Life Cycle Assessment and CDM Potental of Waste Processing Systems

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Where is the waste & the energy ?

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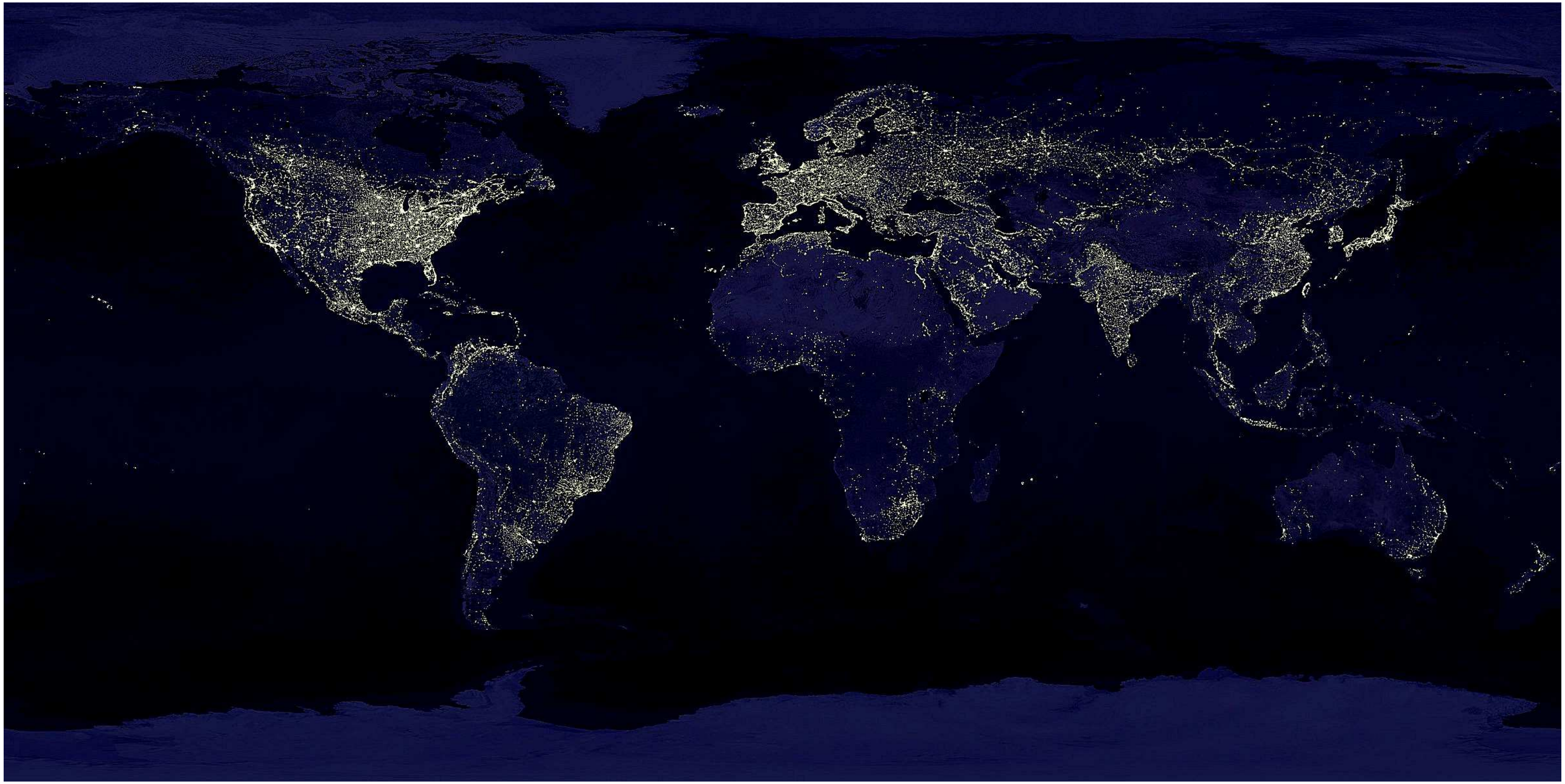

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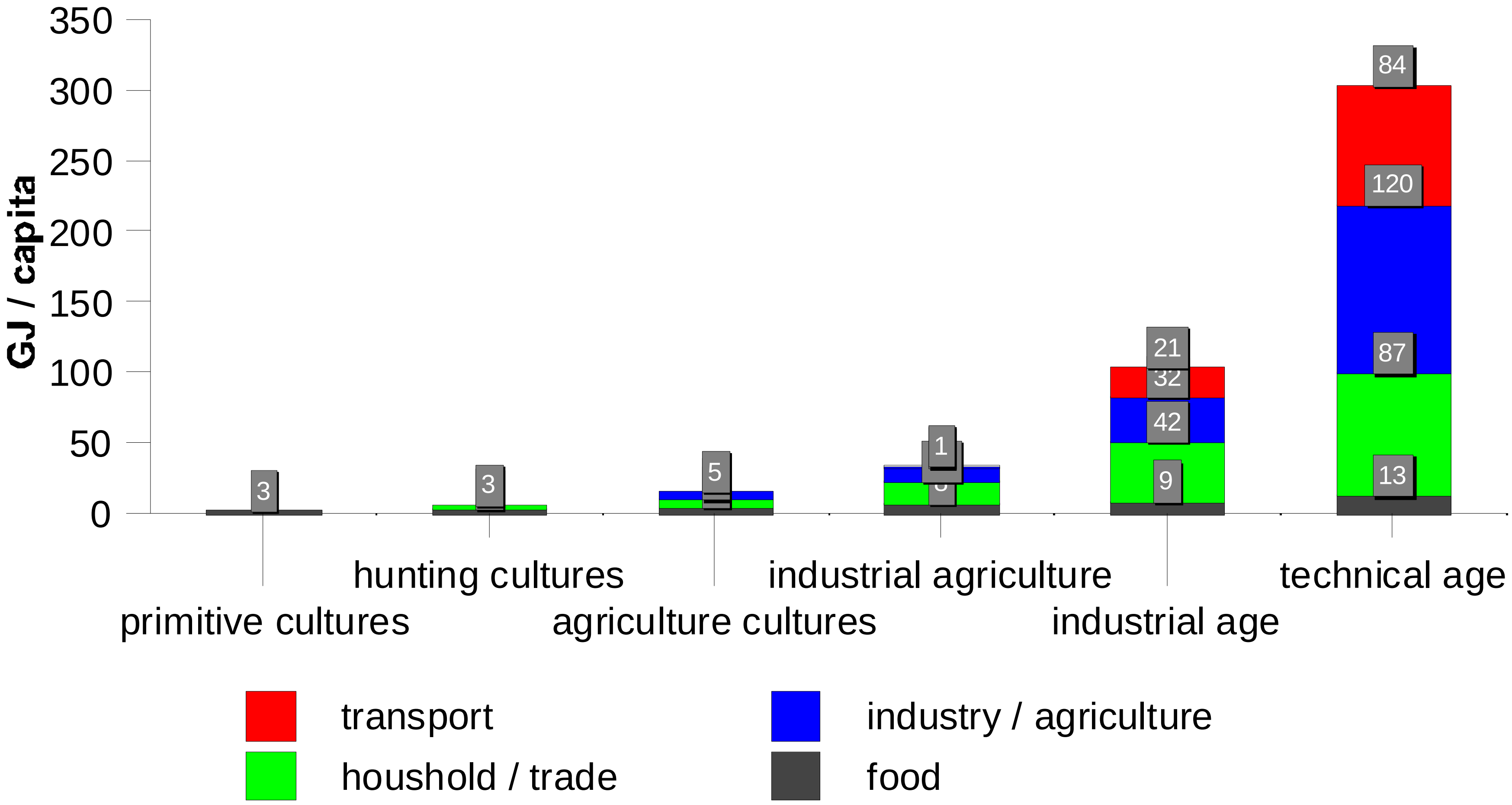
Energy Demand



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Human Habitat Design of Tomorrow

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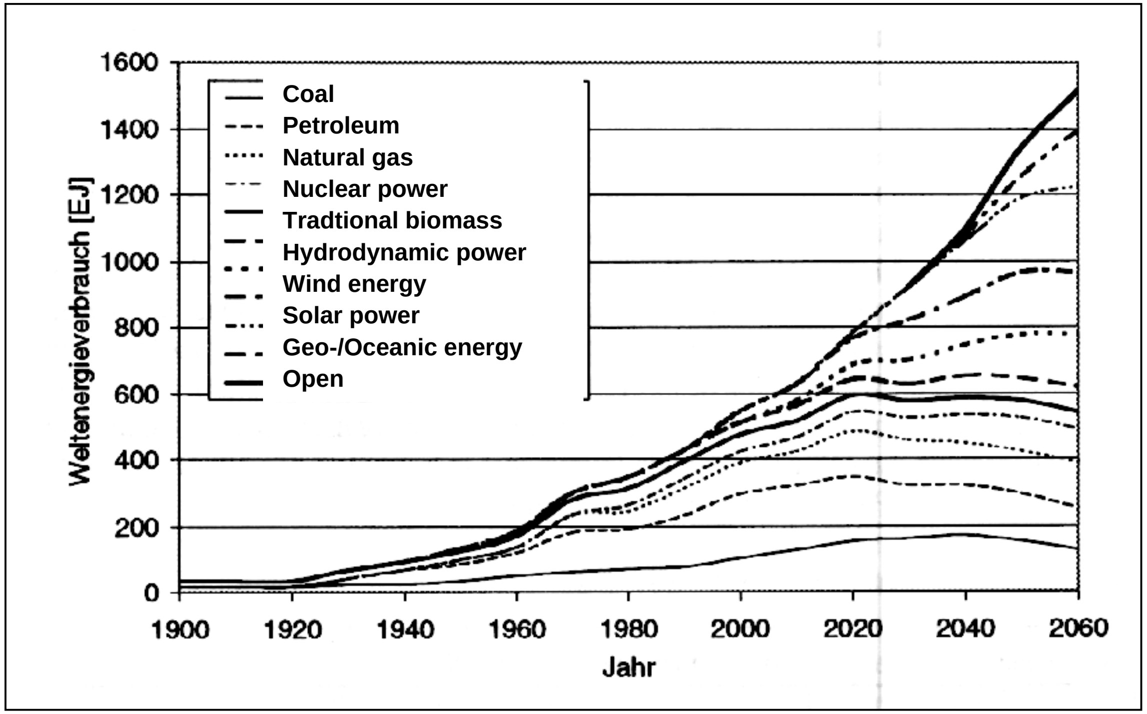
• Conservation of resources
- Energy

Global Primary Energy Consumption



SHELL, 1999 E= Exa 10^{18}

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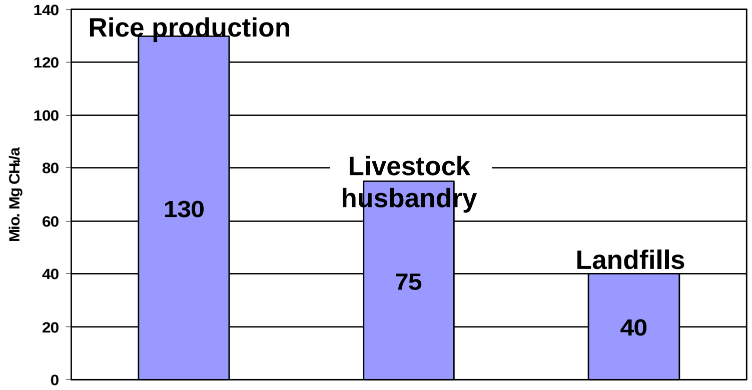
Human Habitat Design of Tomorrow

- **Conservation of resources**

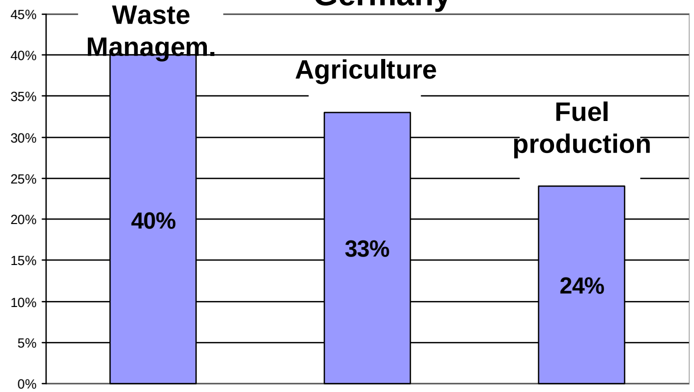
- Climate

Green house effect by landfill emissions

Anthropogenic Methane Emissions World



Anthropogenic Methane Emissions Germany



Human Habitat Design of Tomorrow

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- **Social Security**
- **Peacekeeping**

Human Habitat Design of Tomorrow

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- **Social Security**
- **Peacekeeping**

Water comes in three qualities:
- too much
- too little or
- too dirty

Human Habitat Design of Tomorrow

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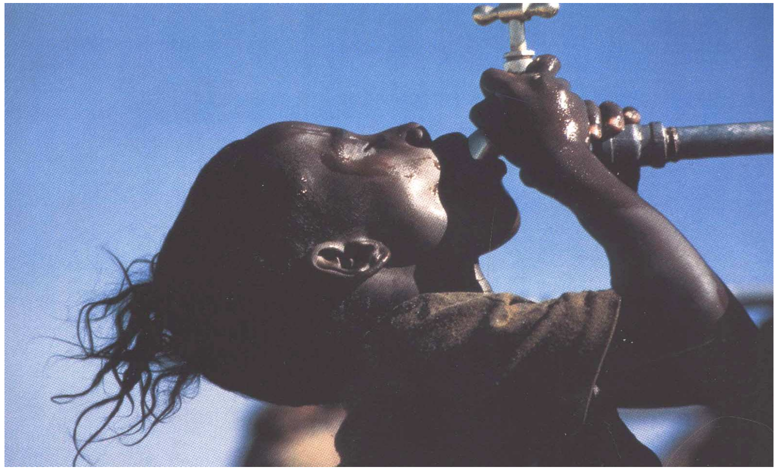
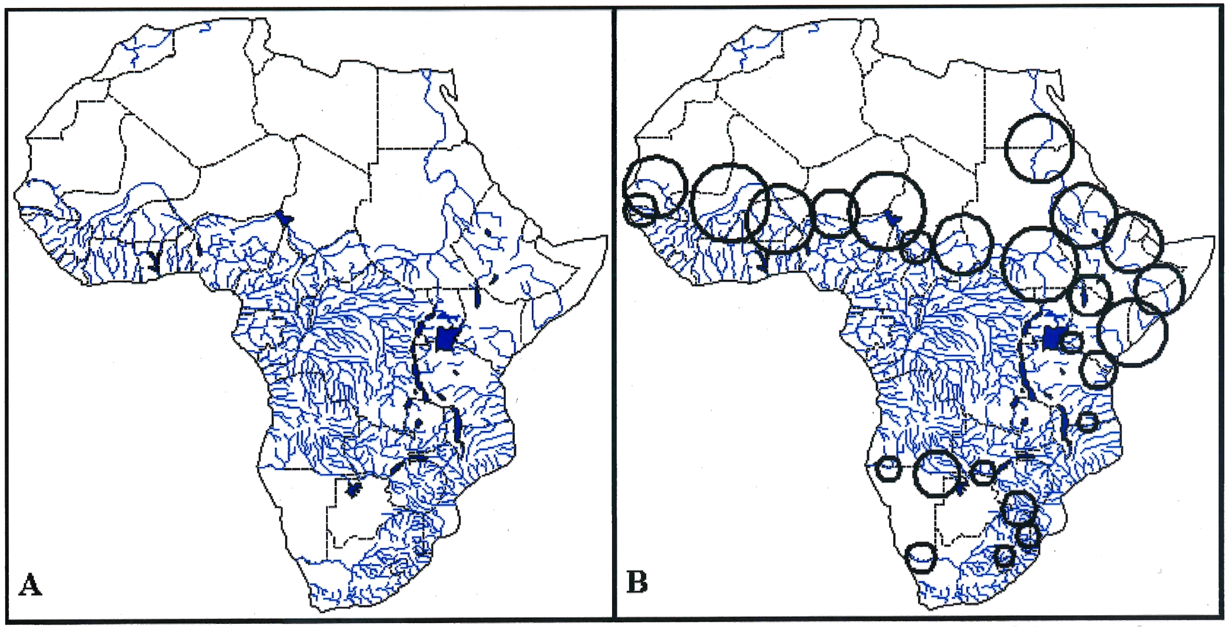
- **Social Security**
- **Peacekeeping**

- 25 Mio. refugees due to water shortage[1)]
- 22 Mio. refugees due to wars/ armed conflicts[1)]

[1)] UN 1999





Year-round water-bearing rivers and lakes in Africa (A) and actual and future conflicts due to water insuffiency

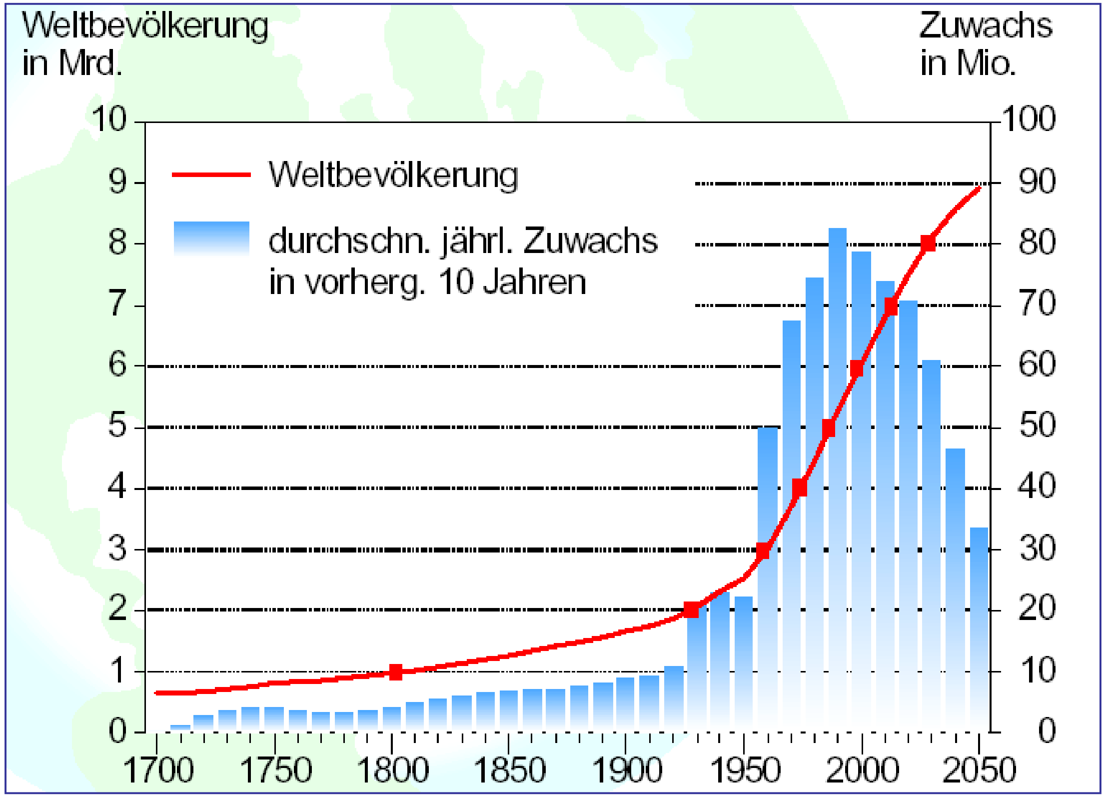
Why should we force and support environmental protection activities in developing contries?

- Pure self-interest !!!!!!!!
- Moral duty, responsability!!!
- Economical Interests!!!

Developments in Developing and Emerging Countries

Fatal law of growth:

- growth of the population
- Direct coupling of the resource consumption and emissions on the growth of the population
- Economical growth



Developments in Germany
- What is qualitative growth?

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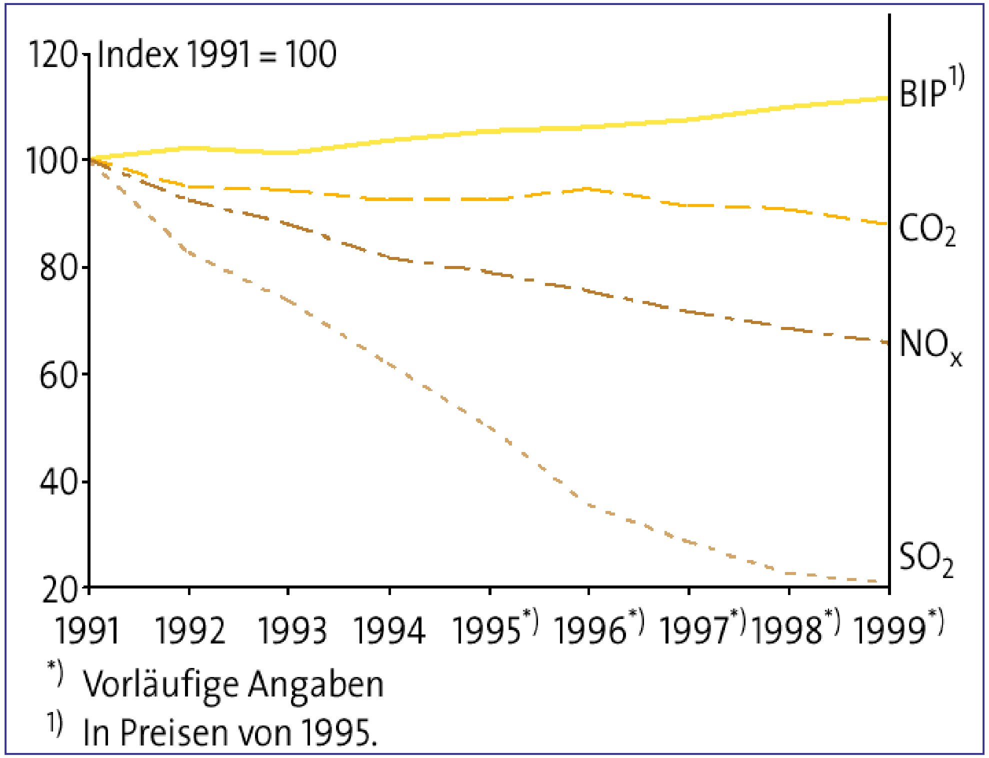
Basic demand:

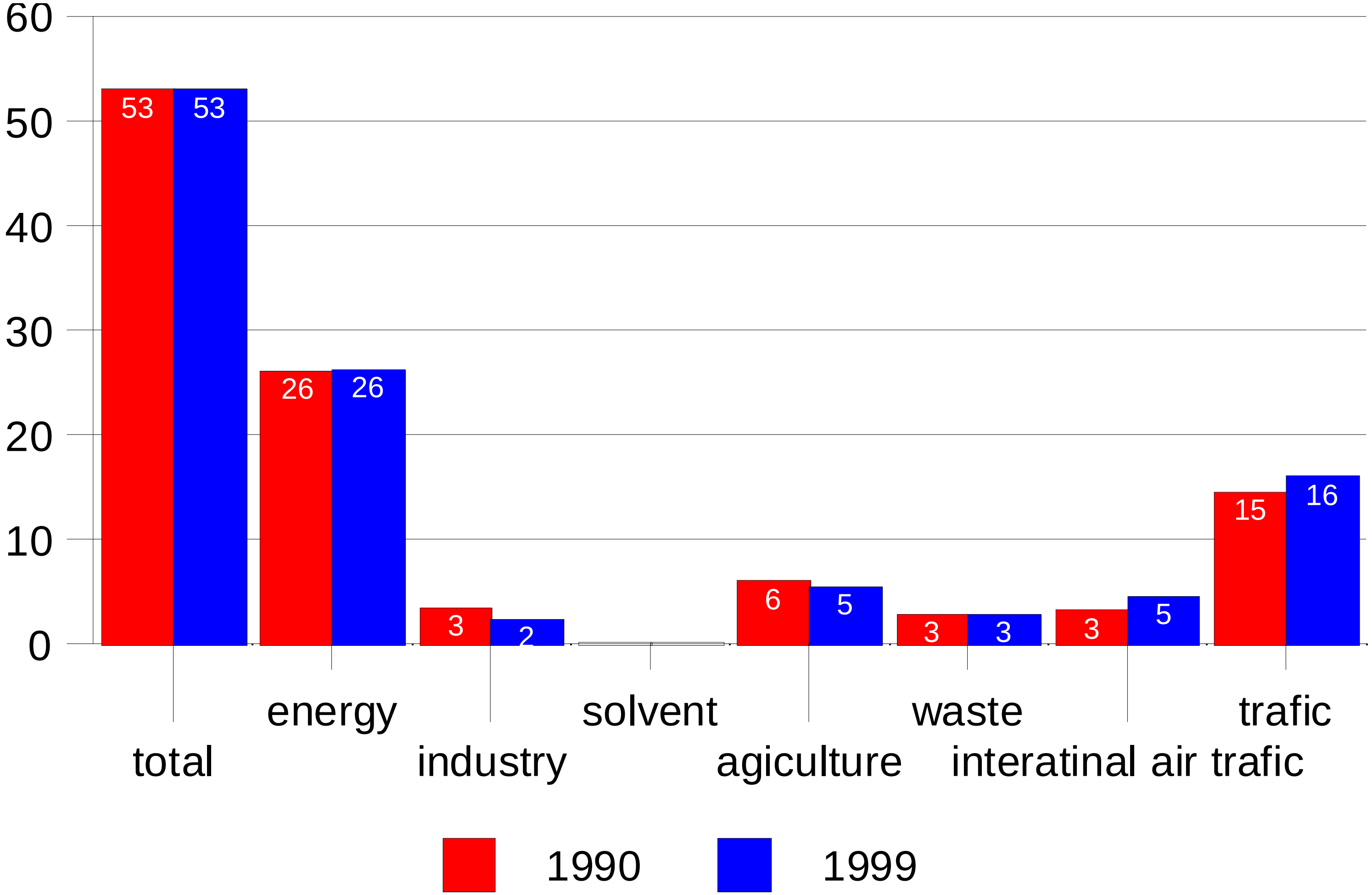
„Uncoupling of the resource consumption from the economical growth“

Economical Development and Pollutant Emissions of in Germany



Quelle: Statistisches Bundesamt 2000

CO_2 Emissions



Dissipation

- 70% of the yearly supply of raw materials were lost.

- Only 0.5% of the supplied materials are available 50 years after primary use.

- Actually, only 2% of the total supplied quantity are used or available.

Where are the emissions?

CO_2- emission per inhabitant and year

Bangladesh:	180 kg/a
Germany:	10.400 kg/a
USA.	20.100 kg/a

The Way to Kyoto

- 1992: 160 heads of state get together
  in Rio de Janeiro

- 1997: the next meeting of the contractual
  states
  Result: Passing of the Kyoto protocol

The Protocol

The Kyoto protocol says, that the industrialised countries should decrease their green house gas emissions by 5.2% until the year 2012. Basis are the green house gas emissions in 1990.

Waste Management Options Assessed

Recycling	– paper and cardboard – glass – plastics – iron and steel – aluminium – textiles – waste electrical and electronic equipment
Composting	– open – partly closed/closed – home composting
Anaerobic digestion	
Mechanical –biological waste treatment	(i.e. whole waste composting as a pre-treatment for landfilling)
Landfilling	– with recovery of landfill gas and utilisation for energy production – with recovery and flaring of landfill gas – no recovery of gas
Incineration with and without energy recovery	– mass-burn – RDF (including fluidised bed) – pyrolysis/gasification e.g. Thermoselect process – combined heat and power

Methodology

Calculate emission factors for each waste material for direct emissions of fossil CO_2, biological CO_2, CH_4 and N_2O from each of the main treatment options

Calculate emissions saved through avoided energy generation for options with energy recovery.

Methodology

- **Calculate transport emissions for each treatment option**
- **The emission factors can then be combined with waste composition data and waste treatment data to give overall greenhouse gas emissions**

Methodology

For the ‘short term’ carbon cycle, as the emissions has previously been offset by the sequestering of the carbon, e.g. Composting then there is no net global warming impact, and no global warming potential is associated with the CO_2 emission

If the emission occurs in the form of CH_4, however, then this has a higher global warming potential than CO_2, so must be accounted for.

Composting: Estimates of Carbon Dioxide Released

	% carbon	degradable fraction	degradable organic carbon	% of DOC which is dissimilable	dissimilable organic carbon	emission factor kg CO_2/t
Paper	32.97	100%	33%	37%	12%	450
Textiles	39.19	50%	20%	37%	7%	266
Miscellaneous combustibles	37.23	75%	28%	37%	10%	379
Food (83%)	14.69	100%	15%			
Garden (17%)	24	100%	24%			
Average putrescibles	16.26	100%	16%	60%	10%	360
Fines	14.34	65%	9%	76%	7%	260

Composting:
Carbon Storage in Soils due to Compost Application

	Half life (y)	% carbon stored after 100 years	Equivalent kg CO2 stored per tonne compost
Upper bound	2000	97%	326
Lower bound	20	3%	11

That means around 75 kg/Mg compost

or 225 kg/Mg treated waste

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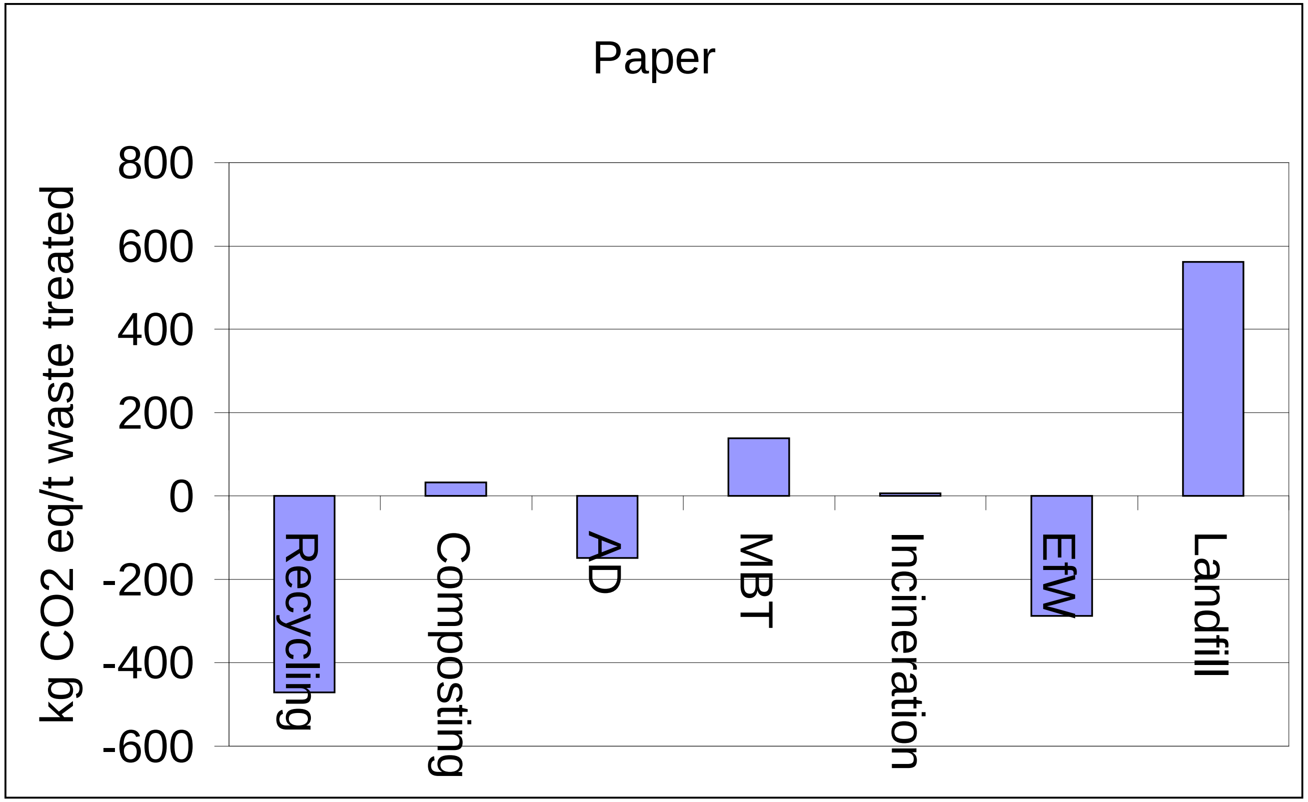
AD:
Estimates of Carbon Dioxide and Methane Released During Anaerobic Digestion

	degradable organic carbon	% of DOC which is dissimilable	dissimilable organic carbon	emission factor kg CO_2/t	methane released kg CH_4/t
Paper	33%	50%	16%	600	0.43
Textiles	20%	50%	10%	359	0.25
Miscellaneous combustibles	28%	50%	14%	512	0.36
Average putrescibles	16%	60%	10%	355	0.25
Fines	9%	76%	7%	260	0.18

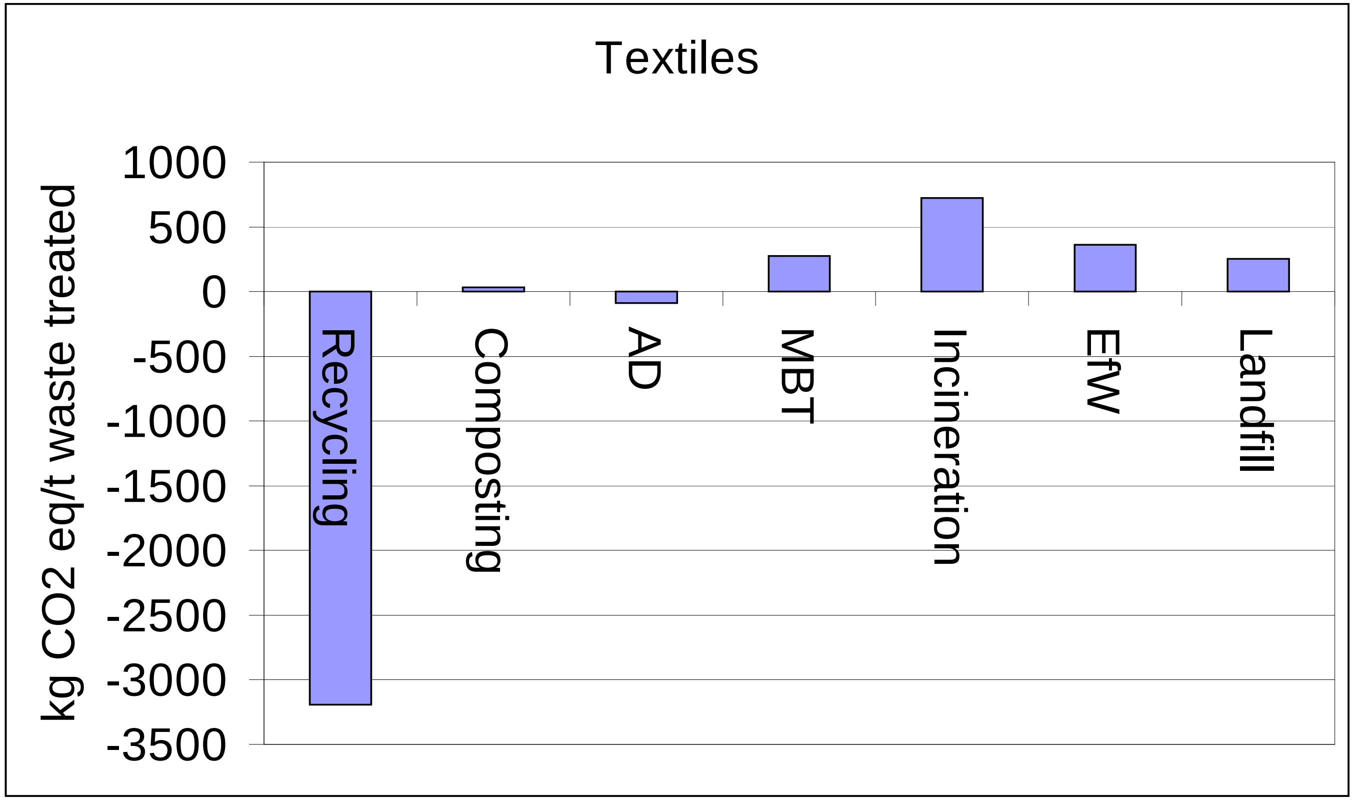
AD:
Net Electricity Generated From Anaerobic Digestion

	carbon released kgC/t	methane generated kg CH4/t	CV of gas kWh/t waste	Electricity for export kWh/t waste
Paper	164	142	1985	399
Putrescible	97	84	1175	236
Textiles	98	85	1189	239
Fines	71	61	860	173
Misc. combustibles	140	121	1694	340

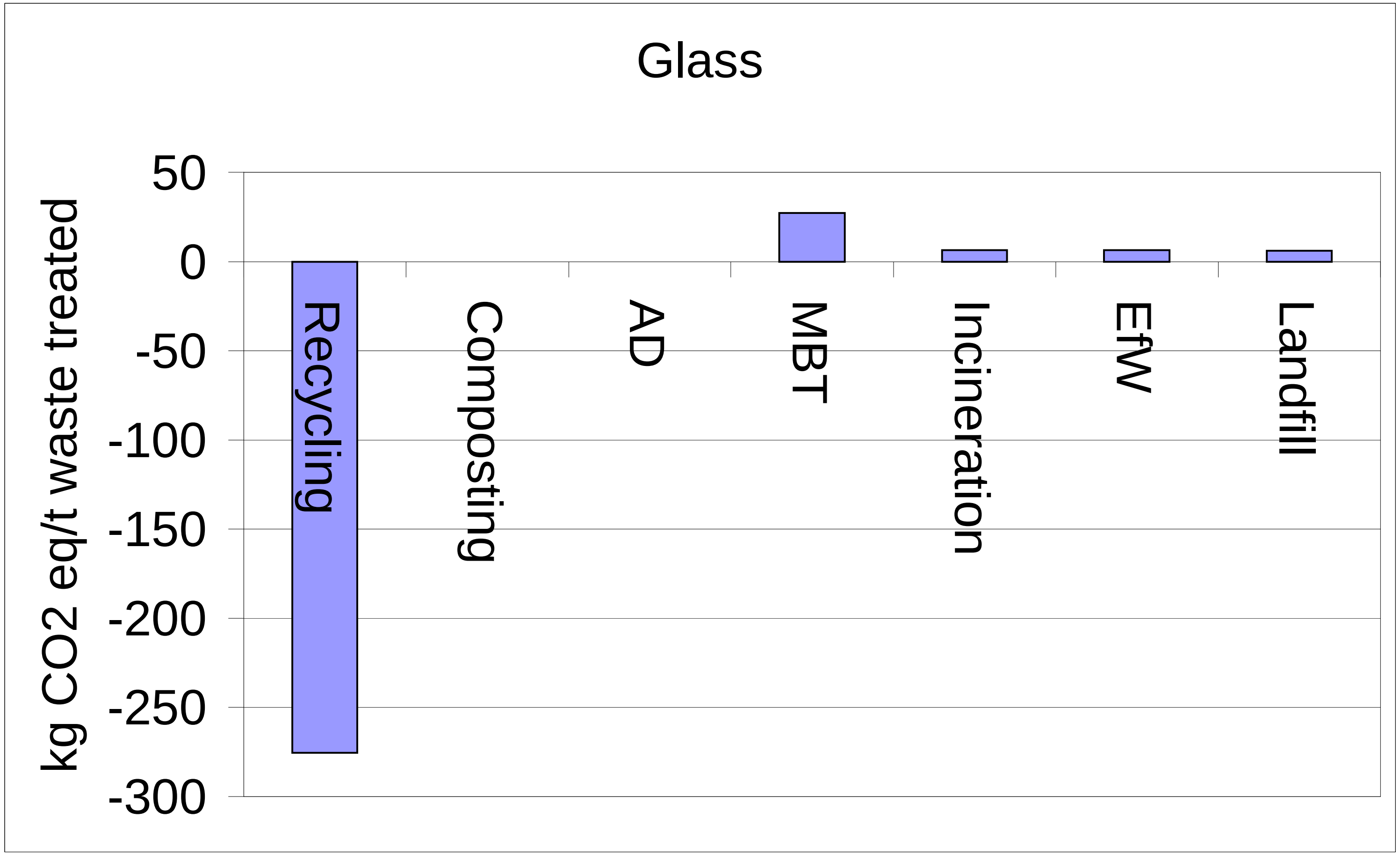
Greenhouse Gas Emissions from Waste Treatment Paper (kg CO2 eq/Mg)



Greenhouse Gas Emissions from Waste Treatment Textiles (kg CO2 eq/Mg)

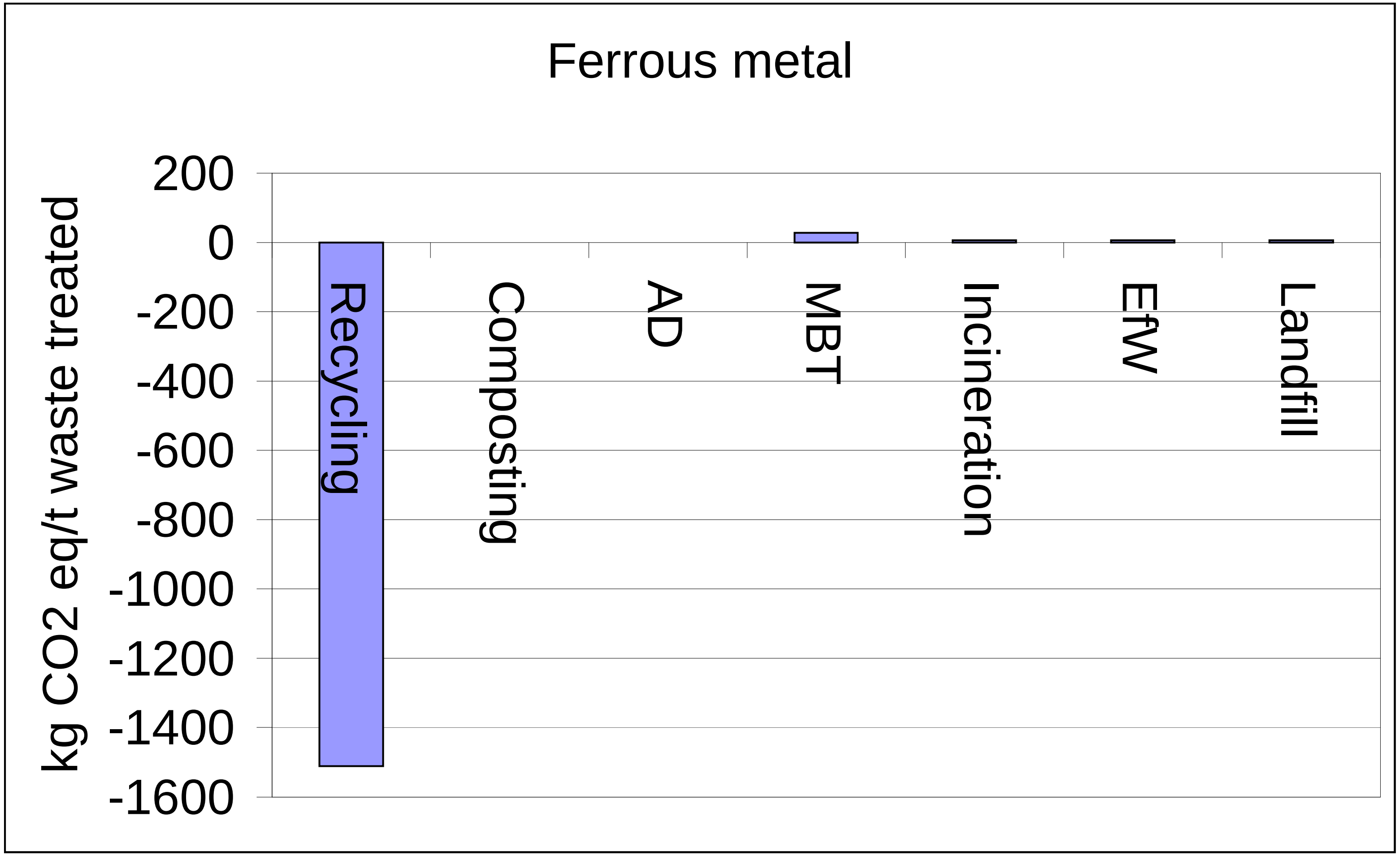


Greenhouse Gas Emissions from Waste Treatment Options (kg CO2 eq/Mg treated) Glass

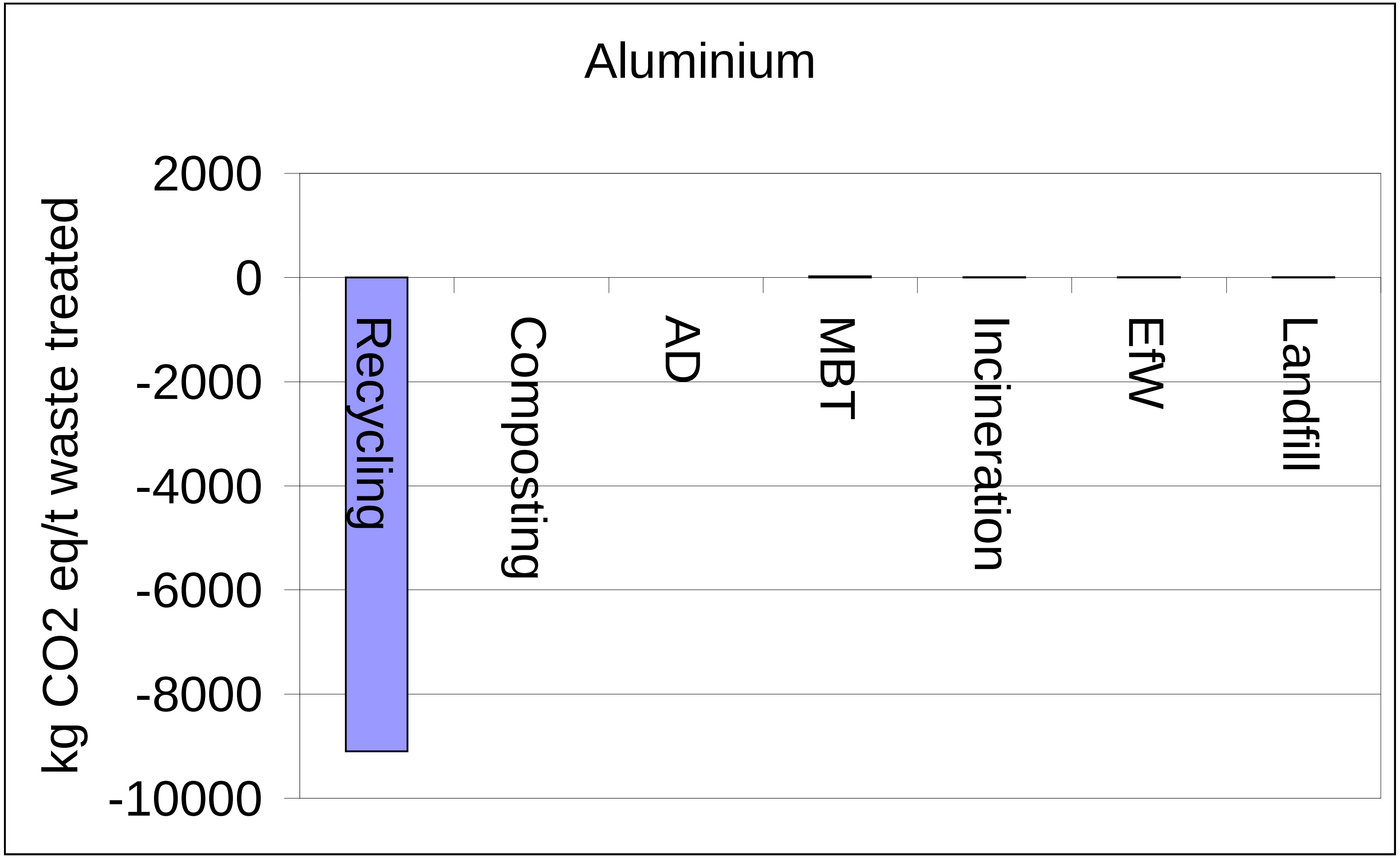


Greenhouse Gas Emissions from Waste Treatment Options kg CO2 eq/Mg treated)

Ferrous Metal

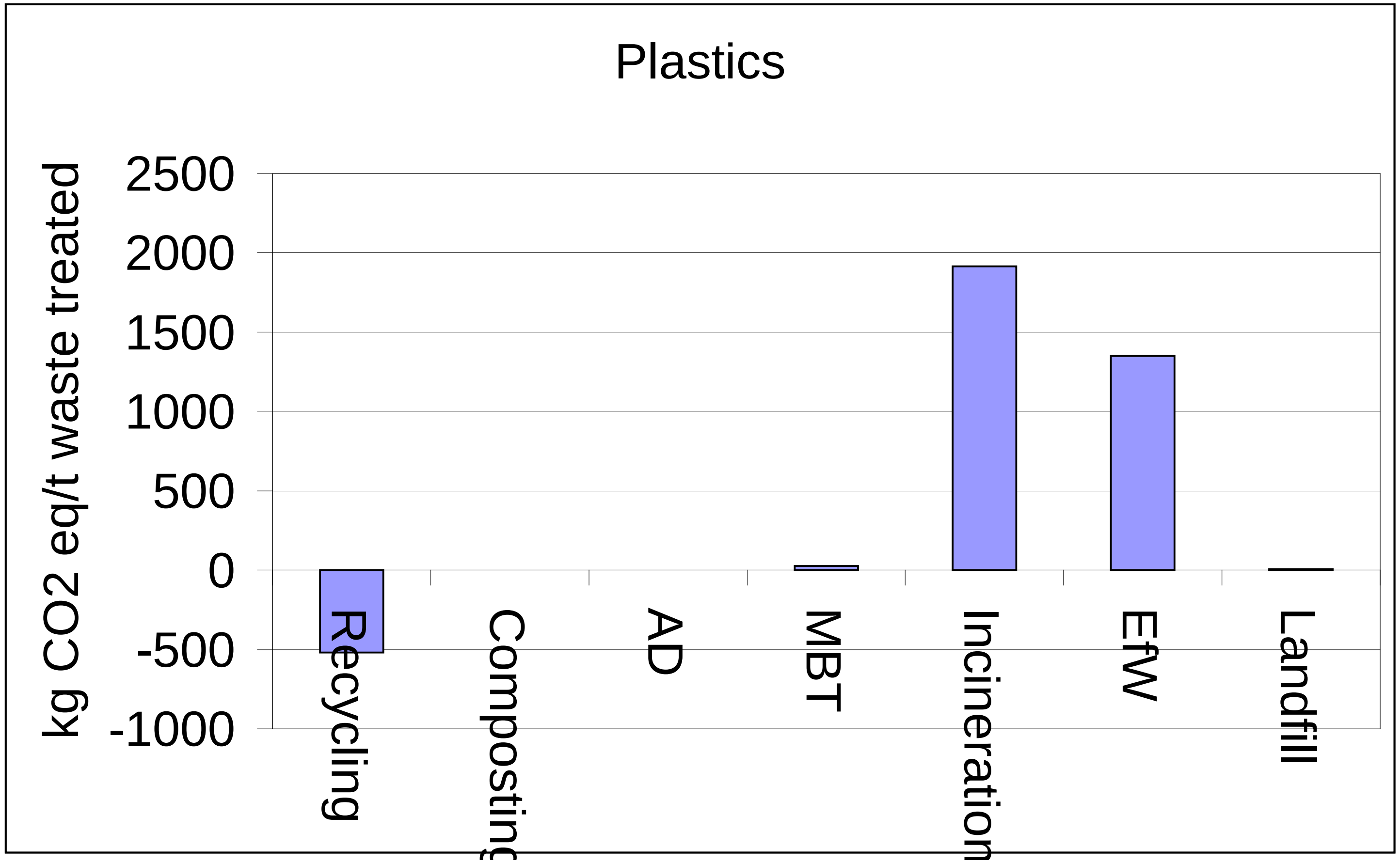


Greenhouse Gas Emissions from Waste Treatment Options (kg CO2 eq/Mg treated) Aluminium

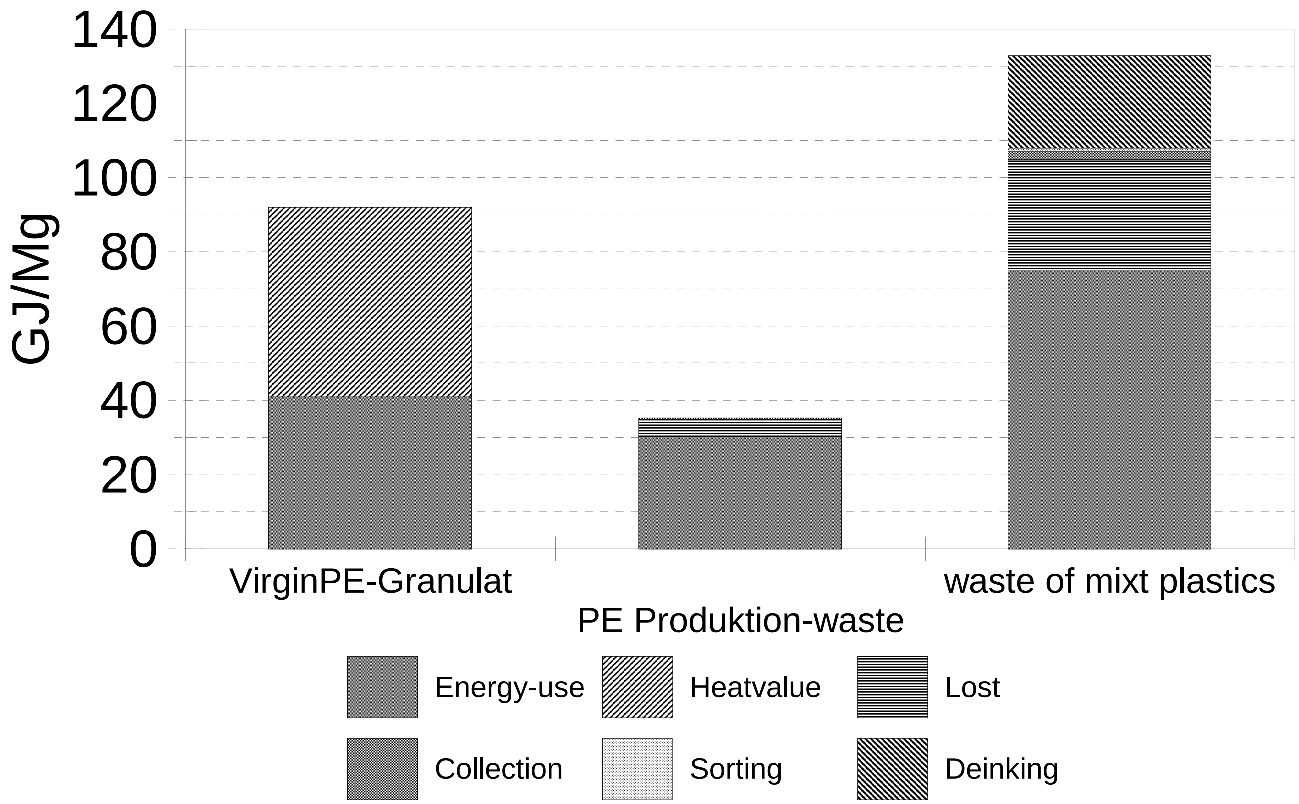


Greenhouse Gas Emissions from Waste Treatment Options (kg CO2 eq/Mg treated)

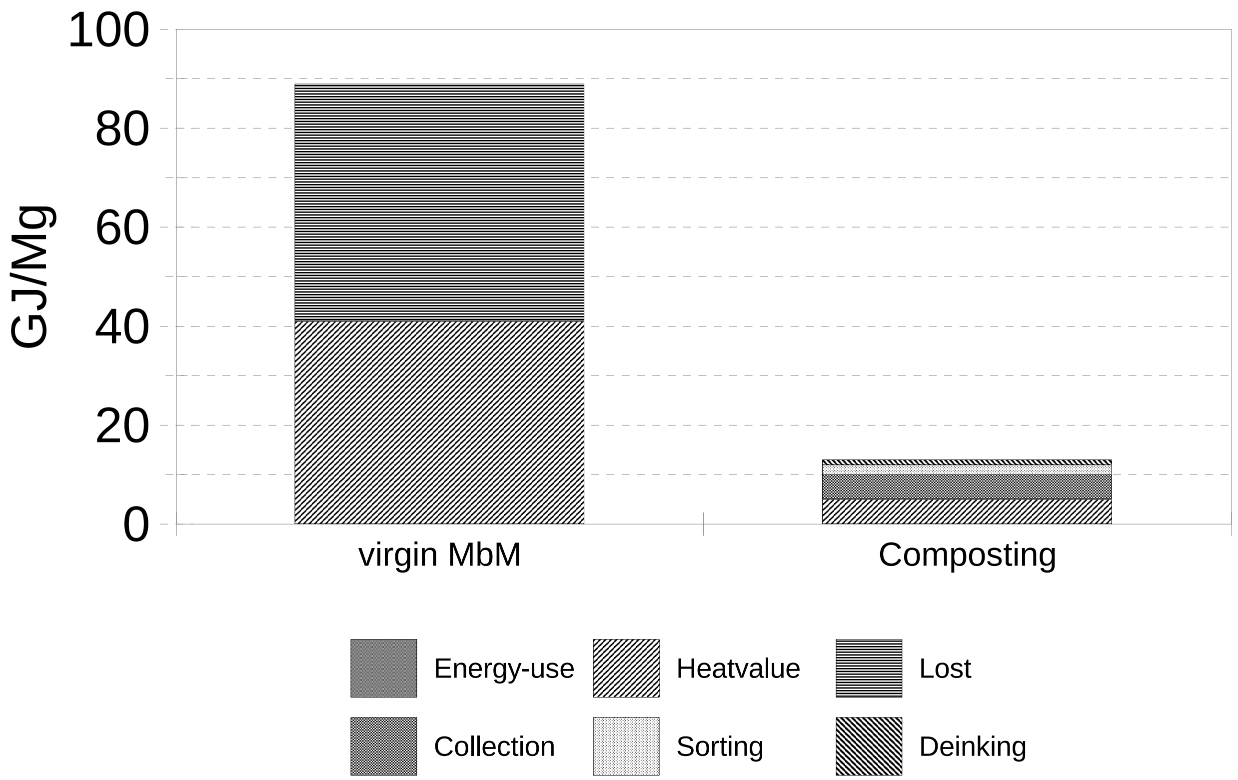
Plastics



Energy Consumption for the Production of 1 Mg PE



Energy Consumption for the Production of 1 Mg Bioplastics



Greenhouse Gas Emissions
Waste Treatment Options (kg CO2 eq/Mg treated)

	Paper	Putres-cibles	Plastics	Glass	Ferrous metal	Alumin-ium	Textiles	Fines	Misc comb	Misc non comb
Recycling	-471	NA	-518	-275	-1511	-9098	-3191	NA	NA	NA
Composting	32	32	NA	NA	NA	NA	32	32	32	NA
AD	-150	-89	NA	NA	NA	NA	-90	-65	-128	NA
MBT	138	108	27	27	27	27	275	91	303	27
Incineration (no energy recovery)	6	6	1916	6	6	6	725	6	348	6
Incineration (with energy recovery) (EfW)	-288	-131	1350	6	6	6	363	-117	-2	-29
Landfill	561	477	6	6	6	6	254	242	476	6

IPCC-Standard

<u>Baseline (IPCC tool „methane avoidance“)</u>

First order decay-Modell

0,9 (Modellkorrektur) 50 % (Methangehalt) 0,8 (Deponiefaktor)

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1 - e^{-k_j}\right)$$

21 (Klimafaktor) 50 % (abbaubarer Teil der Organik)

Abbaumodell (über die Jahre)

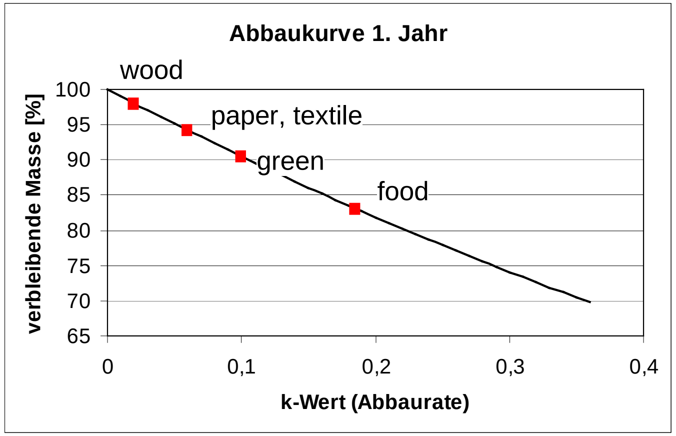
CO_2-Reduktion (Standard)

Jahr 1 bis y

Abbau 1. Jahr

$$\sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1 - e^{-k_j}\right)$$

Abbau Folgejahre



Stoffgruppe j	unit	A	B	C	D	E	F
		Wood	Paper	Food	Textile	Green	Inert
Anteil	%	0,9	3,7	23,4	2	23,4	46,6
$W_{j,x}$ (Masse)	t	360	1480	9360	800	9360	18640
DOCj (Organikanteil)	%	43	40	15	24	20	0
kj (Abbaurate)	[-]	0,02	0,06	0,185	0,06	0,1	0

= 40.000 t

Jahr								t org C	t CO_2eq
2008	t org C	3	35	237	11	178	0	464	**2339**
2009	t org C	3	33	197	10	161	0	404	**2038**

CO_2-Reduktion (Standard)

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Jahr		Wood	Paper	Food	Textile	Green	Inert	t org C	t CO_2eq
2008	t org C	3	35	237	11	178	0	464	**2339**
2009	t org C	3	33	197	10	161	0	404	**2038**

Year	Projektemissionen (t CO_2eq)	Baseline (t CO_2eq)	CER (t CO_2eq)
2008	403	2339	1936
2009	403	4376	3973
2010	403	6156	5753
2011	403	7714	7311
2012	403	9081	8678
2013	403	10284	9881
2014	403	11345	10942
2015	403	12283	11880
2016	403	13114	12711
2017	403	13852	13449
Total	**4030**	**90541**	**86511**

CO_2-Reduktion optimiert

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Option 1:Optimized Model

0,9 (Modellkorrektur)

60 % (Methangehalt)

1,0 eponiefaktor)

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1-e^{-k_j}\right)$$

21 (Klimafaktor)

60 % (abbaubarer Teil der Organik)

Gasmodell (über die Jahre)

Option 2:optimized waste

Food	Green	Inert
33,4	**33,4**	**26,6**
13360	**13360**	**10640**
20	20	0
0,185	0,1	0

Jahr 1 bis y

Abbau 1. Jahr

$$\sum_{x=1}^{y}\sum_{j} W_{j,x}\cdot DOC_j\cdot e^{-k_j\cdot(y-x)}\cdot\left(1-e^{-k_j}\right)$$

Stoffgruppe j	**unit**	**A**	**B**	**C**	**D**	**E**	**F**
		Wood	Paper	Food	Textile	Green	Inert
Anteil	%	0,9	3,7	23,4	2	23,4	46,6
$W_{j,x}$ (Masse)	t	360	1480	9360	800	9360	18640
DOCj (Organikanteil)	%	43	40	15	24	20	0
kj (Abbaurate)	[-]	0,02	0,06	0,185	0,06	0,1	0

Jahr								t org C	**t CO_2eq**
2008	t org C	3	35	237	11	178	0	464	**2339**
2009	t org C	3	33	197	10	161	0	404	**2038**

754	**3802**
651	**3282**

CO_2- Reduktion

Year	Projektemissionen ($t\ CO_2eq$)	Baseline alt ($t\ CO_2eq$)	CER ($t\ CO_2eq$)
2008	403	2339	1936
2009	403	4376	3973
2010	403	6156	5753
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2017	403	13852	13449
Total	**4030**	**90541**	**86511**

Baseline neu ($t\ CO_2eq$)	CER ($t\ CO_2eq$)
6843	6440
12750	12347
17861	17458
22292	21889
26143	25740
29498	29095
32427	32024
34990	34587
37238	36835
39215	38812
259257	**255227**

CO_2-Reduktion optimiert

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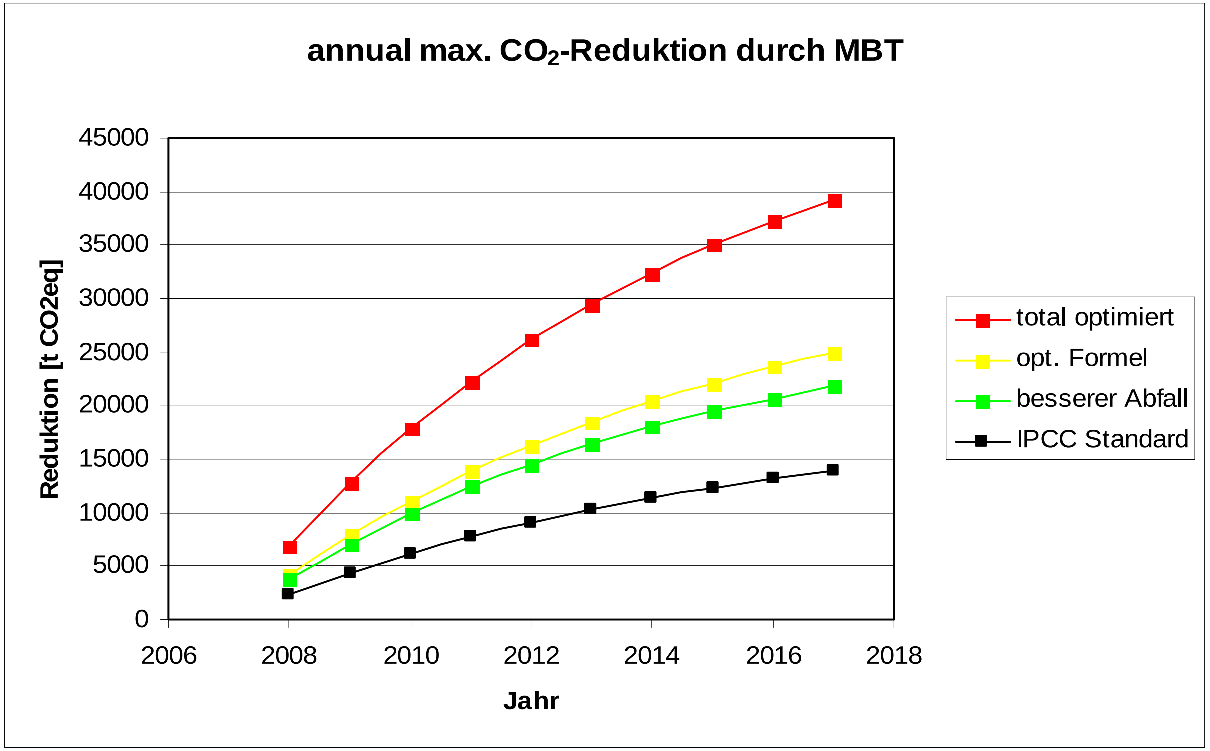

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CO_2-Reduktion MOL

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Baseline (IPCC tool „methane avoidance“)

First order decay-Modell

Oxidation durch Abdeckung

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1-e^{-k_j}\right)$$

offene Deponieoberfläche:	OX = 0
Methanoxidation in Abdeckung, Abbau 30 %:	OX = 0,3
Methanoxidation in Abdeckung, Abbau 90 %:	OX = 0,9

CO_2-Reduktion MOL

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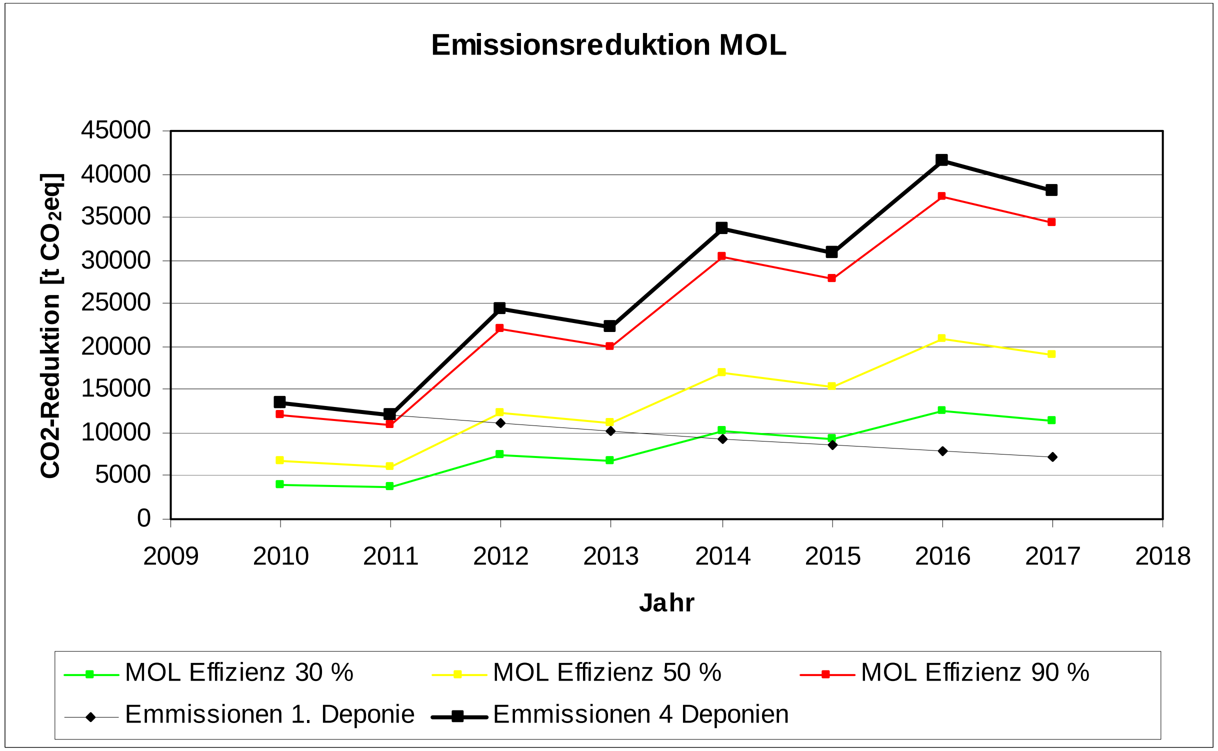

Deponiegröße: 6 ha
Höhe: 10 m
Alter: 15 Jahre
Masse: 40.000 t/Jahr
Abfall: IPCC Standard

Aufbau MOL: 2 Jahre
Beginn: 2008
Reduktion:
ab 2010 (1. Deponie)
ab 2012 (2. Deponie)

max. Emissionen aus 1. Deponie: 13.300 t (2010) bis 7.300 t (2017)

max. Emissionen aus 4 Deponien: ca. 40.000 t (2016/17)

Emissionsreduktion 50 % = ca. 20.000 t CO_2 90 % = ca. 35.000 t CO_2


The End?