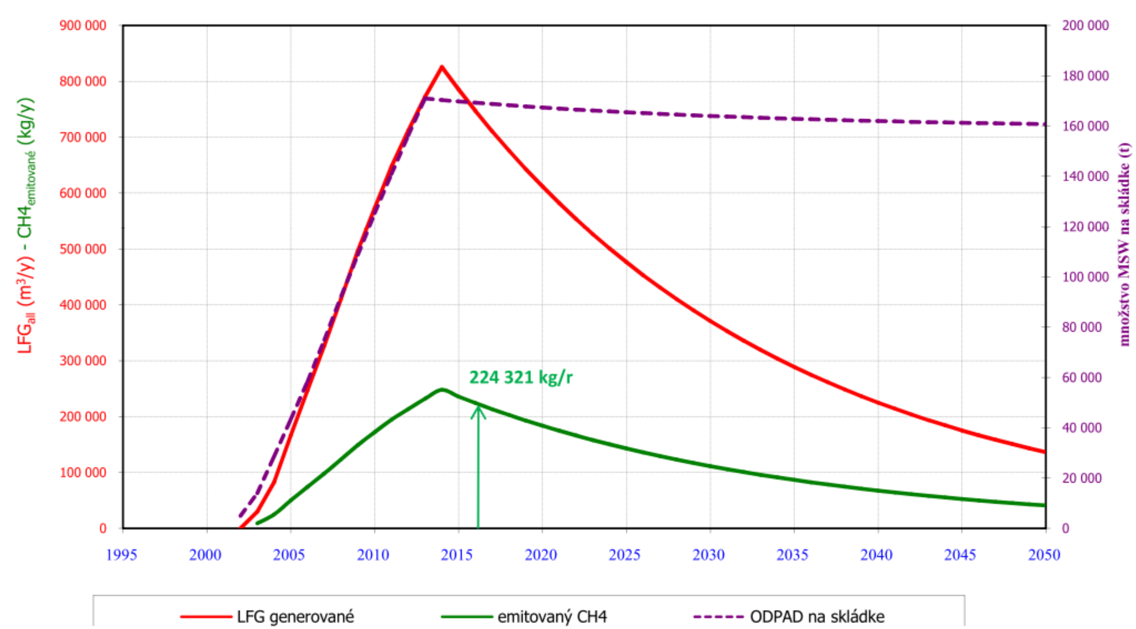
skládka [redacted] k = 0,050 Lo= 60,00

rok	Množstvo uloženého odpadu (T/rok)	Suma odpadu na skládke (T)	Redukovaný odpad na skládke (T)	LFG generované: (m^3/hod)	LFG generované: (m^3/rok)	Produkcia CH_4 (m^3/deň) pri 50 % koncentrácii	Povrchová oxidácia (%)	Emitovaný CH_4 (m^3/hod)	Emitovaný CH_4 (kg/rok) pri 50 % konc.
2002	5 000	5 000	5 000	0,0	0	0	0%	0	
2003	9 000	14 000	13 979	3,4	29 965	41,0	10%	1,5	8 996
2004	14 639	28 639	28 559	9,4	82 442	112,9	10%	4,2	24 750
2005	14 938	43 578	43 379	19,0	166 156	227,6	10%	8,5	49 883
2006	15 243	58 821	58 445	28,3	247 578	339,1	10%	12,7	74 327
2007	16 787	75 608	74 998	37,3	326 856	447,7	10%	16,8	98 128
2008	17 624	93 232	92 329	47,0	411 521	563,7	10%	21,1	123 546
2009	16 848	110 080	108 822	56,7	497 073	680,9	10%	25,5	149 230
2010	16 959	127 039	125 371	65,5	573 802	786,0	10%	29,5	172 265
2011	16 008	143 047	140 917	73,9	647 454	886,9	10%	33,3	194 377
2012	15 880	158 927	156 289	81,3	711 815	975,1	10%	36,6	213 699
2013	15 213	174 140	170 950	88,2	772 269	1 057,9	10%	39,7	231 849
2014	0	174 140	170 361	94,3	825 778	1 131,2	10%	42,4	247 913
2015	0	174 140	169 800	89,7	785 504	1 076,0	10%	40,4	235 822
2016	0	174 140	169 266	85,3	747 195	1 023,6	10%	38,4	224 321
2017	0	174 140	168 759	81,1	710 754	973,6	10%	36,5	213 381

Rozdiely medzi modelmi:
± 10 %

- LandGEM
- LMOP
- Afvalzorg

k = 0,05   Lo = 60



Výpočet zachyteného LFG pre reálnu skládku

220 x 85 m

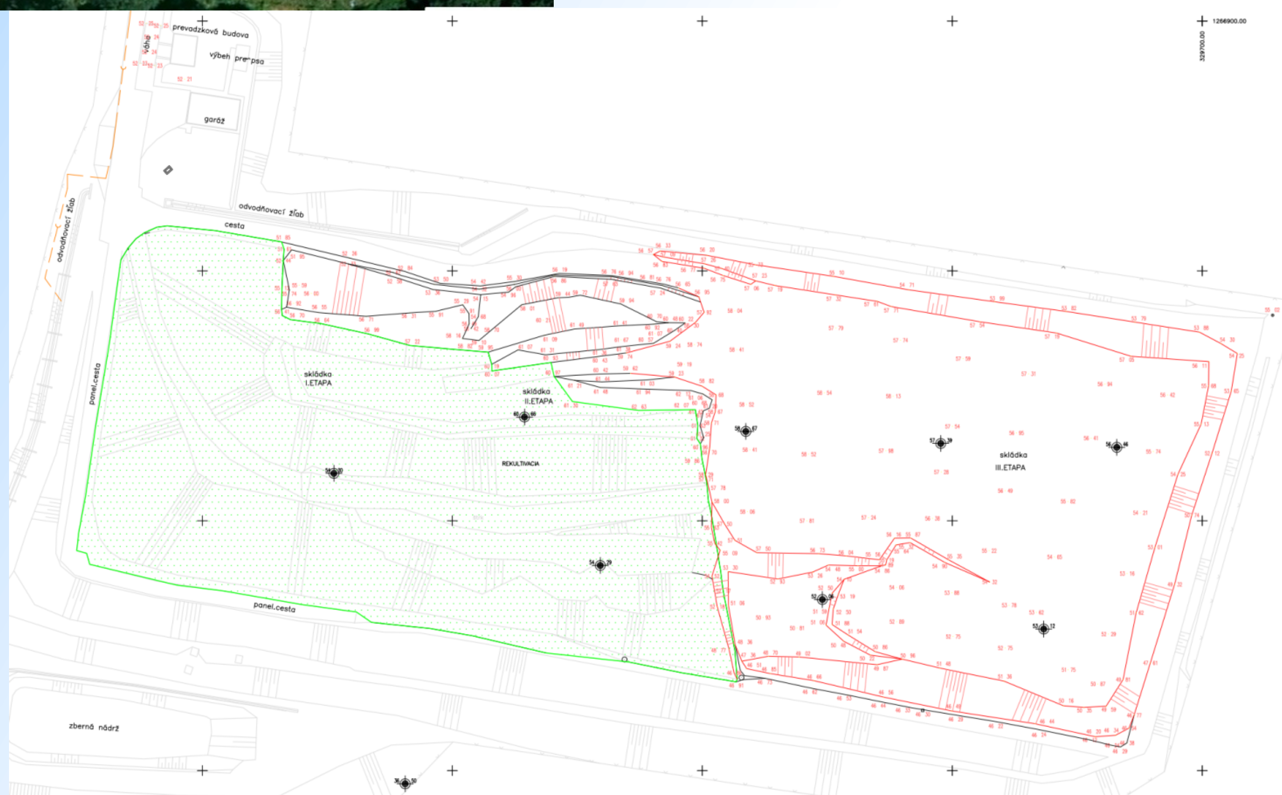
S = 17 100 m^2

$S_{akt.}$ = 8 300 m^2

V = 142 550 t odpadu

≈ 90% = MSW (20 03 01)

8x LFG studne (3 + 5)



Verifikácia LFG – výpočet / meranie

$LFG_{gen: (m3/r)}$	LandGEM	Scholl C.	AFVAL
vypočet:	**730 133**	**747 851**	**655 700**
vypočet S_a:	357 765	366 447	321 293
	320 - 370 000		
$LFG_{rec:}$	*89 441*	*109 934*	*112 453*
	25%	30%	35%
	90 - 115 000		
meranie:	**109 850**		
efektivita CE:	25%	30%	35%
	439 400	366 167	313 857
	314 - 440 000		

Verifikácia LFG – výpočet / meranie

Teoretická produkcia skládkového plynu (LFG)

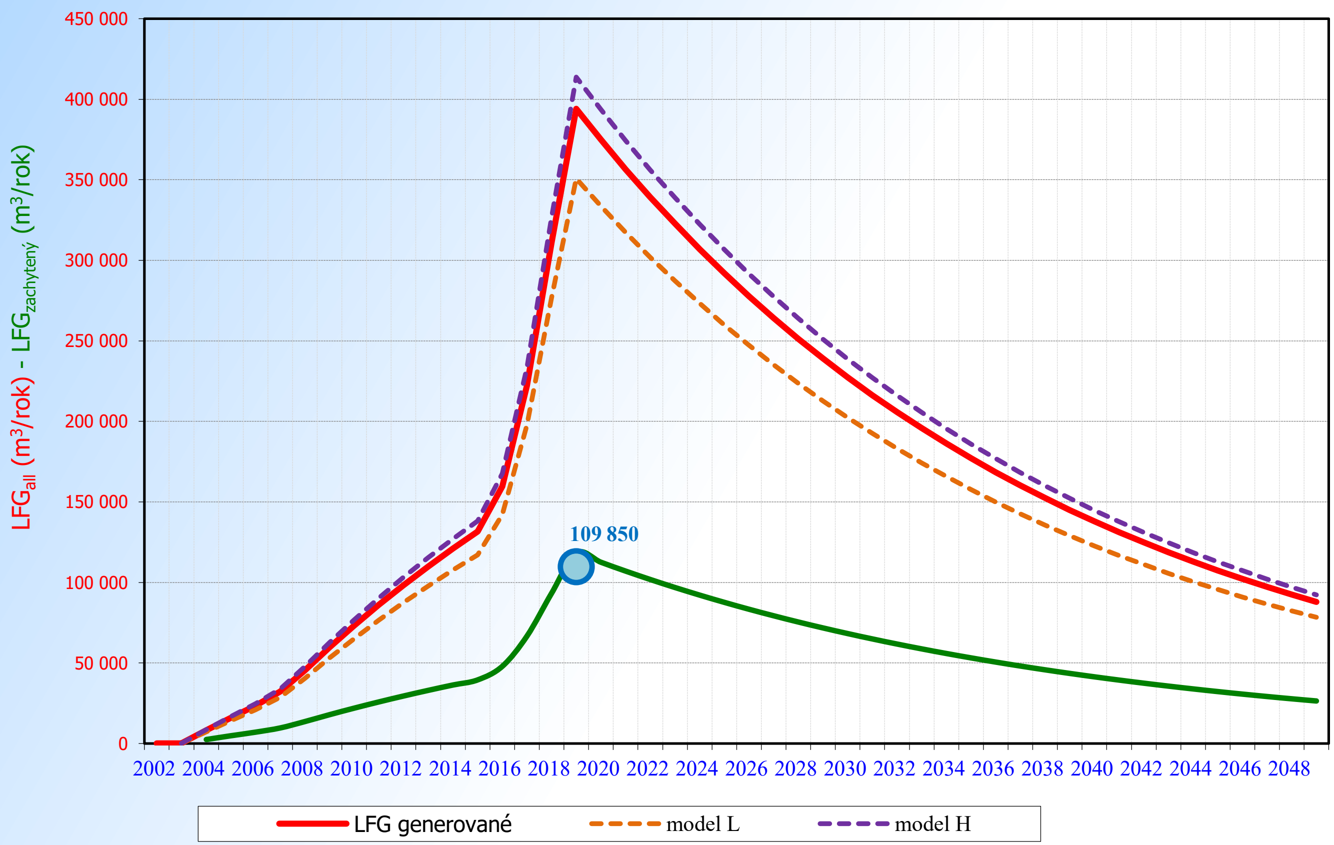
skládka Tornaľa				Lo=	67,0	k =	0,050	CH$_4$ =	50%		
rok	Množstvo uloženého odpadu (T/rok)	Suma odpadu na skládke (T)	Redukovaný odpad na skládke (T)	LFG generované: (m^3/min)	(m^3/hod)	(m^3/rok)	Produkcia CH$_4$ (m^3/deň) pri % koncentrácii	CH$_4$ oxidovaný (%)	CH$_4$ emitované (m^3/hod)	Emisie CH$_4$ (kg/rok)	(m^3/rok)
2002	0	0	0	0,000	0,0	0	0	0%	0		
2003	2 500	2 500	2 500	0,0000	0,0	0	0,0	10%	0,0		
2004	2 500	5 000	4 988	0,0319	1,9	16 778	23,0	10%	0,9	5 391	7 550
2005	2 500	7 500	7 465	0,0623	3,7	32 737	44,8	10%	1,7	10 518	14 732
2006	3 000	10 500	10 430	0,0912	5,5	47 918	65,6	10%	2,5	15 396	21 563
2007	4 500	15 000	14 884	0,1250	7,5	65 714	90,0	10%	3,4	21 114	29 571
2008	5 000	20 000	19 817	0,1764	10,6	92 708	127,0	10%	4,8	29 787	41 719
2009	5 000	25 000	24 730	0,2316	13,9	121 742	166,8	10%	6,3	39 116	54 784
2010	5 000	30 000	29 624	0,2842	17,1	149 360	204,6	10%	7,7	47 989	67 212
2011	5 000	35 000	34 498	0,3342	20,0	175 630	240,6	10%	9,0	56 430	79 034
2012	5 000	40 000	39 355	0,3817	22,9	200 620	274,8	10%	10,3	64 459	90 279
2013	5 000	45 000	44 195	0,4269	25,6	224 390	307,4	10%	11,5	72 097	100 976
2014	5 000	50 000	49 019	0,4699	28,2	247 002	338,4	10%	12,7	79 362	111 151
2015	10 500	60 500	59 327	0,5109	30,7	268 510	367,8	10%	13,8	86 272	120 830
2016	21 407	81 907	80 501	0,6200	37,2	325 881	446,4	10%	16,7	104 705	146 646
2017	30 297	112 204	110 474	0,8631	51,8	453 646	621,4	10%	23,3	145 757	204 141
2018	29 872	142 075	139 892	1,2079	72,5	**634 846**	869,7	10%	32,6	**203 976**	**285 681**

NV Afvalzorg Multiphase Model - version January 2015 TORNALA 2018 - zloženie TKO podľa SK

Results (m3 CH4)

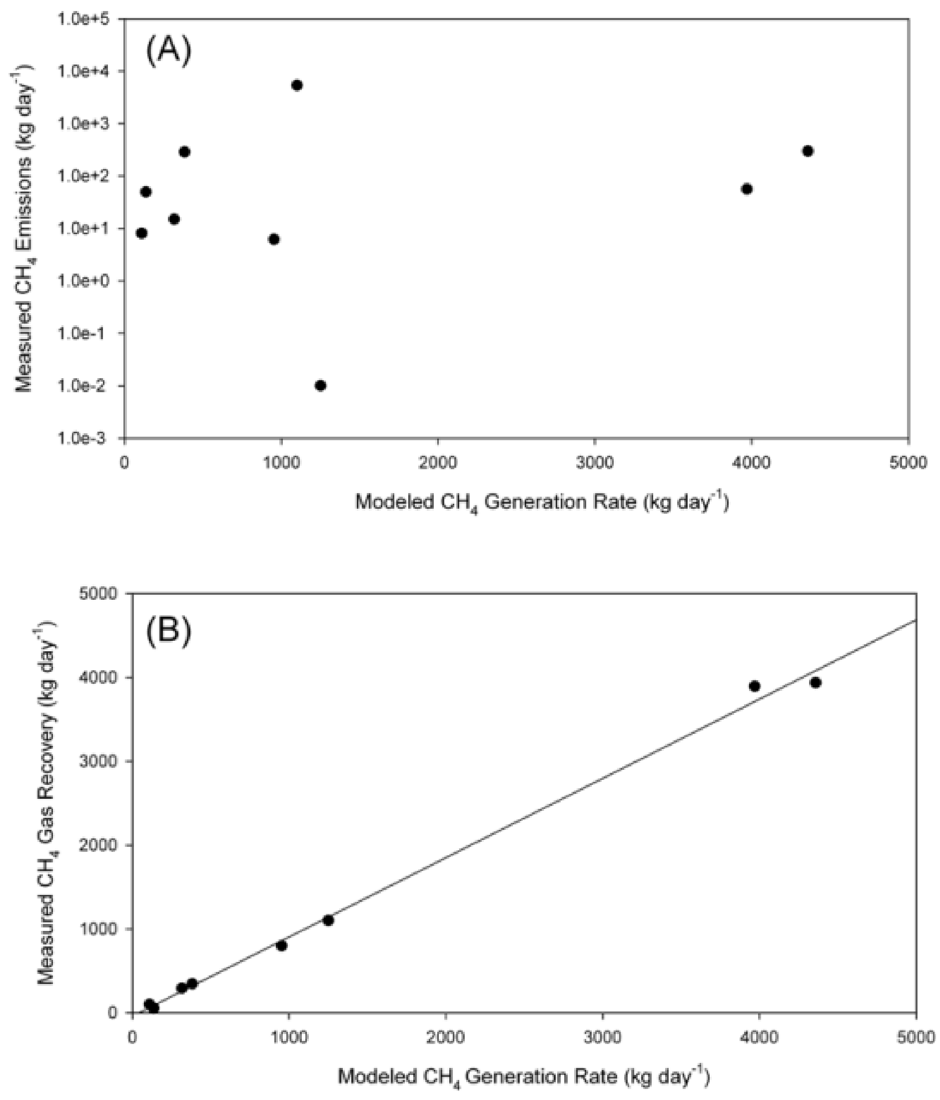
Year	CH$_4$ generation m^3/h	CH$_4$ generation m^3/year (x1.000)	CH$_4$ - recovery %	CH$_4$ - recovery m^3/h	CH$_4$ - recovery m^3/year (x1.000)	Oxidation % of Gen - Rec	Oxidation m^3/h	Oxidation m^3/year (x1.000)	Emission %	Emission m^3/h	Emission m^3/year (x1.000)
2002	0,0	0,000	0%	0,0	0,000	0%	0,0	0,000	0%	0,0	0,000
2003	0,0	0,000	#########	0,0	0,000	#########	0,0	0,000	#########	0,0	0,000
2004	1,0	8,400	0%	0,0	0,000	39%	0,4	3,257	61%	0,6	5,143
2005	1,8	16,184	0%	0,0	0,000	30%	0,5	4,814	70%	1,3	11,370
2006	2,7	23,403	0%	0,0	0,000	29%	0,8	6,784	71%	1,9	16,619
2007	3,6	31,783	0%	0,0	0,000	27%	1,0	8,460	73%	2,7	23,323
2008	5,1	44,602	0%	0,0	0,000	25%	1,3	11,024	75%	3,8	33,579
2009	6,6	58,182	0%	0,0	0,000	24%	1,6	13,740	76%	5,1	44,442
2010	8,1	70,792	0%	0,0	0,000	24%	1,9	16,787	76%	6,2	54,005
2011	9,4	82,512	0%	0,0	0,000	23%	2,2	19,132	77%	7,2	63,381
2012	10,7	93,415	0%	0,0	0,000	23%	2,4	21,312	77%	8,2	72,103
2013	11,8	103,564	0%	0,0	0,000	23%	2,7	23,342	77%	9,2	80,223
2014	12,9	113,022	0%	0,0	0,000	22%	2,9	25,234	78%	10,0	87,789
2015	13,9	121,843	0%	0,0	0,000	22%	3,1	26,998	78%	10,8	94,845
2016	17,0	148,557	0%	0,0	0,000	22%	3,8	32,866	78%	13,2	115,691
2017	24,0	210,024	0%	0,0	0,000	22%	5,2	45,160	78%	18,8	164,864
2018	33,9	296,932	0%	0,0	0,000	21%	7,1	62,541	79%	26,8	234,391
2019	42,9	376,154	0%	0,0	0,000	21%	8,9	78,386	79%	34,0	297,769
2020	39,9	349,365	0%	0,0	0,000	21%	8,3	73,028	79%	31,5	276,337
2021	37,1	324,750	0%	0,0	0,000	21%	7,8	68,105	79%	29,3	256,645
2022	34,5	302,125	0%	0,0	0,000	21%	7,3	63,580	79%	27,2	238,545
2023	32,1	281,318	0%	0,0	0,000	21%	6,8	59,419	79%	25,3	221,900
2024	29,9	262,177	0%	0,0	0,000	21%	6,3	55,590	79%	23,6	206,586
2025	27,9	244,558	0%	0,0	0,000	21%	5,9	52,066	79%	22,0	192,491
2026	26,1	228,333	0%	0,0	0,000	21%	5,6	48,822	79%	20,5	179,512
2027	24,4	213,385	0%	0,0	0,000	21%	5,2	45,832	79%	19,1	167,553

Produkcia LFG na skládke - model a meranie



Verifikácia LFG – výpočet / meranie

Figure 2. Comparison of predicted (modeled) CH4 generation to: (A) measured surface emissions and (B) measured landfill gas recovery rates. Data from seven full-scale field cells as described in Spokas et al. (2006). The r2 for the linear regression shown in Figure 2 (b) is 0.997.



Zhrnutie:

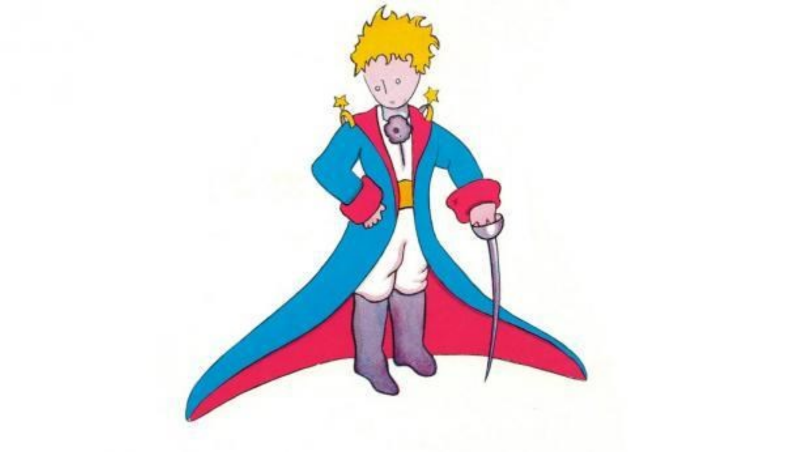
378 569 854 741 523 156 874

Kapitola XIII – Byznysmen

Na čtvrté planetě bydlil byznysmen. Byl to člověk tak zaměstnaný, že při příchodu malého prince nezvedl ani hlavu.

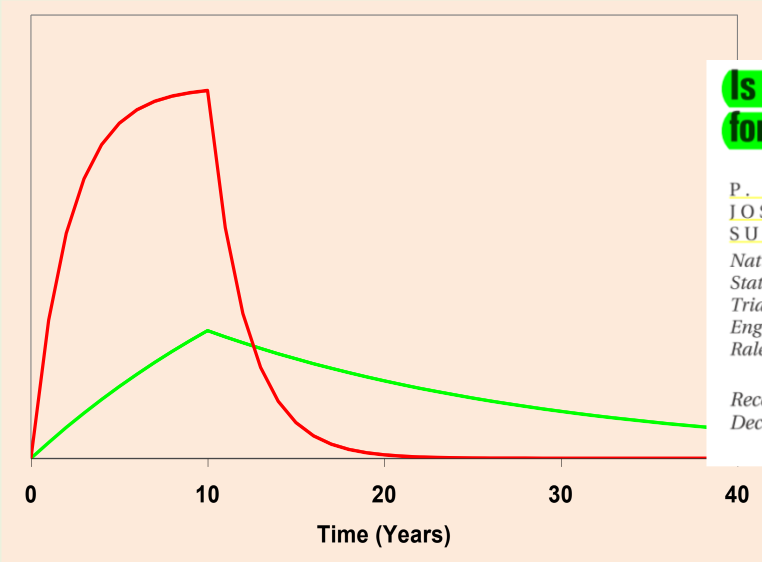
„Pět set jeden milión šest set dvacet dva tisíce sedm set třicet jedna. Já jsem vážný člověk**, já jsem přesný**."

„To znamená, že napíšu na papírek počet svých hvězd. A potom zamknu ten papír do zásuvky."



To je zábavné, pomyslil si malý princ. Je to dost poetické, ale ne moc **seriózní.**

Bioreactor landfill .

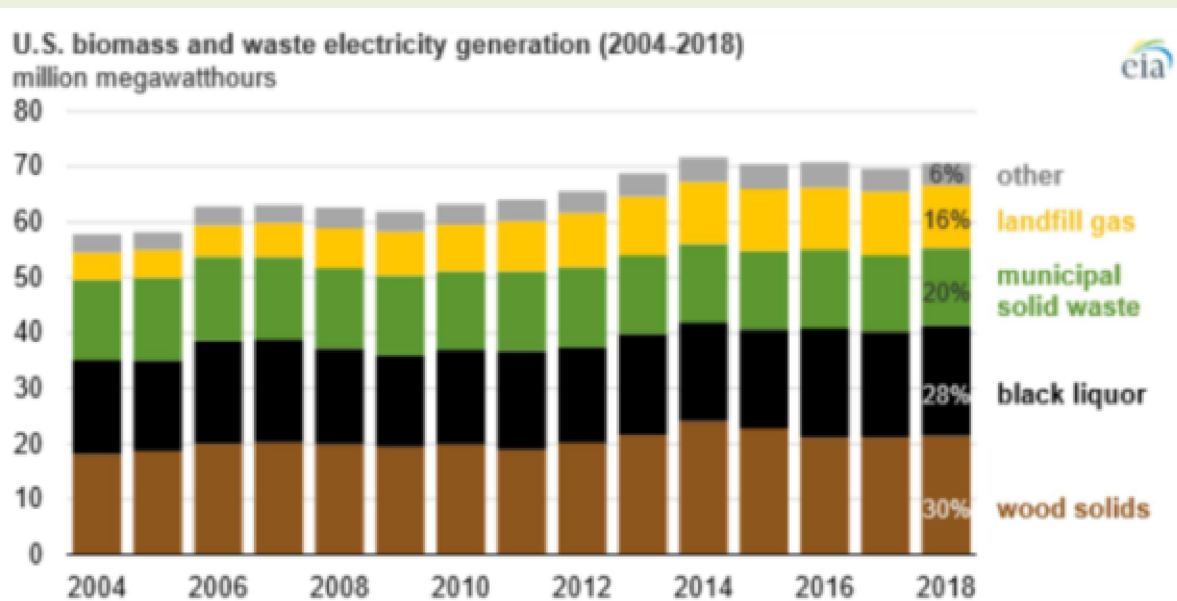


Is It Better To Burn or Bury Waste for Clean Electricity Generation?

P. OZGE KAPLAN,*,†
JOSEPH DECAROLIS,‡ AND
SUSAN THORNELOE§

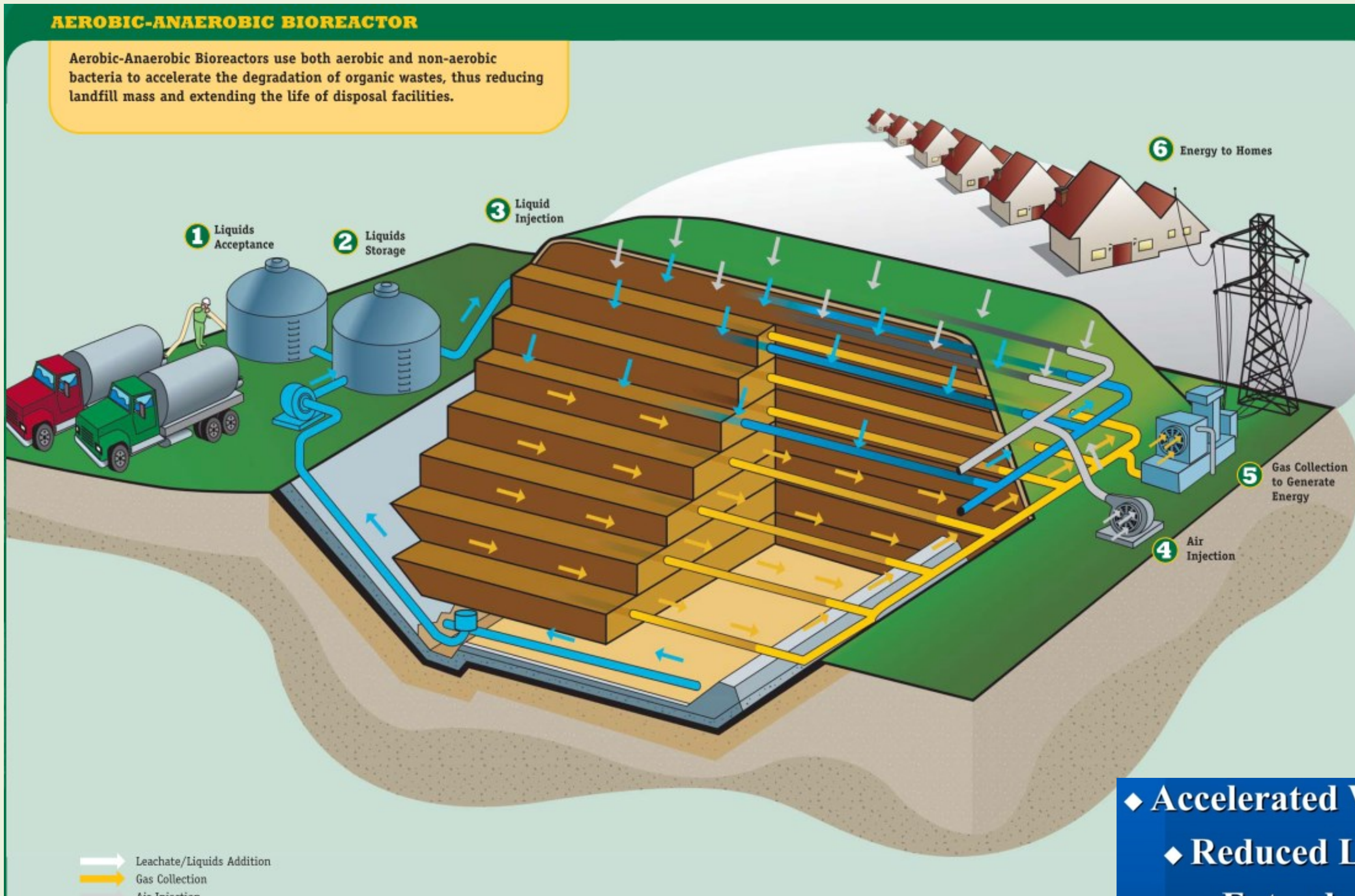
National Risk Management Research Laboratory, United States Environmental Protection Agency (U.S. EPA), Research Triangle Park, North Carolina 27711, and Department of Civil Engineering, North Carolina State University, Raleigh, North Carolina 27695

Received August 26, 2008. Revised manuscript received December 13, 2008. Accepted December 30, 2008.



Vývoj výroby elektrické energie z biomasy a odpadu v USA mezi lety 2004 a

1995-2000: Bioreaktor landfill



Infiltráciu priesakov reguluje PC na základe
čidiel vlhkosti v telese skládky a tvorby LFG

kombinácia **3 v jednom**:

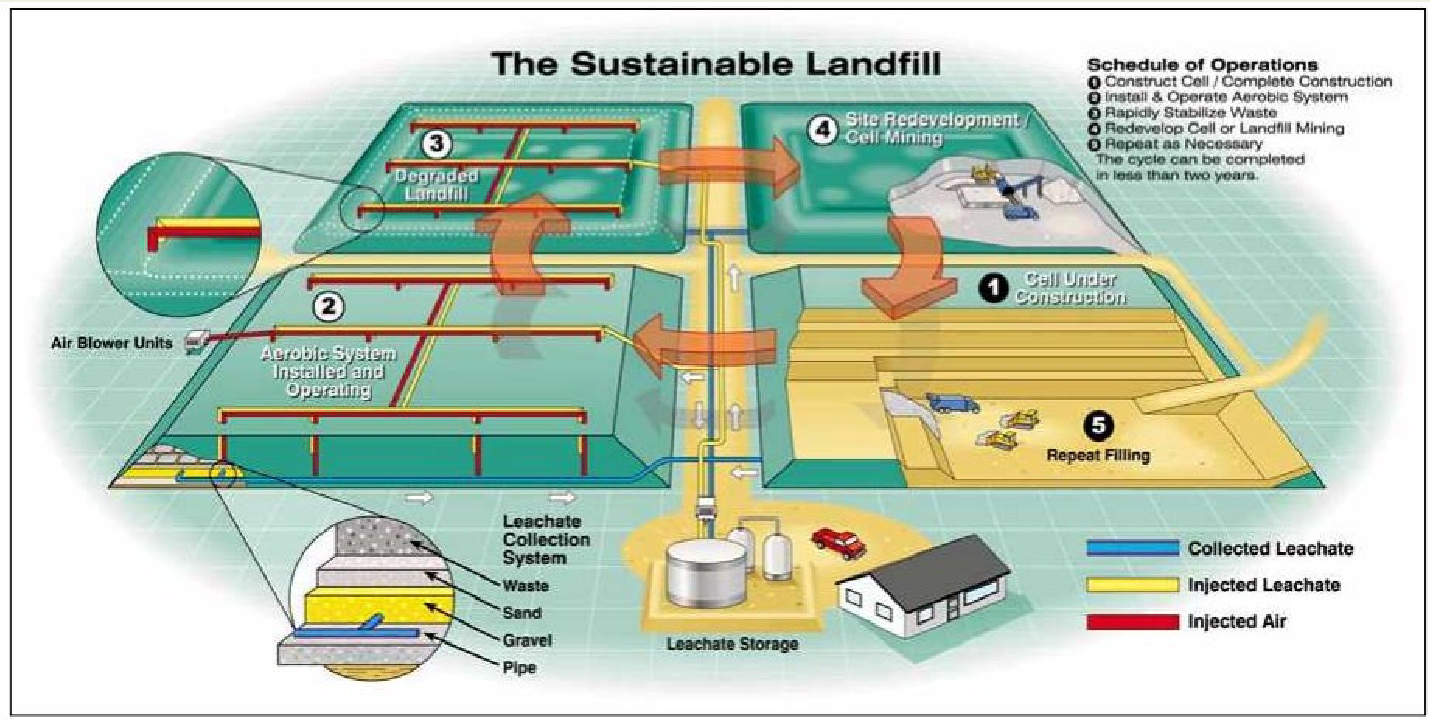
„SKLÁDKA + BIOplynka + KOMPOSTáreň“

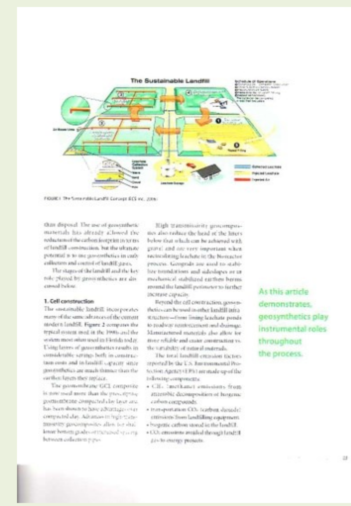
- Accelerated Waste Degradation
- Reduced Long Term Risks
- Extended Landfill Life
- Reduced Need for New Landfills
- More Efficient LFG Collection
- More Economical Leachate Treatment

SWANA

Budúcnosť skládkovania ?

(podľa ECS Inc. 2006)





Geosynthetics

The sustainable landfill revisited

Geosynthetics | April 2012

By Donald E. Hullings and Hal S. Boudreau III

Maximalizovať biodegradácia odpadu:

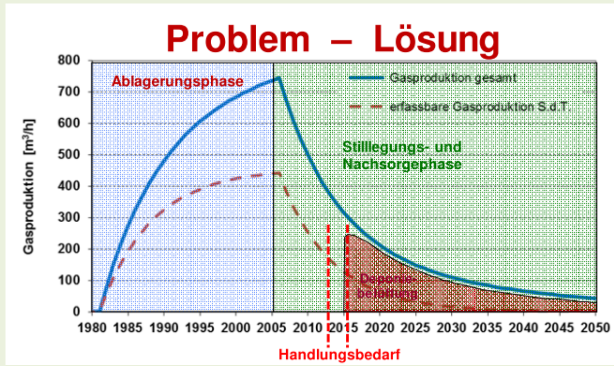
- podporovať anaeróbny rozklad odpadu = využitie LFG
- dokončiť rozklad „C“ v aeróbnych podmienkach = venting

Ziele und Verfahren der Deponiebelüftung

Deponiebelüftung als Klimaschutzmaßnahme
Workshop am 26. November 2013 in Berlin

Rainer Stegmann, Kai-Uwe Heyer, Karsten Hupe

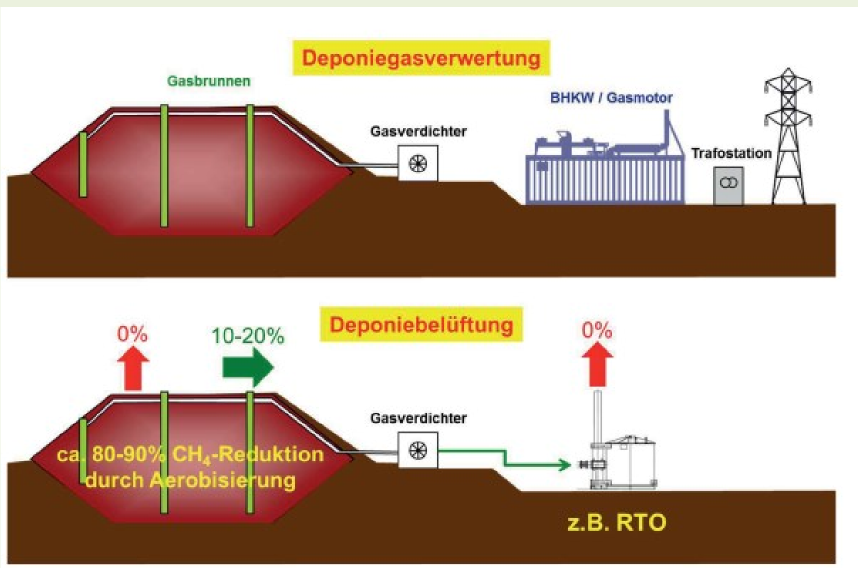
IFAS - Ingenieurbüro für Abfallwirtschaft, *Prof. Stegmann und Partner*
Schellerdamm 19-21, 21079 Hamburg
Tel.: 040 / 7711 0741 (42); Fax: 040 / 7711 0743; Email: info@ifas-hamburg.de

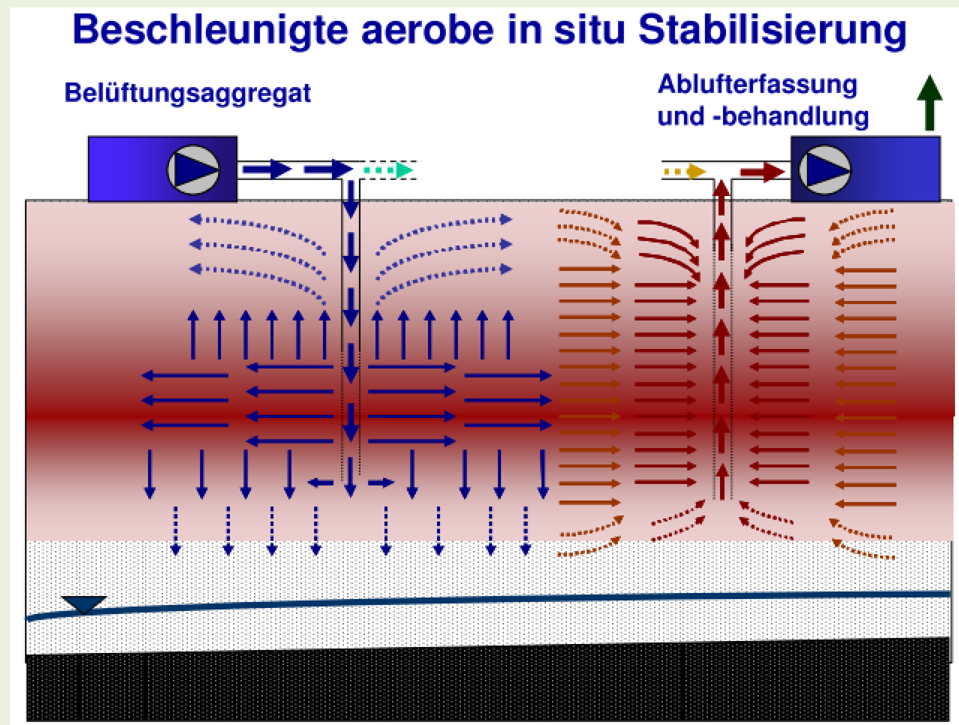


Deponiebelüftung als Klimaschutzmaßnahme und zur höherwertigen Folgenutzung

Ventilace skládky jako opatření na ochranu klimatu a pro kvalitativně vyšší následné využití

K.-U.Heyer; K. Hupe; R. Stegmann[1] (IFAS)[2]





Uplatniť LCA pre výber metódy eliminácie metánu z LFG !

Table 1. Overview of scenarios showing methane oxidation, gross gas collection efficiency and energy efficiency (bold indicates changes in comparison to the base scenarios).

Technology	Scenario	Oxidation in landfill cover (%)	Gross gas collection efficiency (%)	Electricity efficiency (%)	District heating efficiency (%)
No mitigation action	I-no mitigation	10			
Biocover	B1-base oxidation	80[1]			
	B2-high oxidation	**90**			
	B3-low oxidation	**70**			
Gas collection and energy utilisation	G1-base collection	10	60	27,8[2]	
	G2-high collection	10	**80**	27,8	
	G3-low collection	10	**40**	27,8	
	G1 with district heating (avg.)	10	60	27,8	**51,9**[2]
	G1 with district heating (natural gas)	10	60	27,8	**51,9**
	G1 with high electricity	10	60	**39,3**[3]	
	G1 with low electricity	10	60	**19,8**[3]	
	G1 with base collection 30 years[4]	10	60	27,8	
	G2 best	10	**80**	**39,3**	**51,9**
	G3 worst	10	**40**	**19,8**	
	G1 with biocover	80	**60**	**27,8**	

[1] Scheutz et al., 2014.
[2] Calculated average based on data provided by the Danish Energy Agency (from Energiproducenttællingen 2013).
[3] Respectively, high and low electricity efficiency based on data from the Danish Energy Agency (from Energiproducenttællingen 2013).
[4] In this scenario, the gas collection period was set at 30 years, from 2015 to 2045. In all other gas collection scenarios, the gas collection period was 20 years, from 2015 to 2035.

An environmental assessment of landfill gas mitigation, using a biocover system

Møller, J.; Kjeldsen, Peter; Scheutz, Charlotte

Published in:
Proceedings Sardinia 2017 / Sixteenth International Waste Management and Landfill Symposium

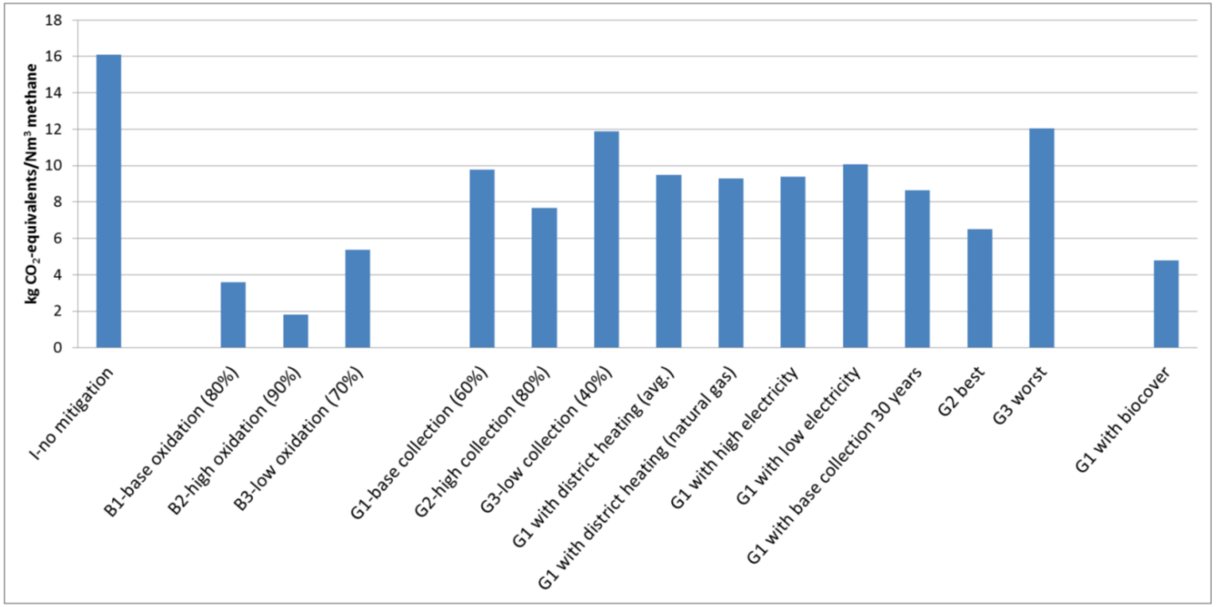
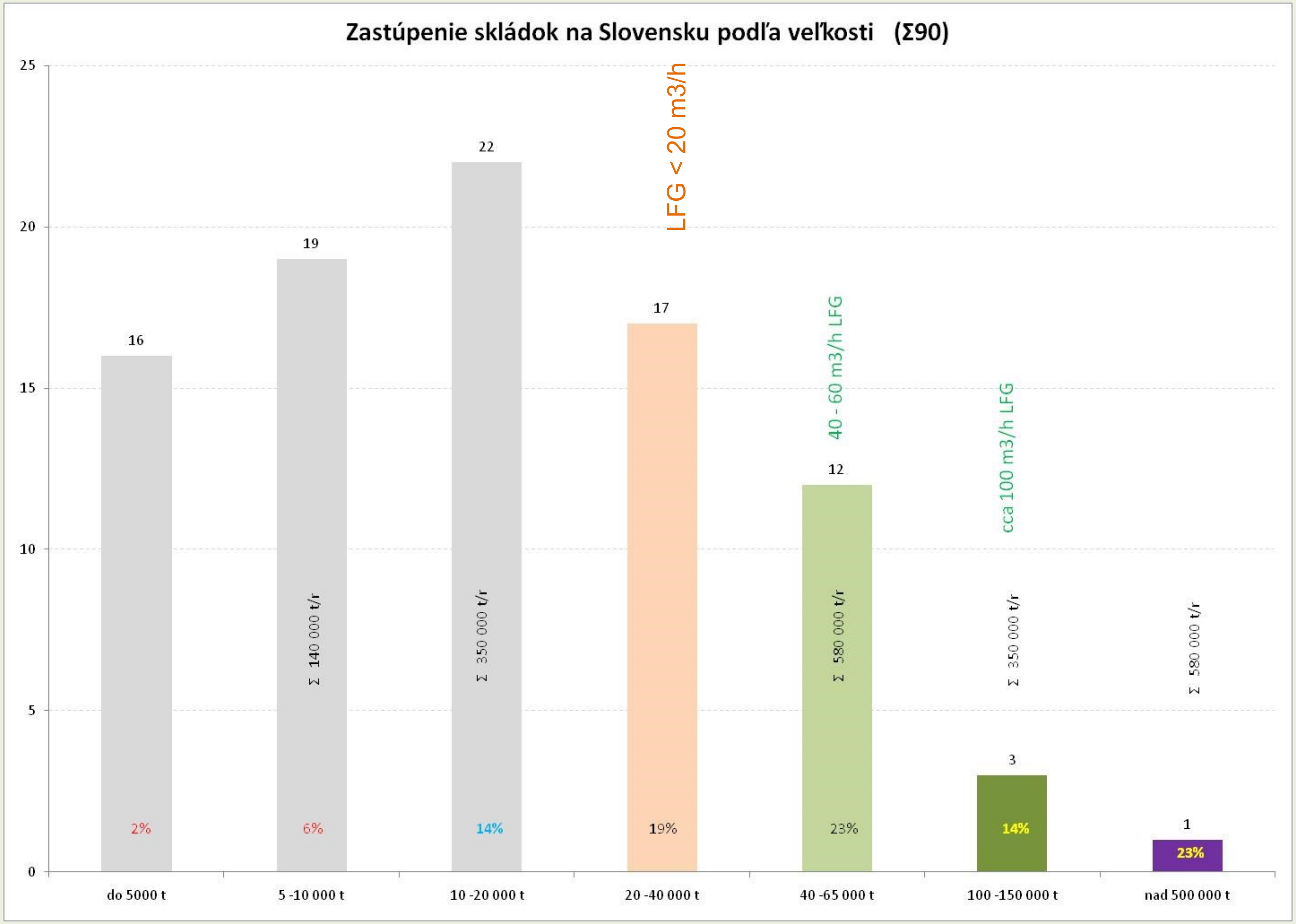


Figure 1. Total potential global warming impact in CO_2 equivalents in 15 scenarios with the implementation of varying methane mitigation actions at Danish waste landfills.

Skládkovanie odpadov na Slovensku
(skládky NNO)



11 skládok
s výrobou EL.

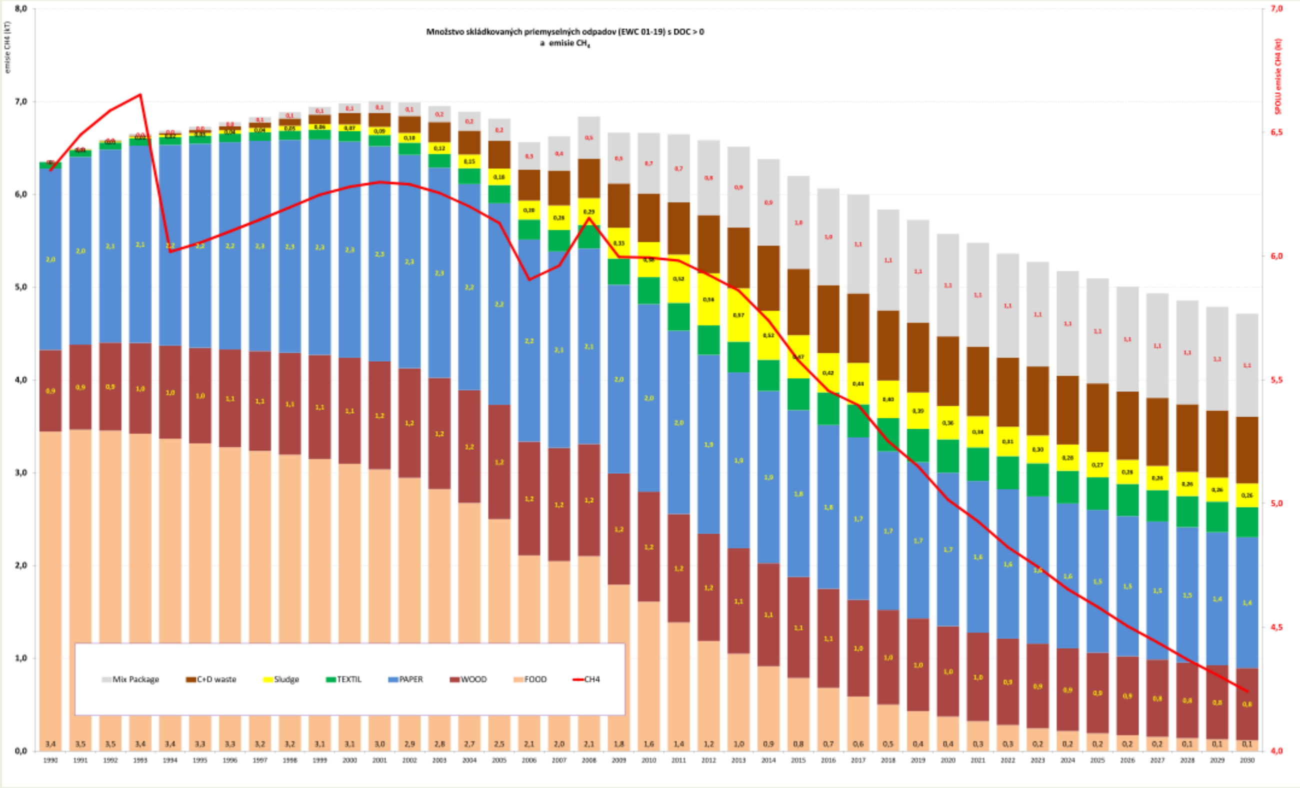
10 000 MWh
el./r

± 30-35% ???
skládkovaného
odpadu (t)
sa využíva na
výrobu elektriny !

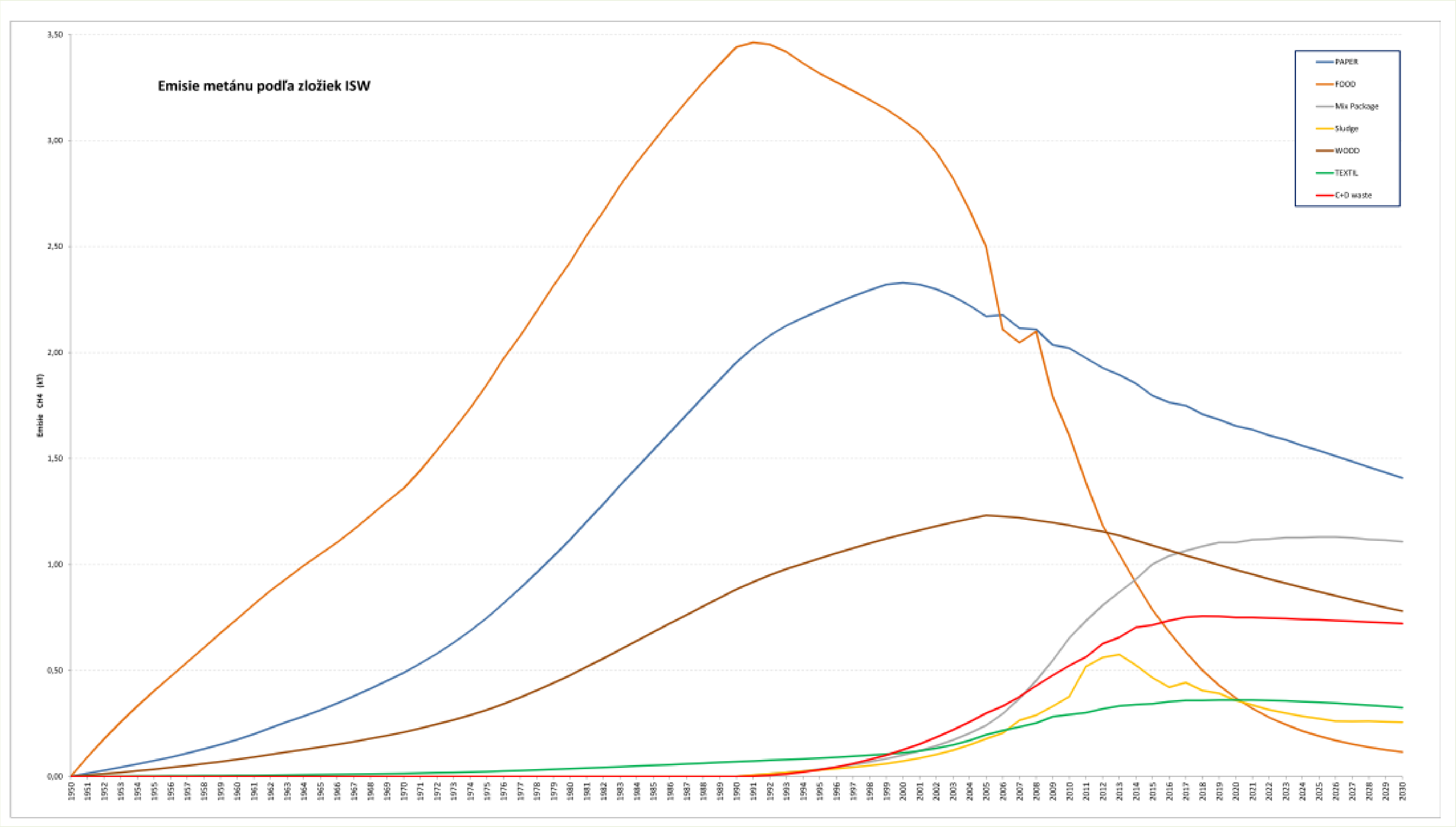
Skládkovanie ISW na Slovensku

	Amounts deposited in SWDS							
Year	FOOD	WOOD	PAPER	TEXTIL	C+D waste	Mix Package	Sludge	Deposited ISW (total)
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	127,380	25,993	41,960	2,785	5,129	5,321	4,256	212,825
1991	121,640	24,940	40,261	2,869	14,559	6,019	4,664	214,953
1992	116,078	23,930	38,630	2,956	23,588	6,808	5,112	217,102
1993	110,680	22,961	37,066	3,045	32,219	7,702	5,602	219,273
1994	105,434	22,031	35,565	3,137	40,449	8,712	6,138	221,466
1995	100,327	21,139	34,124	3,232	48,278	9,855	6,727	223,681
2000	74,403	17,191	22,217	4,412	85,956	18,254	12,658	235,091
2001	65,316	16,495	19,073	5,347	95,860	20,649	14,702	237,442
2002	56,468	15,827	16,374	6,481	104,232	23,358	17,077	239,816
2003	47,760	15,186	14,057	7,855	111,099	26,423	19,835	242,214
2004	39,088	14,571	12,068	9,520	116,462	29,889	23,038	244,636
2005	4,200	8,612	19,665	7,751	101,048	41,357	23,350	**205,981**
2006	39,313	8,032	9,386	7,134	123,202	51,477	37,843	**276,386**
2007	51,456	6,336	16,509	7,414	138,601	59,967	26,863	**307,143**
2008	6,093	5,985	6,860	10,288	133,308	66,149	34,171	**262,852**
2009	14,557	5,620	13,711	5,764	126,861	73,316	37,543	**277,376**
2010	5,707	4,430	9,147	5,653	111,794	61,435	73,096	**271,259**
2011	3,983	5,183	8,767	7,568	161,932	59,749	46,136	**293,317**
2012	7,482	3,388	10,225	6,989	99,121	56,160	38,385	**221,748**
2013	4,906	2,487	8,944	5,435	134,999	57,622	16,781	**231,174**
2014	3,276	2,234	6,604	5,156	64,387	63,732	10,616	**156,010**
2015	3,348	2,186	9,246	6,402	84,750	50,638	12,086	**168,653**
2016	2,418	1,775	11,327	5,632	77,854	43,572	33,030	**175,609**
2017	1,432	2,040	7,859	4,572	55,770	43,183	12,879	**127,733**
2018	1,750	1,696	9,550	4,920	42,857	41,641	19,632	**122,045**
2019	1,510	1,511	8,835	4,485	35,411	33,095	11,758	**96,562**

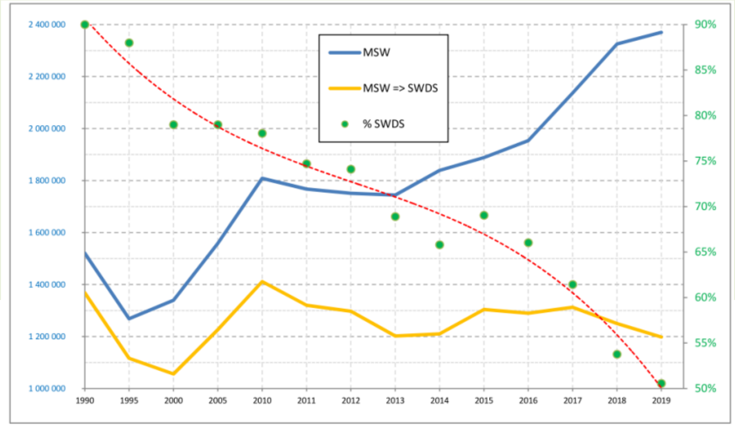
FOOD	WOOD	PAPER	TEXTIL	C+D waste	Mix Package	Sludge	Deposited ISW (total)
23,12	6,92	13,23	7,67	124,60	58,45	31,95	**265,95**
2,09	**1,84**	**9,36**	**5,20**	**59,33**	**42,43**	**17,88**	**138,12**



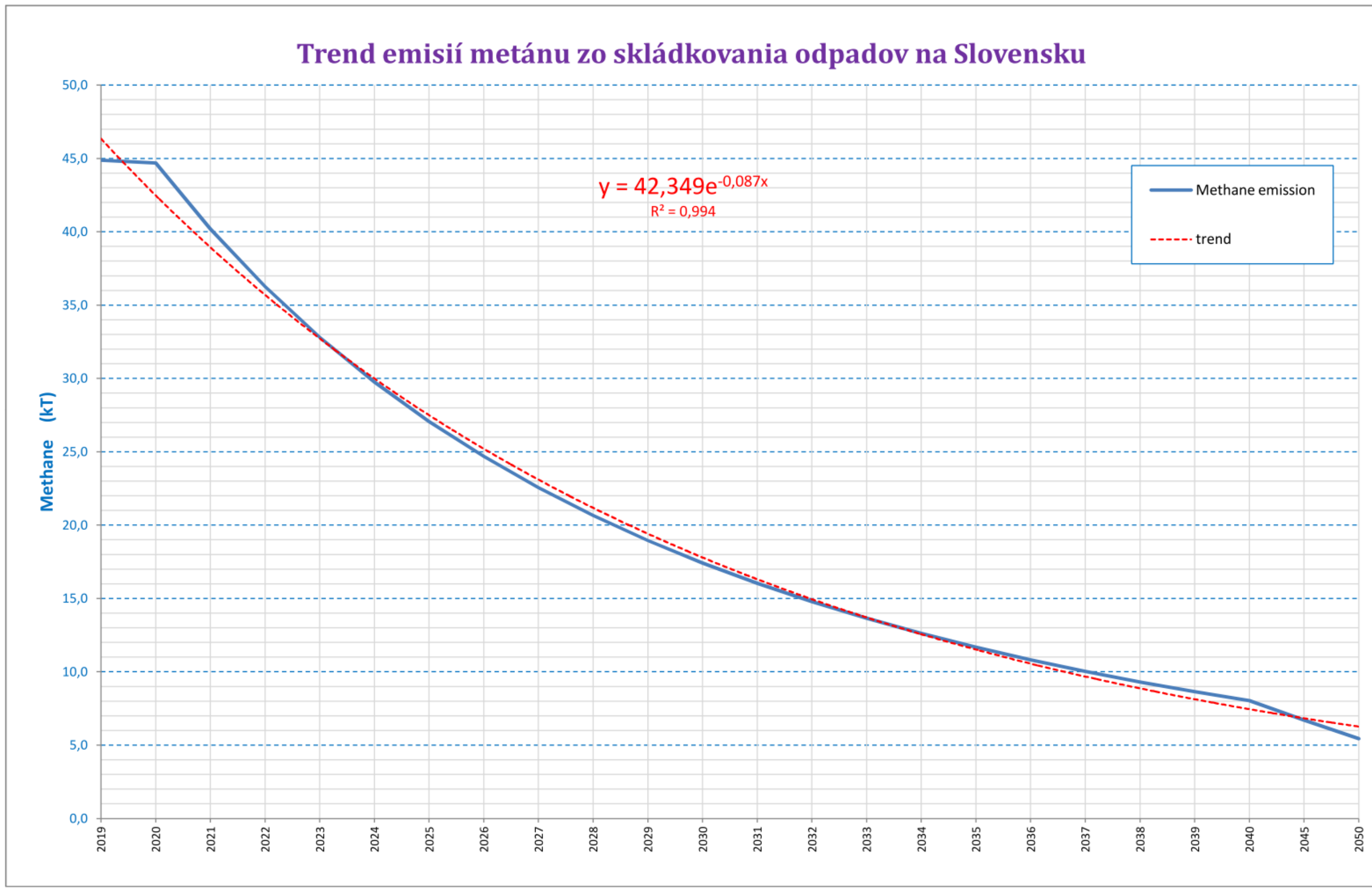
Skládkovanie ISW na Slovensku



ZERO landfill scenár.



	MSW	ISW	MSW + ISW
	Methane emission	**Methane emission**	**Methane emission ALL**
	Gg	Gg	Gg
2019	39,737	5,151	44,887
2020	39,664	5,015	44,7
2021	35,494	4,695	40,2
2022	31,855	4,404	36,3
2023	28,667	4,140	32,8
2024	25,867	3,898	29,8
2025	23,397	3,676	**27,1**
2026	21,213	3,471	24,7
2027	19,274	3,282	22,6
2028	17,547	3,107	20,7
2029	16,004	2,945	18,9
2030	14,621	2,794	**17,4**
2031	13,377	*2,654*	16,0
2032	12,255	*2,526*	14,8
2033	11,241	*2,406*	13,6
2034	10,321	*2,295*	12,6
2035	9,484	*2,192*	**11,7**
2036	8,721	*2,096*	10,8
2037	8,024	*2,006*	10,0
2038	7,386	*1,921*	9,3
2039	6,800	*1,841*	8,6
2040	6,261	*1,765*	**8,0**
2045	*5,050*	*1,650*	**6,7**
2050	*3,950*	*1,500*	**5,5**



Epilóg:

„Technikám manažmentu sa často prikladá až príliš veľký význam

namiesto toho,

aby sme najprv dôkladne pochopili,

ako to vlastne celé funguje.“

Ďakujem za pozornosť.

Ing. Marek Hrabčák, Prešov - Slovensko
Email: m.hrabcak61@gmail.com, Mobil: **0903 141 550**