Tables & Figures

Table 10.1. *Comparison of average income, solid waste generation, and % recyclables (Cointreau-Levine, 1994).*

Country	**Low Income**	**Middle Income**	**High Income**
Average Income (1988 US$/cap/yr)	350	1950	17500
Municipal Solid Waste Generation (t/cap/yr)	0.2	0.3	0.6
% Recyclables	15	30	60

Table 10.2. *Regional and total 1990 and 2001 generation of high organic industrial wastewater*: often treated in municipal wastewater systems (World Bank, 2005). *All other industrial wastewater discussed in Chapter 7.*

	kg BOD/day		Kg BOD /worker /day		Percentage (%) of 2001 total by industry							
					Primary metals	Paper Pulp	Chemicals	Food Beverages	Mining, Ceramics Glass	Textiles	Wood	Other
Year	**1990**	**2001**	**1990**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**
OECD North America	**T** 3060963 **A** 1020321	**T** 2577720 **A** 859240	0.2	0.17	9.3	15.4	10.7	44.2	0.17	6.7	3.3	10
OECD Pacific	2162770 540724	1746561 436640	0.15	0.18	8	20.2	6	46	0.17	7.3	3	9
Europe	5153933 239606	4770100 234770	0.18	0.17	9.3	22.4	9	40	0.25	7.4	3	9
Countries inTransition	3403651 127910	2424562 161637	0.15	0.21	13	8	6.3	50	0.22	14	3.5	5
Sub-Saharan Africa	592665 511801	511801 511801	0.23	0.25	3	12	6.1	60	0.14	13	4	2.2
Northern Africa	409555 120073	387394 96853	0.2	0.18	9.7	4.4	6.3	49.6	0.45	24.5	1.3	3.7
Middle East	255047 26683	298519 29852	0.19	0.19	9	11.5	10	52	0.63	11	2.7	4
Caribbean, Central, & S America	1481857 87174	1322362 82445	0.23	0.24	4.5	11	8	61	0.15	11	2	2.5
Developing countries East Asia	8298777 830647	7678749 851881	0.14	0.16	11	14.2	9.8	36	0.31	15	4.1	9.5
Developing countries South Asia	1655622 351943	2045767 409045	0.18	0.16	5.3	7.3	6	42.3	0.37	35.4	1.3	2.1
Developed countries	**10377666** **600217**	**9094381** **509000**										
Developing countries	**12693523** **241000**	**12244592** **248500**										

T – Total A – Average

Table 10.3. *Estimated global trends for CH_4 and N_2O emissions from landfills and wastewater from UNFCCC national inventories and projections.* ***(a)*** *CH_4 and N_2O emission trends from landfills and wastewater from Scheele and Kruger (2005). N_2O trends from human sewage only.* ***(b)*** *GHG emissions from waste management from Konte, 2005 (http://ghg.unfccc.int). Includes landfill CH_4, wastewater CH_4 and N_2O, and CO_2 from incineration of fossil C. Totals for Annex I countries only are shown in brackets. The year 2000 was not included because of a limited number of reporting countries.* ***(c)*** *SRES scenarios AIB and B2 (Nakicenovic et al., 2000). See discussion in text. [Mt CO_2e/year]*

Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2050 (SRES AIB/B2)**
(a) Landfill CH_4	756	777	777	819	882	945	1008	
(a) Wastewater CH_4	357	399	420	441	462	483	504	
(a) Total CH_4	1113	1176	1197	1260	1344	1428	1512	
(b) Total CH_4 [Annex I]	716 [646]	831[630]						
(c) Total CH_4 (SRES AIB/B2)	1281/1302							4011/4662
(a) Wastewater N_2O	73	78	82	86	90	93	97	
(b) Total N_2O[Annex I]	41.5 [39]	42.5[1.5]						
(b) CO_2 from Incineration of fossil C [Annex I]	33.01 [33]	37.01[37]						

Table 10.4. *Qualitative comparison of GHG mitigation strategies from waste management. (IPCC, 2001, *modified using landfill gas recovery efficiency from Spokas et al., 2005)*

Mitigation options			**Effectiveness**	**Technical requirement**	**Applicability**	**Cost**
Solid Waste	waste reduction		high	low to high (depending on site)	high	low to moderate
	waste diversion	recycling	high (if focused on organic waste)	low to moderate	high	low to moderate
		composting	high (if well managed)	low	high	low
		incineration	high	high	low to moderate (less applicable for developing countries)	high
	landfilling with CH_4 recovery		high (*>85% of CH_4 recoverable)	moderate	high (especially in the near-term)	low to moderate (depending on site)
Wastewater	waste reduction		high	low to high (depending on site)	high	low
	waste diversion		high	low	high	low
	aerobic treatment		high	moderate to high	low to moderate	moderate to high
	CH_4 recovery		moderate to high	moderate	high (especially in near term)	low to moderate (depending

					on site)

Table 10.5. *Cost analysis for GHG gases from waste management strategies compared to landfilling (Bates and Haworth, 2001). AD= anaerobic digestion; MBP=mechanical-biological pretreatment. The 2001 rate of landfill gas recovery for the EU as a whole was estimated to be 20% while 70% was assumed to be the maximum %* CH_4 *recovery over the lifetime of an individual site.*

Option			Composting	Composting	AD	AD	MBP	Incineration	Incineration	Paper recycling
Applicability (1=UK; 2=Netherlands)			1	2	1	2	1+2	1	2	1+2
cost per t waste treated										
capital cost	• 1990/t waste/yr		154	182	172	208	154	228	517	455
operating cost	• 1990/t waste		32	37	26	54	32	22	25	154
diposal of residues	• 1990/t waste		8	8	3	0	20	0	0	0
income from energy	• 1990/t waste		0	0	-5	-3	0	-15	-15	0
other income	• 1990/t waste		-10	-10	-17	0	0	0	0	-207
avoided cost of landfilling	• 1990/t waste		30	30	30	30	30	30	30	30
annualised cost per t waste treated										
at 2% discount rate	• 1990/t waste		13	27	-10	37	35	-9	12	-59
at 4% discount rate	• 1990/t waste		15	29	-8	39	37	-6	18	-53
at 6% discount rate	• 1990/t waste		17	32	-6	42	39	-3	25	-46
total reduction in GHG emissions										
Assuming 20% recovery of LFG	t CO2 eq/t waste		1.2	1.2	1.3	1.3	1.2	1.1	1.1	1.2
Assuming 70% recovery of LFG	t CO2 eq/t waste		0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5
Cost-effectiveness(CH4 and CO2)										
Assuming 20% recovery of LFG										
at 2% discount rate	• 1990/t CO2 eq		10	16	-8	29	28	-9	11	-47
at 4% discount rate	• 1990/t CO2 eq		12	17	-6	31	30	-6	17	-43
at 6% discount rate	• 1990/t CO2 eq		13	19	-4	33	31	-3	24	-37
Assuming 70% recovery of LFG										
at 2% discount rate	• 1990/t CO2 eq		28	41	-19	73	75	-23	31	-126
at 4% discount rate	• 1990/t CO2 eq		32	46	-15	78	79	-16	47	-114
at 6% discount rate	• 1990/t CO2 eq		36	51	-11	83	83	-8	65	-100

Table 10.6. *Costs for mitigating CH_4 emissions from waste*

a Cost-effectiveness of mitigating CH_4 emissions from waste in the Netherlands, including low- to high-technology strategies and assuming a 20 year project life (de Jager and Blok, 1996).

measure	**capital cost**	**operating cost**	**profit**	**CH_4 emission reduction**	**net cost**	**net cost**
	$/ t/yr ($CH_4$)	$/ t/yr ($CH_4$)	$/ t/yr ($CH_4$)	kt/yr (CH_4)	$/t CH_4	$/t CO_2e
landfill CH_4 recovery with onsite electrical generation	500	28	120	72	-48	-2.3
recovery and utilisation: upgrading of waste gas to natural gas quality	700	105	200	31	-35	-1.7
recovery: flaring	85	0.3	0	51	8	0.4
aerobic composting		950	650	5	300	14.3
anaerobic digestion		1,400	750	1	650	31.0
incineration		10,000	2150	6	7850	373.8

b. Range of investment costs for onsite electrical generation from landfill gas (Willumsen, 2003).

System component	**Cost (2003 US$/kW installed power)**
landfill gas collection (vertical wells or horizontal collectors; header)	200-400
landfill gas recovery and conditioning (blower/compressor, dehydration, flare)	200-300
landfill gas utilization (engine)	850-1200
planning and design	250-350
Total	**1500-2250**

Table 10.7. *Policies and measures for the waste management sector.*

Policies and Measures	Activity Affected	GHG Affected	Type of Instruments
Waste prevention, reuse, and recovery			
Extended Producer Responsibility (EPR)	Manufacturing of products Recovery of used products Disposal of waste	CO_2 CH_4 F-gases	Regulation Voluntary
Unit pricing / Variable rate pricing / Pay-as-you-throw (PAYT)	Recovery of used products Disposal of waste	CO_2 CH_4	Economic incentive
Landfill tax	Recovery of used products Disposal of waste	CO_2 CH_4	Economic incentive
Separate collection and recovery of specific waste fractions	Recovery of used products Disposal of waste	CO_2 CH_4 F-gases	Regulation
Subsidies for activities such as reuse, recycling, and composting	Recovery of used products Disposal of waste	CO_2 CH_4	Subsidy
Promotion of the use of recycled products	Manufacturing of products	CO_2 CH_4	Regulation Voluntary
Reduction of landfill CH_4 emissions and energy recovery from landfill gas			
Reduction in biodegradable waste in landfills	Disposal of biodegradable waste	CH_4	Regulation
Standards for landfill performance to reduce landfill CH_4 emissions by capture and combustion of landfill gas with or without energy recovery	Management of landfill sites	CH_4	Regulation
Incineration (waste-to-energy)			
Subsidies for construction of incinerator, combined with standards for energy efficiency	Performance standards for incinerators	CO_2	Regulation
Tax exemption for electricity generated by waste incinerator and for waste disposal with energy recovery	Energy recovery from incineration of waste	CO_2	Economic incentive
Reduction of post-consumer F-gas emissions			
Substitutes for F-gases used commercially	Production of fluorinated gases	F-gases	Regulation Economic incentive Voluntary
Collection of fluorinated gases from end-of-life products	Management of end of life products	F-gases	Regulation Voluntary
Emission reductions from waste water treatment			
Collection of CH_4 from waste water treatment system	Management of waste water treatment system	CH_4	Regulation Voluntary
JI and CDM in waste management sector			
JI and CDM		CO_2 CH_4	Kyoto mechanism

Figures

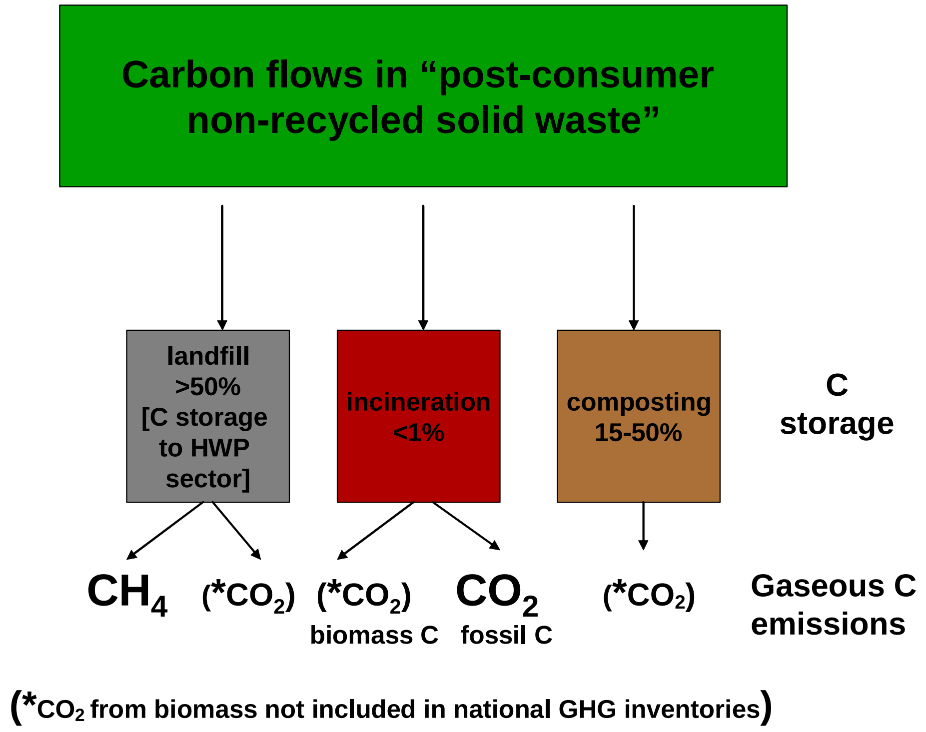
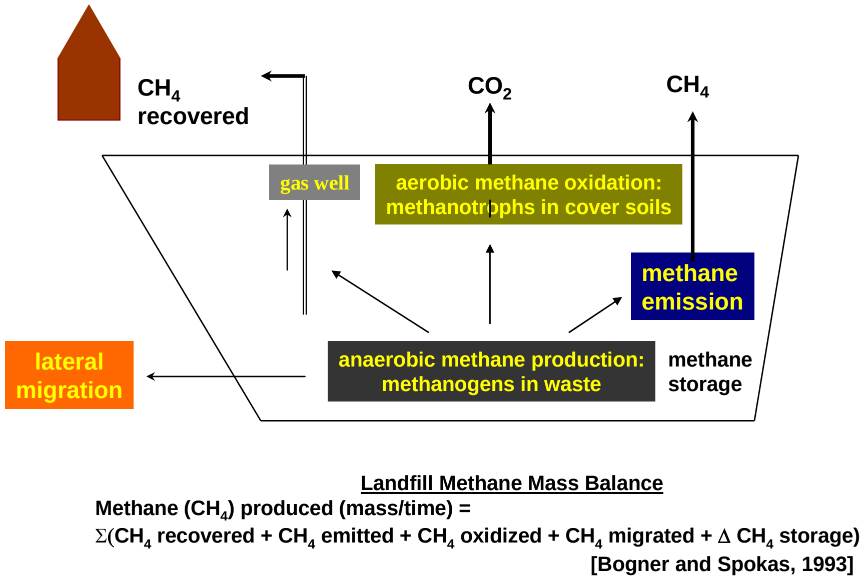


Figure 10.1. *Carbon flows through major waste management systems including C storage and gaseous C emissions. Note that CH_4 from landfills and CO_2 from incineration of fossil C are the emissions included in national GHG inventories.*



a. Landfill methane mass balance: pathways for methane generated in landfilled waste, including methane emitted.

b. Pathways for N_2O and CH_4 emissions through wastewater systems.

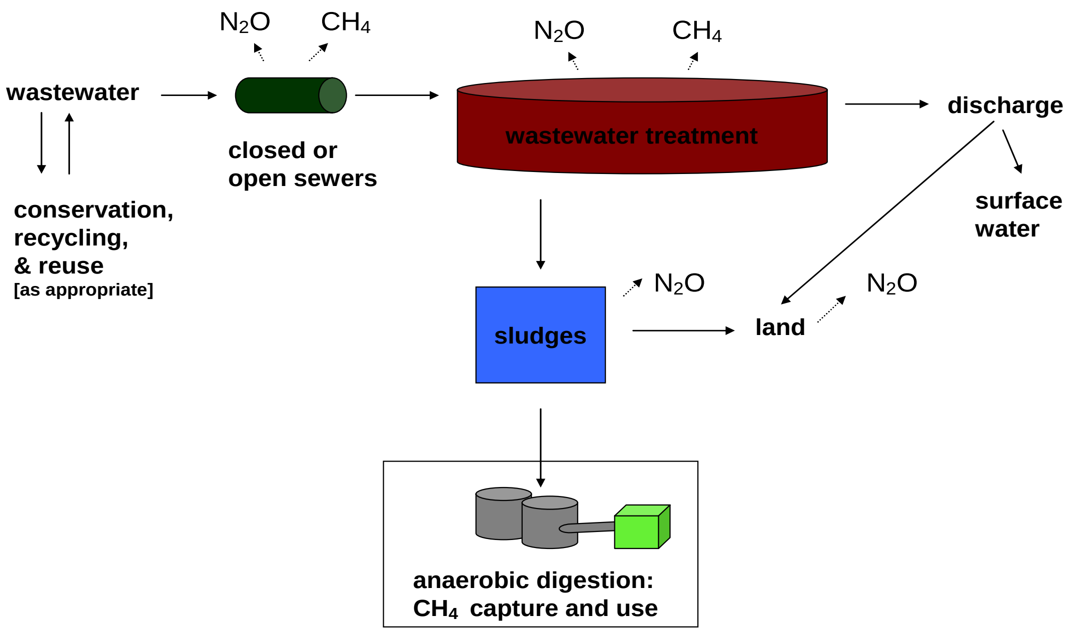


Figure 10.2. *Pathways for GHG emissions from landfills and wastewater systems.*

Figure 10.3a. *Annual rates of post-consumer waste generation 1971-2002 (Tg) using energy consumption surrogate.*

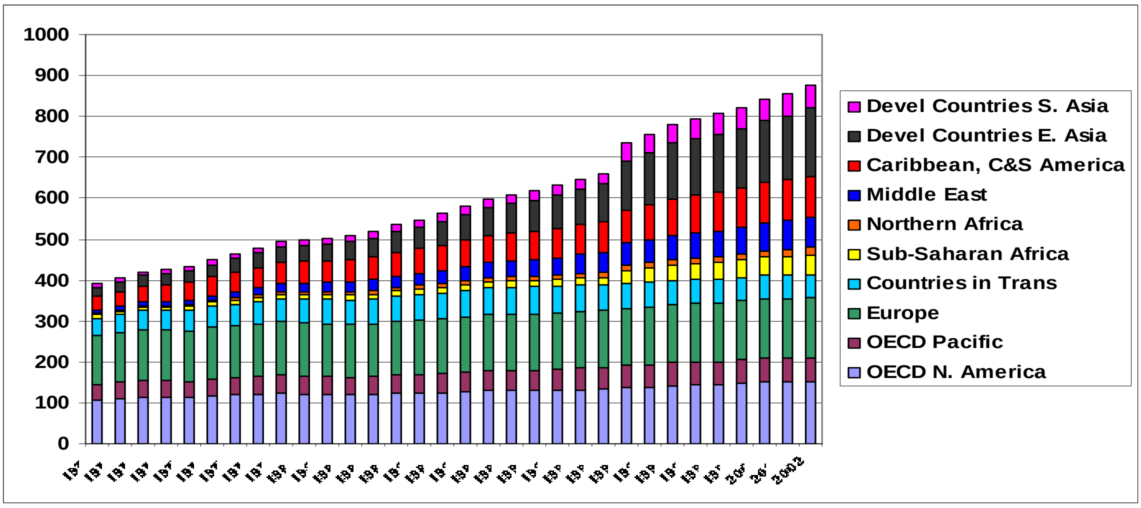
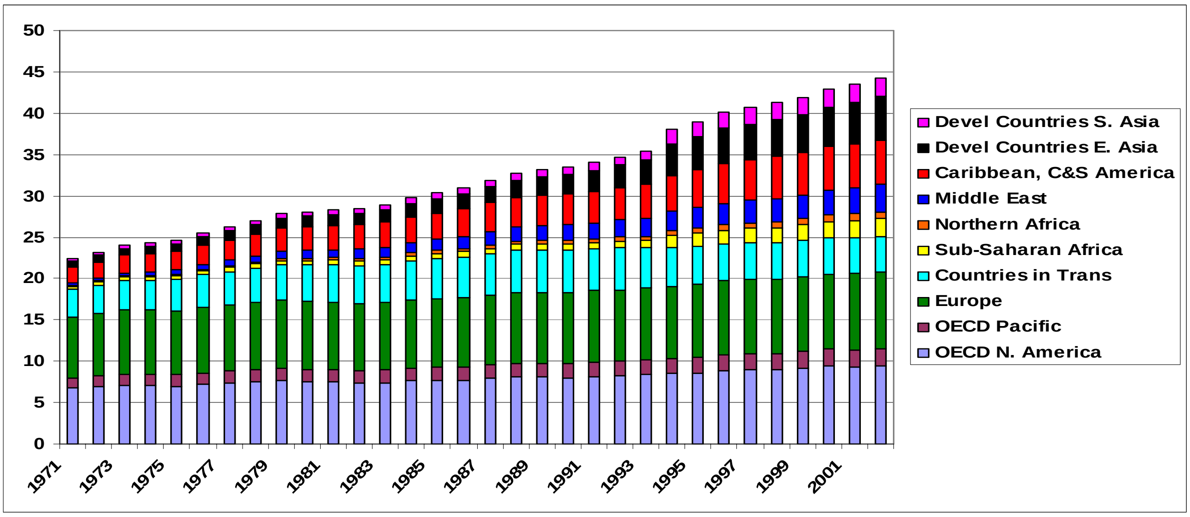


Figure 10.3b. *Minimum annual rates of carbon storage in landfills from 1971-2002 (Tg C).*



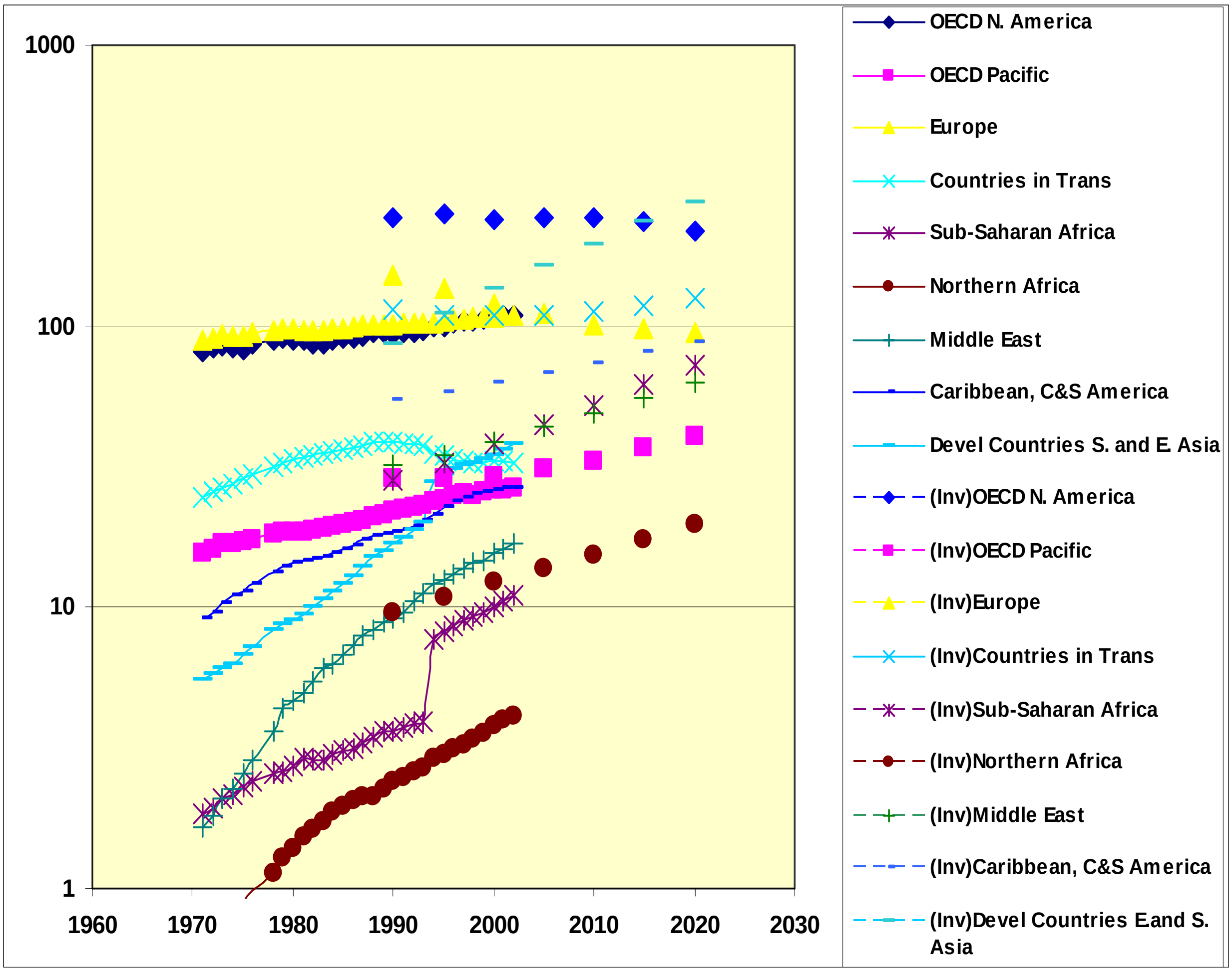
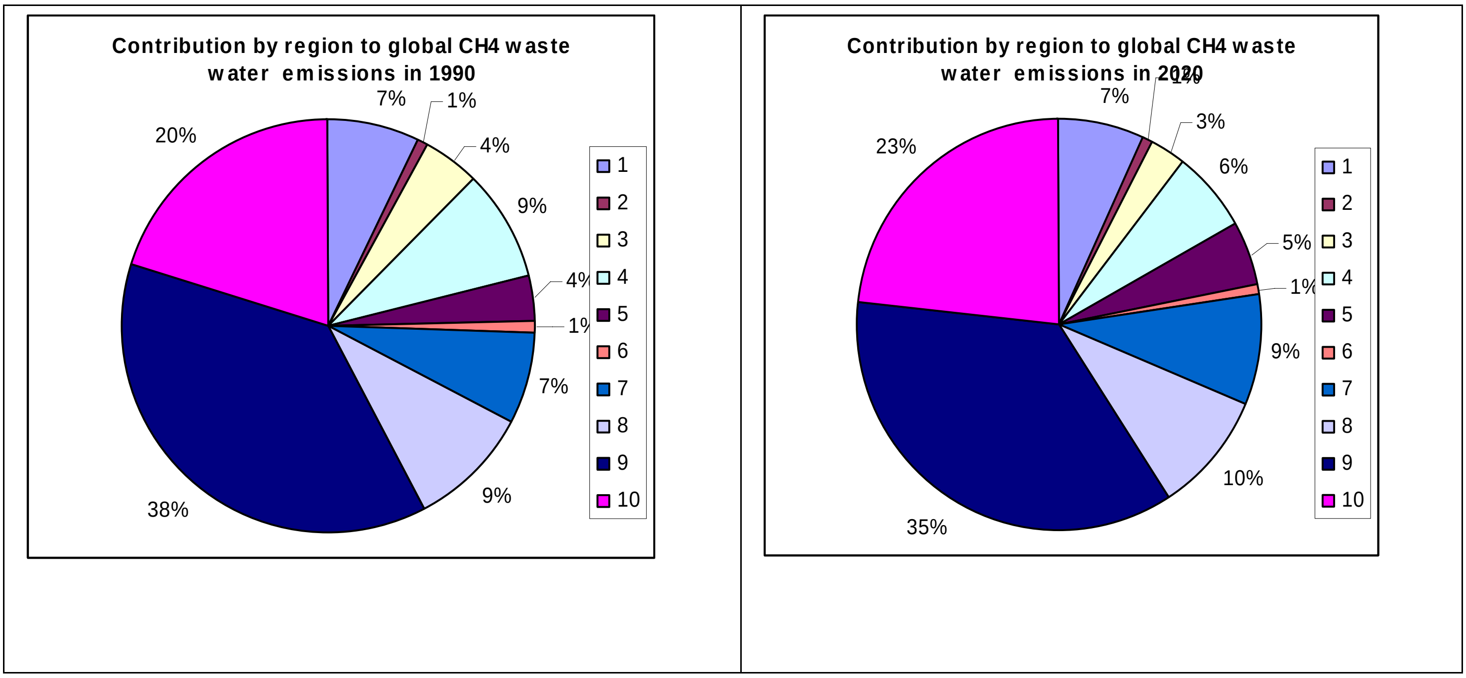


Figure 10.4. *Regional landfill CH_4 emission trends. [Mt CO_2e]*

(1) IPCC national inventory estimates and projections for 5-year intervals from 1990-2020 (Scheele and Kruger, 2005, in review). Labeled "Inv".

(2) Annual emission trends from 1971-2002 using methodology from Bogner and Matthews, 2003.

a. Regional distribution of CH_4 emissions from wastewater and human sewage in 1990 and 2020.



b. Regional distribution of N_2O emissions from human sewage in 1990 and 2020.

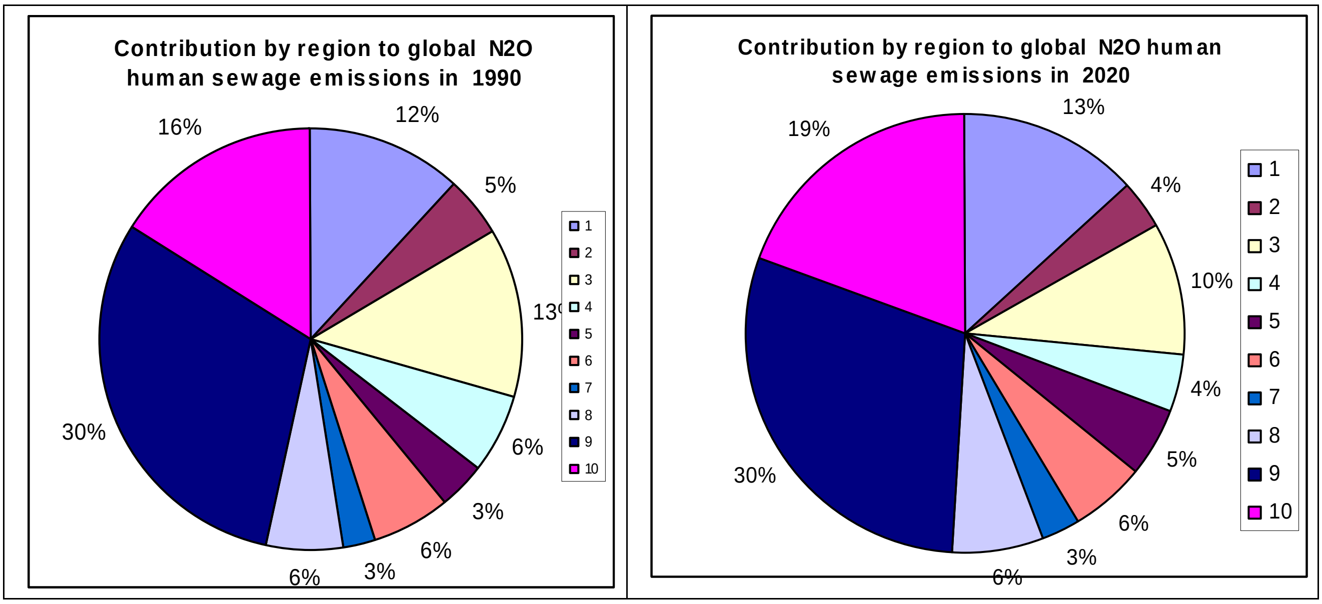
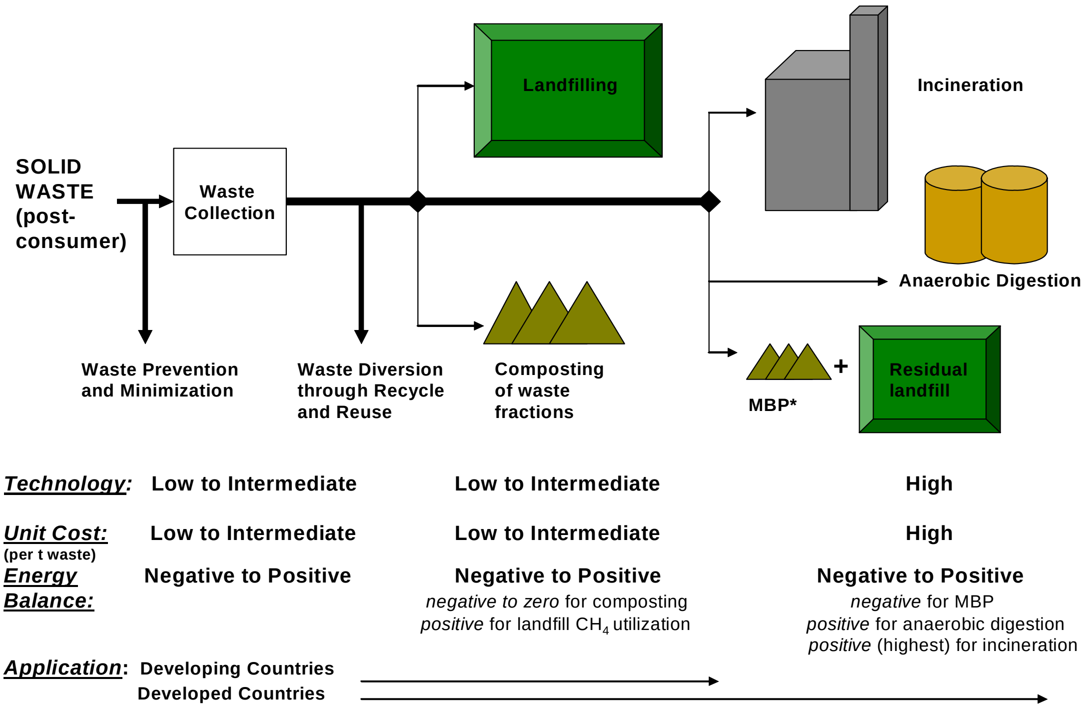


Figure 10.5. *Regional distribution of CH_4 and N_2O emissions from wastewater and human sewage in 1990 and 2020 (UNFCCC/IPCC, 2004).*
The numbered regions are: 1) OECD N America; 2) OECD Pacific; 3) Europe; 4) Countries in transition; 5) Sub-Sahara Africa; 6) N Africa; 7) Middle East; 8) Caribbean and S America; 9) E Asia; 10) S Asia. See Table 10.3 for totals.



***MBP: Mechanical Biological Pretreatment.**

Figure 10.6. *Technology gradient for waste management: Low- to high-technology options applicable to major urban areas*